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GLOBALIZATION AND INNOVATION IN EAST ASIA

Edited by
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This report consists of all research papers from ***ERIA Microdata Research Project of Fiscal Year 2010***. The project is part of the broader ERIA's research pillar on ***Deepening Economic Integration***. It addresses the theme of globalization and innovation, with **"Globalization and Innovation in East Asia"** as the title of the project and of this report. As indicated in the first chapter of this report, understanding the process and determinants of innovation is unarguably a research and policy issue of vast importance. Innovation is important for sustaining a country's competitiveness in a more globalized environment. All of the papers presented in three workshops over the period of September 2010 to February 2011.

We incurred debts of gratitude to all members of the Project's working group who have actively contributed to the outcome of the research. We would like to also express our sincere appreciation for the time willingly surrendered by all members to actively communicate with ERIA and to participate in the three Project's long workshops held in Jakarta, Bali, and Bangkok over the course of the project.

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Chin Hee Hahn
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EXECUTIVE SUMMARY

Schumpeterian creative destruction or, in other words, innovation is the integral part of a country's economic growth. For developing countries, it would not be an exaggeration to say that the challenges of economic development have been regarded by policymakers as synonymous with the challenges of innovation: how to make indigenous firms acquire new technologies and produce new products that they could not previously. Therefore, understanding the process and determinants of innovation is unarguably a research and policy issue of vast importance.

At the same time, a vast amount of previous studies have examined the causes and as well consequences of globalization. These studies have shown, although with some controversies remaining, that trade and/or investment liberalization has a positive effect on growth and productivity of firms, industries, and countries involved.

Then, how is globalization related to innovation? Is globalization a cause of innovation, or is innovation a cause of globalization, or both? Does increased trade and investment liberalization lead to more innovation, or does it depress innovation activity? In either case, what are the exact mechanisms? These are some of the most important questions that this report aims to address. These are some of questions that this report attempts to answer.

This report, of course, is not the first that explores globalization-innovation linkage. In fact, this topic is at least decades old. Previous studies on trade and growth have examined at least the following main channels through which trade affects growth: knowledge spillovers, increased competition, and larger market size. And these channels are either directly or indirectly related to firm's innovation activity. Traditional argument goes that, for example, if trade or investment liberalization facilitates knowledge spillovers, this will reduce the cost of research and development (R&D) or raise the rate of return to such activity, leading to increased innovation. Increased market size associated with trade raises the rate of return to innovation activity. Enhanced competition through trade may exert pressure on firms to innovate, or it could hurt the incentive to innovate by squeezing out the ex-post profit from a successful innovation. There are numerous empirical studies that examine these channels in detail. In this regard, this report is, in some sense, a revisit to an old issue.

This report collects many interesting findings based on the papers/studies done to cover many countries in East Asia region. Along with its wide international coverage, this project utilizes micro-level data at plant, firm, or product level. While innovation may be an old topic, there have not many studies in the literature that utilize data at this micro level, addressing the innovation linkage to globalization, and focusing on the most rapidly growing region in the world. There are, therefore, rich insights that one can draw from all papers in this report.

In terms of key findings, there are many papers that confirm the positive impact of exporting on firm innovation activities and performance. While almost all papers in this report provide evidence for this, there are three papers that specifically show this evidence in the context of the role of innovation in the exporting-productivity relationship. In particular, the evidence supports to the existence of 'learning-by-exporting' behavior, which is one possible explanation for this relationship. The Japanese case study on this subject shows that the first-time exporters indeed increase their R&D expenditure immediately after they export, albeit the increase depends on the export-market destinations. One of the Korean studies and the Australian study also support the positive exporting-innovation relationship. The former shows that exporting promotes the creation of new product while the latter reveals the behavior that exporters in services sector do indeed increase their process-innovation activities. All of these studies, in addition to establishing the positive exporting-innovation linkage, also show that the positive impact is further translated to superior firm performance.

Firm's R&D activities are the focus of the other three chapters in the report. As input of innovation outcome, R&D activities provide useful information about the extent of knowledge creation. Key findings within this subject are related to the role of foreign ownership in affecting firm innovation. The first is multinational enterprises (MNEs) tend to import their technology from their parent companies, resulting in rather low innovation activities of these MNEs in their host countries. The Thai and Chinese studies highlight this observation. This rather discouraging finding, however, does not mean that there is no positive effect of MNE presence on R&D or innovation process. In fact, as indicated by the Thai study, as well as the Indonesian study, the presence of MNEs is suggested to stimulate locally owned firms to conduct R&D. In other words, there exist what so-called the ‘R&D spillovers’ from MNEs presence.

The Indonesian study also finds an interesting fact of a positive relationship between the acquisition of new machinery and the extent of R&D expenditure. In other words, at least for Indonesia in this case, the ups and downs of firm innovation output are closely related to the ability of the firm in acquiring new machinery.

Other chapters examine the impact of globalization on innovation through competition link. The Philippines and Vietnamese studies address this subject. The Philippines study finds that trade reforms increases the extent of competition in domestic markets. Reduction in tariff is related to reduction in profitability. This study further finds that higher competition stimulates R&D. Thus, overall, trade liberalization positively affects R&D through product market competition channel. All these findings are generally the same even after it takes into consideration the firm selection impact as a result of much tighter competition (i.e., firm entry and exit). Consistent finding on the impact of competition is shown by the Vietnamese study. Tight price competition is found to increase the likelihood of Vietnamese small and medium enterprises (SMEs) to engage in R&D.

Globalization and knowledge creation and absorption is closely related. Another Korean paper shows that positive innovation premium can be accounted for by both the utilization of existing knowledge and active investment in new knowledge. The degree of importance for each of these knowledge sources, however, is different, depending on the characteristics of the global activity that a firm involves in. Investing in new knowledge seems to be more important than utilization of existing knowledge in explaining the premium of the non-MNE exporters and domestic MNE parents with export participation. In contrast, foreign MNE affiliates that participate in export markets seems to utilize existing knowledge more than investing in new knowledge in generating their positive innovation premium. The paper utilizing the Malaysian innovation survey, meanwhile, attempts to draw whether there is relationship between various aspect of organization and innovation. This study finds it to be a complex one. Different types of internal and external knowledge flows are likely to be driven by different organizational variables. For example, while knowledge flows from other companies within the same group are determined by whether or not the firm is a subsidiary. Meanwhile, examining the impact of international research collaboration involving patent registered in Korea, China, and Taiwan, another study in this report finds that international co-inventions are strongly associated with more science linkage, with higher quality of patent, and larger group of research team.

The research conducted by all papers in this project asserts that globalization encourages firm-level innovation. This policy implication is very important in the context of the usual approach that countries rely on R&D subsidies. The key message coming out from this research, therefore, is the existence of an alternative way for a country to promote innovation, which is done by, and through, maximizing the benefit from globalization.

There are more specific policy-implications implied by this broad message. First, policy to promote exports encourages firm innovation; hence, policy to assist firms to export more, as well as to make more firms to engage in exports, seems warranted. A number of findings on the positive relationship between exporting and innovation activities and/or performance support this policy implication. Second, policies for higher foreign involvement should be encouraged. The justification of this comes mostly on the evidence on the existence of 'R&D-spillovers' impact on domestically owned firms, from the presence of MNEs.

Third, keeping in track with ongoing trade liberalization and maintaining a relatively open trade regime is suggested. A high degree domestic market competition drives firms to always engage in innovative-enhancing activities, through the ability of the competition to create a contestable market situation. The findings from the Philippine study provide some evidence to support this. Having a liberalized trade regime could even be more beneficial if it is put in a framework of deepened integration of a country in Southeast and East Asia regions. The case study of Thai manufacturing in this report underlines this in the context of linking firms the already-established international production networks in these regions. The Thai study finds positive relationship between participation in the production networks on greater R&D activities by firms.

Fourth, findings from the research suggest that globalization seems to also benefit SMEs – not only large firms. This is encouraging given the common perception of unfavorable impact of globalization on SMEs. But there is more on this; how does one devise policies to materialize this benefit? The Australian study in this report suggests that, at least conceptually, the policy is to gear SMEs to learn more about process innovation – rather than product innovation – from utilizing globalization forces.

CHAPTER 1

Globalization and Innovation in East Asia

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1. Background and Objective

This report consists of the papers submitted to ERIA’s research project “Globalization and Innovation in East Asia” in fiscal year 2010. This project aims to examine the relationship between globalization and innovation, as well as the impact of various policies on innovation process and/or its outcomes in a globalized economic environment, utilizing various firm-, plant-, and/or product-level micro datasets for East Asian countries.

As is well understood, the process of Schumpeterian creative destruction or, in other words, innovation, is an integral part of economic growth in every country. Particularly for developing countries in East Asia, but also in other regions, it would not be an exaggeration to say that the challenges of economic development have been regarded by policymakers as synonymous with the challenges of innovation: how to make indigenous firms to acquire new technologies and produce new products that they could not previously. It is therefore clear that understanding the process and determinants of innovation is unarguably a research and policy issue of vast importance.

At the same time, numerous studies have examined the causes and consequences of globalization. These studies have shown, although with some controversies remaining, that trade and/or investment liberalization has a positive effect on the growth and productivity of the firms, industries, and countries involved. Partly as a result of the progress in our knowledge in this field, openness of their trade and investment regimes is considered as a key necessary condition for the economic growth and development of developing as well as developed countries.

So, how is globalization—a process of closer economic integration by way of increased trade, foreign investment, and international labour mobility—related to innovation? Is globalization a cause of innovation, or is innovation a cause of globalization, or both? Does increased trade and investment liberalization lead to more innovation, or does it depress innovation activity? In either case, what are the exact mechanisms? These are some of the most important questions that this report aims to address.

There are numerous additional issues that bear on this report. These include, for example, how innovation activity is organized within multinational enterprises (MNEs), and whether, and precisely how, globally engaged firms (either directly through foreign direct investment (FDI) or trade, or indirectly through interactions with foreign firms) differ in innovation activity and innovation outcome. Other issues are the causes and consequences of the globalization of innovation activity itself, and the role of firm characteristics and/or firm-heterogeneity in the trade-innovation linkage. Then there are the roles of competition in the trade-innovation nexus, and of openness policies in innovation policies and vice versa. Then, how a country's level of development, protection of intellectual property, and technical standards and regulations, affect the relationship between globalization and innovation, and so on. Some of these questions are also addressed by the chapters included in this report.

Of course, this report is not the first to explore the globalization-innovation linkage. In fact, this topic is at least decades old.[1] Previous studies on trade and growth have examined the following main channels through which trade affects growth: knowledge spillovers, increased competition, and larger market size. And these channels are either directly or indirectly related to the firm's innovation activity. Traditional argument goes that, for example, if trade or investment liberalization facilitates knowledge spillovers, this will reduce the cost of R&D or raise the rate of return to such activity, leading to increased innovation. Increased market size associated with trade raises the rate of return to innovation activity. Enhanced competition through trade may exert pressure on firms to innovate, or it could hurt the incentive to innovate by squeezing out the ex-post profit from a successful innovation. There are numerous empirical studies that examine these channels in detail. In this regard, this report is, in some sense, a revisit to an old issue.

However, we think that the primary distinguishing feature of this report is the use of micro-data. Although trade and innovation may be an old topic, to the best of our knowledge, there are not many previous studies that utilize firm- or plant-level *micro data* and examine the linkage between globalization and innovation, particularly in East Asian countries. In addition, most chapters in this report use a variety of data sources

[1] See Helpman (2004) for an excellent review of the literature on this topic.

and employ explicit measures of innovation input and innovation outputs (process or product). We think that the use of micro data allows us to clarify further the relationship between globalization and innovation, which studies based on aggregated data were unable to do. Furthermore, we think that using micro data allows us to examine the possible roles of firm characteristics, such as productivity, size, and other technical characteristics, in the globalization-innovation linkage.

The use of micro data, as well as recent developments in academic literature (and in the real world), make this report not just a revisit of the old issue but rather a revisit of the old issue in a new context and with a new approach. It is clear that globalization these days has new features compared with globalization, say, before the 1980s. The prime example of this is the so-called fragmentation of production or internalization of production. It is well known that the evolution of this process has been most pronounced in East Asian countries. So, these days, FDI directed to the developing East Asian region as well as FDI originating from developed East Asian countries, such as Japan, frequently involves the relocation of a certain production process in search of a lower production cost. Although there are increasing numbers of studies on the causes and consequences of this so-called vertical FDI, studies examining the consequences of this FDI on the host and home country firm's innovation activity are rare. Some of the chapters in this report bear on this issue.

Recent developments in heterogeneous firm trade literature also provide new insights and a theoretical framework for some of the chapters in this report. Earlier version of the heterogeneous firm trade theory, pioneered by Melitz (2003), helped not only to clarify the channels through which the benefits of globalization are materialized (reallocation of resources across firms within industries and/or across products within firms and/or across different technologies), but also identified firm-level characteristics (primarily productivity) that matter in shaping the relationship between globalization and aggregate growth and productivity. More recent literature has incorporated the firm-level innovation decision into the model, and examined various dynamic relationships that could exist among trade, innovation, and productivity. For example, this literature implies that there exists a bi-directional causal relationship between trade and innovation and that firm level productivity is both a cause and a consequence of past trade and innovation activities. Some of the chapters in this report use this theoretical framework in their empirical analyses.

It is our belief that examining the trade and innovation linkage in a new context and with new approach, and addressing the important questions discussed above can provide us with rich policy implications. For example, many chapters in this report provide strong empirical evidence that a firm's globalization activities are at least a determinant of its innovation inputs and outputs or, in some cases, that there exists a bi-directional causal relationship between globalization and innovation. This suggests a strong case for coordination between trade/investment liberalization policy on one hand and innovation policy on the other. In view of the often observed reality that these two policies are separately planned and governed by different ministries, this report's findings have potentially profound implications.

Below, we provide a synopsis of what follows and summarize the main policy implications that arise out of this report.

2. Report Structure and Main Findings

This report consists of eleven papers that address the globalization-innovation issues in nine countries, namely Japan (two papers), Korea (two papers), China, Taiwan, Australia, Thailand, Indonesia, Malaysia, the Philippines, and Vietnam. These papers can be classified into four groups according to more specific themes, that is, (i) exporting, innovation, and productivity, (ii) the firm's R&D decision and globalization, (iii) trade liberalization, competition, and innovation, (iv)globalization of R&D, organization, and knowledge flows.

2.1. Exporting, Innovation, and Productivity

The first three chapters address the role of innovation in the relationship between exporting and productivity, in the context of learning-by-exporting and the self-selection hypothesis. In Chapter 2, Ito addresses the role of innovation in the context of the learning-by-exporting hypothesis. She asks whether the effect of learning-by-exporting on innovation exists and, subsequently, whether and how the impact of exporting on innovation affects productivity. The paper attempts to find answers to these questions by examining the behavior and performance of first-time exporters in Japanese manufacturing. Ito's paper, therefore, not only seeks evidence for the positive impact of learning-by-exporting on innovation but also moves deeper to find insights on the source of the learning-by-exporting.

In her investigation, Ito finds that the first-time exporters are able to increase their sales and employment growth to a greater extent than those serving domestic markets. More importantly, the decision to begin to export evidently promotes innovation; she finds that the first-time exporters record an increase in R&D intensity and volume. In going deeper into the mechanism of learning-by-exporting, Ito examines whether there are differences in the performance of innovation and other performance variables, arising from engaging in exporting to different destinations. She finds that starting to export to North America/Europe has larger positive effects on productivity than starting exporting to Asia. This difference is also observed for the other performance variables (i.e., sales and employment growth), innovation variables, and some characteristics of the firms. Ito ascribes this to differences in absorptive capacity; i.e., the first-time exporters to North America/Europe have greater absorptive capacity than those exporting for the first time to Asia.

Chapters 3 and 4 examine how innovation affects the export-productivity/performance link. Unlike the previous chapter, these chapters examine the effect in the context of the two hypotheses. Specifically, these chapters examine the possible two directional relationships between export participation and innovation. Hahn and Park in Chapter 3 utilize a rich combination of plant- and product-level data from Korean manufacturing in their investigation. Unlike the previous studies, however, Hahn and Park adopt a rather different approach in defining product innovation. That is, they use plant-and-product matched data to distinguish two types of product innovations: those that are new to the plant (termed 'product addition') and those that are new to the Korean economy (termed 'product creation'). The former tends to capture the product cycle phenomenon or international knowledge spillover, while the latter reflects imitation by domestic competitors or the process of domestic knowledge diffusion.

Product creation could mean product addition although this does not necessary work the other way around.

Hahn and Park find evidence to support the learning-by-exporting hypothesis for the role of innovation in the export-productivity relationship. Using propensity score matching, they find a statistically significant positive impact of exporting on product creation. They cannot however infer the existence of this relationship when innovation is defined by product addition; the impact of exporting on product addition is not statistically significant, albeit showing the same (i.e., positive) sign. Hahn and Park meanwhile, are not able to find evidence to support the selection hypothesis. More specifically, they cannot find any significant effect of innovation – for both product creation and addition – on exporting. Hahn and Park extend their investigation by using the vector autoregressive (VAR) method. This route is taken in order to examine the dynamic interdependence between export and innovation, as well as productivity. The key results from it are consistent with the key finding that exporting significantly affects product creation. The finding from the VAR indicates that this impact is quite persistent; it takes more than five years for the impact on product creation to die out. The VAR results, in addition, show that productivity significantly and positively affect both exporting and product creation.

Palangkaraya in Chapter 4 conducts his investigation on the direction of causality using firm level data from Australian small and medium enterprises (SMEs). His investigation also specifically looks at the direction of causality for the group of new exporters and new innovators; this is done to ensure the robustness of his investigation results. It is worth mentioning that Palangkaraya's analysis is rather different from the other research papers in this report in terms of sectoral coverage in that it takes in not only manufacturing firms but also enterprises in the services and other non-manufacturing sectors. This offers a distinct value added to the research on the subject, considering the argument that the lessons from the usual samples from the manufacturing sector may not be valid for the other sectors.

Unlike Hahn and Park, Palangkaraya finds evidence that the relationship between exporting and innovation runs in both directions. However, this only appears for process innovation and in the services sector; not for product innovation and not in manufacturing or other non-manufacturing sectors. The investigation also finds that the positive two-way relationship varies across industries. In his interpretation, Palangkaraya attributes all these results to the uniqueness of the innovation characteristics of SMEs and the importance of services in the Australian economy. More specifically for the former, process innovation matters more than product innovation because SMEs are usually financially constrained and product innovation is arguably substantially more expensive than process innovation.

2.2. Firms' R&D Decisions and Globalization

Firms' research and development (R&D) activities are the focus of the next three chapters. As an input resulting in an innovation outcome, R&D activities provide useful information about the extent of knowledge creation. The next three chapters examine whether and how globalization affects a firm's R&D performance. In Chapter 5, Jongwanich and Kohpaiboon examine the roles of multinationals (MNEs) and exporting in determining the decision to carry out R&D, and the actual intensity of R&D activities, in firms in the Thai manufacturing sector, utilizing the most recent (i.e., 2006) industrial census data. Unlike the other studies that measure different types of R&D in their total value terms, Jongwanich and Kohpaiboon disaggregate R&D activities into three categories, namely: (i) R&D leading to improved production technology, (ii) R&D leading to product development, and (iii) R&D leading to process innovation. This chapter examines not only the direct effect of MNEs on R&D activities, but also the indirect effect of MNEs on the presence and intensity of R&D in locally owned plants (termed here 'R&D spillovers').

Jongwanich and Kohpaiboon find that globalization, through exporting and FDI, can play a role in encouraging firms to commit to R&D investment. The role played by FDI, however, seems to be different from that played by export. They found that the R&D propensity of MNE affiliates is lower than that of locally owned firms. This suggests that MNE affiliates in Thailand prefer to import technology from their parent companies rather than investing in R&D in the host country (Thailand). Nonetheless, this does not mean that there is no effect arising from MNE presence on firm R&D propensity and intensity. In fact, Jongwanich and Kohpaiboon find evidence that the presence of MNEs stimulates locally owned firms to conduct R&D activities. Jongwanich and Kohpaiboon also find that firms participating in international production networks are more active than those are not participating. As for the role of exporting, Jongwanich and Kohpaiboon find a positive and significant impact on R&D activities, from being in production networks, although this is limited only to R&D in product development. They do not find a significant impact for the other forms of R&D (i.e. R&D leading to improvement in production technology and R&D leading to process innovation). This finding implies that entering export markets helps firms to learn more from competing products, and from customer preferences, but their information relating to improving production technology and process innovation is still limited.

In Chapter 6, Kuncoro examine the globalization determinants of the decision to invest in R&D and the intensity of R&D expenditure, of medium-and large-sized manufacturing firms in Indonesia. Kuncoro considers export participation, foreign investment, and trade protection as the variables that represent globalization. In addition, he looks at the impact of spatial concentration of MNEs in affecting the firm's R&D investment decision and expenditure. Kuncoro uses data from the period of mid 1990s to mid 2000s in his empirical investigation.

Kuncoro finds that being an exporter significantly affects a firm's decision to invest in R&D, as well as the extent of the firm's R&D expenditure. As for the importance of foreign ownership, Kuncoro finds that it is an important determinant only of the firm's R&D investment decision; he finds that it is not an important factor in determining the amount of R&D expenditure that the firm commits. In terms of testing the potential R&D spillover effect arising from concentration of MNEs in a location, he finds that R&D activities tend to be higher in big urban areas; not in a specialized or agglomerated location. In his interpretation of the findings related to foreign ownership and the presence of MNEs, he asserts that there may be needed a critical mass of MNEs in a location, or in an agglomeration area, for these MNEs to have meaningful impact in terms of innovation or R&D performance. Another element of globalization, trade protection, is found to be negatively related to a firm's R&D investment decision and expenditure. In other words, lowering the protection or trade barrier will create a positive impact on R&D activities. In addition, Kuncoro interestingly finds a positive relationship between R&D expenditure and investment in new machinery. He asserts that investment in new machinery may reflect another indirect effect of globalization on the firm's innovation performance or R&D activities; it may reflect the desire of a firm to remain competitive, which can be accomplished by installing new machinery, bringing new technology.

Chapter 7 by Mairesse *et al*. examines the determinants of decisions on R&D and its intensity in four major Chinese manufacturing sectors, namely, textiles, apparel, transport equipment, and electrical equipment. The authors examine the determinants in the framework of the Crepon, Duguet, Mairesse (hereafter CDM) structural model that links between innovation input, innovation output, and performance. Hence, in addition to examining the R&D decision and R&D intensity, they also examine how R&D intensity affects innovation output, as well as how innovation output determines performance. Exporting and foreign ownership are included in the determination of the R&D decision and R&D intensity as well as in the determination of innovation output and performance. They use the data from manufacturing censuses conducted in 2005 and 2006.

Mairesse *et al*. find evidence that exporting increases the likelihood of firms making an R&D investment, and the level of R&D intensity; however, they find this to be the case only in the textile industry. They find conflicting evidence in the case of the electronic equipment industry. Given the fact that many firms in this industry have some share of foreign ownership, Mairesse *et al*. interpret this finding as a reflection of the position that much R&D activity is carried out by parent companies located in other countries, not in China as the host country. Their interpretation is consistent with their other finding which suggests that foreign firms tend to innovate less than other firms in China, compared to the state-owned ones. In addition, to all these, Mairesse *et al*. interestingly find that exporting does improve innovation output, and here specifically in terms of improving new products.

2.3. Trade Liberalization, Competition, and Innovation

Chapters 8 and 9 address the impact of trade and investment liberalization on innovation. Aldaba in Chapter 8 examines this issue in the case of manufacturing firms in the Philippines, utilizing firm-level panel data over the period 1996-2006. In her examination, she asks the following questions: what is the impact of the removal of trade barriers on firms' innovative activities? And does an increase in competition arising from trade reforms lead to increases in innovation? The analytical framework adopted by Aldaba postulates that the trade-liberalization relationship operates through the competition channel; hence, the impact of trade liberalization is examined through a two-stage approach where competition is endogenous. She also takes into consideration the selection, or firm-dynamic impact of competition, in her empirical model.

Aldaba finds that trade reforms (i.e. reduction of tariff and/or non-tariff barriers) conducted several times in the Philippines from the 1990s to the 2000s have had a strong impact on the Philippines' manufacturing sector, by increasing the extent of competition in domestic markets. The tariffs are found to be positively related to the price-cost margin. This is the finding from the first step of her econometric estimation. From the second step of the estimation, Aldaba finds that profitability is negatively related to R&D expenditure. In other words, higher competition stimulates R&D. Thus, overall, trade liberalization positively affects R&D through the product market competition channel. All these findings are generally the same even after she controls for firm entry and exit, which are proxies for the industry selection impact arising from competition. Further, from the results of her estimation in the 'mixed' sector (i.e. a broad sector group that consist of mostly exporting and importing industries), she finds that the net-entry variable is negatively related to profitability. Together with a negative relationship between profitability and R&D expenditure, this indicates that as more firms exit (presumably the inefficient ones), the surviving firms tend to engage in R&D, in order to out-compete the new firms entering the market.

In chapter 9, Nguyen *et al*. examine the determinants of innovation by Vietnamese SMEs in the context of increased competition as a result of rapid trade expansion in the 2000s. Nguyen *et al*. use data of 2007 and 2009 from the Vietnam SME Survey. The years of the data are chosen to capture the period when Vietnam experienced rapid trade liberalization. Unlike the approach taken by other studies, Nguyen *et al*. use information on pricing strategy to capture the extent of competition among firms. The use of this information is really driven by the availability of the information in the data set used.

Nguyen *et al*. find some importance of competition effects, both domestic and international. Specifically, matching the price of competitors has a positive impact on product innovation using the 2007 data and on product improvement using the 2009 data. As for the impact of international competition, they found that the pressure from foreign firms – in terms of price set by them – evidently improves all kinds of innovation activities by the Vietnamese SMEs (i.e. product innovation, product modification, and process innovation). This finding, however, slightly differs when the experiment uses 2009 data. Nguyen *et al*. not only address the globalization impact through the competition channel, but also further test whether linkages with foreign firms help the SMEs to increase their innovation activities. They find rather convincing evidence on this, using both years of the data and the other innovation activities they consider.

2.4. Globalization of R&D, Organization, and Knowledge Flows

Chapter 10 by Choi and Park examines the link between the "innovation premiums" from engaging in global activity and sources of knowledge in Korean manufacturing. They first examine whether these premiums exist and, based on their findings on this, they examine what sources of knowledge could explain the premiums. To capture the premiums, Choi and Kim compare the innovation output of various types of firms that engage in global activities with the innovation output of domestically-focused firms. Global activities of the firms are defined according to their export participation and/or their FDI engagement. Choi and Kim measure innovation output in terms of product or process innovation (or both of these) as well as number of patents. They also consider two groups of knowledge sources, namely investment in new knowledge and utilization of existing knowledge (either from inside or outside firms). This paper draws data from Korea's Innovation Survey conducted in 2002, 2005, and 2008, as well as data from the Kore EXIIM bank.

Choi and Kim show that there indeed exists a premium in terms of innovation output from engaging in global activities. The comparison they make shows that performance in generating innovation outputs is the highest for firms that export and have foreign ownership participation, but is the lowest for purely domestic firms (i.e. domestic firms without any exports and without any foreign ownership). In their further investigation, Choi and Kim find that the positive innovation premium can be accounted for both by the utilization of existing knowledge and by active investment in new knowledge. The degree of importance of each of these knowledge sources, however, is different, depending on the characteristics of the global activity that a firm is involved in. Investing in new knowledge seems to be more important than utilization of existing knowledge in explaining the premiums of the non-MNE exporters and the domestic MNE parents with export participation. In contrast, foreign MNE affiliates that participate in export markets seem to utilize existing knowledge more than investing in new knowledge in generating their positive innovation premium. Another important finding is that, when Choi and Kim analyze product and process innovation separately, they find that utilization of existing knowledge and investment in new knowledge are equally important in explaining the positive premium for product innovation. However, only information from existing knowledge seems to be important in explaining the premium for process innovation.

Chapter 11 by Lee is another paper in this report addressing the issue of knowledge flows in innovation. Lee uses Malaysian manufacturing as the case study in his paper. In his research, Lee gauges the determinants of knowledge flows in the decision to invest in R&D as well as in the intensity of a firm's R&D activities. This is the first step in his investigation. Measures of R&D activity considered by this paper are: (i) in-house R&D activity, (ii) acquisition of machinery, equipment, and software, and (iii) training. Further, in the second step he attempts to find some evidence on whether the variation in the extent of knowledge flows can be explained by firm organizational factors. He considers various organizational factors classified into three broad groups according to the characteristics of the factor, namely, (i) vertical boundary of firm, (ii) ability to adapt to changing environment, and (iii) collaborative activities with external parties.

Lee incorporates globalization into each of these steps by introducing variables that identify a firm's export participation and the existence of foreign participation in the firm's ownership structure. Lee also differentiates collaborative variables – as one of the groups of organizational variables – according to the domestic or foreign collaborative partners; this is another way of incorporating globalization into his knowledge flows and organization equation.

Lee finds evidence that establishes the relationship between knowledge flows and innovation. However, the extent and direction of the relationship is likely to depend on the type of innovation activities. For in-house R&D, for example, the knowledge flow from other firms within the same group of companies is negatively related to the decision to undertake this activity. Also, there is evidence of less emphasis on in-house R&D investment if knowledge flows from customers are of high importance. In the case of the acquisition of machinery, equipment, and software, external knowledge flows are important, especially those coming from suppliers, customers, competitors, and consultants. As for the importance of globalization-related variables (i.e. exporting and foreign ownership) in determining these activities, Lee finds them to be relatively insignificant. Lee only finds a positive impact from globalization when the innovation activity considered is training, and the globalization variable introduced is exporting. Specifically, exporting is associated with higher investment in training.

As for the relationship between knowledge flows and various aspects of organization, Lee finds it to be a complex one. Different types of internal and external knowledge flows are likely to be driven by different organizational variables. For example, while knowledge flows from other companies within the same group are determined by whether or not the firm is a subsidiary, as well as by cooperation involving foreign customers and foreign private research centers, external knowledge flows seem to be determined only by some of the variables that reflect the firm's ability to adapt to its changing environment (i.e. improvement in the quality of goods and services, improvement in employee satisfaction and reduction in employee turnover). Despite this complexity, Lee finds evidence to support the positive role of globalization in determining the extent of knowledge flows; the globalization-related variables, i.e. exporting and foreign ownership, are generally found to be important for certain types of external knowledge flows, particularly those originating from customers.

The last of the chapters of this report, by Nagaoka and Tsukada, addresses international collaboration in research. Specifically, they analyze whether and how international research collaboration affects invention in three countries, namely Korea, China, and Taiwan. In their investigation, they focus on patents registered in the patent office in these countries as well as in the US Patent Office.

Nagaoka and Tsukada find that international co-inventions are strongly associated with more science linkage; that is, more references to scientific literature in Korea and Taiwan. A research project with a high degree of science linkage is often based on a basic research, which reflects the extent of absorptive capability. This finding indicates that Korea and Taiwan have stronger absorptive capabilities for exploiting scientific knowledge than China, at least for the period under the study. Another important finding is that international research collaborations are associated with higher patent quality. This is in terms of forward citation in China and Taiwan, even after controlling for the number of inventors and the literature cited. Thus, the benefits of international research collaboration in terms of creating synergy or exploitation of know-how may be significant for these economies.

3. Implications for Policy

The research conducted in all papers in this project asserts that globalization encourages firm-level innovation. The findings from all papers consistently point to this conclusion. This policy implication of these findings is very important in the context of the approach taken by many countries in their national innovation policy, which relies on what are usually termed R&D subsidies (Herrera and Nieto, 2008). The key message coming out from this research, therefore, is the existence of an alternative means for a country to promote innovation, which is by, and through, maximizing the benefit from globalization.

One can elaborate this broad policy implication to some rather specific policy implications, based on the elements of globalization. First, policy to promote exports encourages firm innovation; hence, policy to assist firms to export more, as well as to cause more firms engage in exports, seems warranted. A number of findings on the positive relationship between exporting and innovation activities and/or performance support this policy implication. Among others, and perhaps most importantly is the evidence on the positive effect of 'learning-by-exporting' on exporters' innovation. According to the results of Hahn and Park's Korean case study (Chapter 3), exporting encourages the creation of new products. The investigation by Ito in Chapter 2 points to the usefulness of promoting exports to a destination, or a region, that has greater extent of absorptive capacity, for the reason that this seems to create a much larger marginal benefit drawn from learning-by-exporting.

Second, policies for higher foreign involvement should be encouraged. The justification for this comes mostly from evidence of the existence of the impact of ‘R&D-spillovers’ on domestically owned firms; that is, the presence of MNEs encourages the locally owned firms to gain technological knowledge and capability from various possible channels, such as the demonstration effect, the competition effect, etc. One of the key findings of the chapter by Jongwanich and Kohpaiboon on Thai manufacturing underlines the importance of this policy suggestion. Moreover, from a more macro and practical perspective, encouraging a higher presence of foreign ownership, or MNE units, requires a policy to sustain excellent infrastructure quality, both physical and institutional. The logic is clear; MNEs certainly would consider investing in host countries if they are able to operate efficiently, and one of the key factors is supportive infrastructure. Moreover, as pointed out by Kuncoro using the Indonesian data, much of the R&D spillover from the presence of MNEs in Indonesian manufacturing exists within industrial agglomerations; if policy makers would like to really maximize the benefit from the spillover effect, the idea of having well connected agglomerations benefiting from well developed and good quality infrastructure is clearly the path to take.

It is worth mentioning that the suggestion of supporting exports and encouraging greater MNE participation can also be justified from the perspective of knowledge absorption and creation by firms in their innovative activities. The findings of two chapters in our research underline this (i.e. Chapters 10, 11, and 12). In Chapter 10, for example, the case study of Korean manufacturing suggests that not only are firms absorbing large amounts of existing knowledge by exporting, or by jointly operating with foreign owners, or both, but they are also able to create more new knowledge themselves. As a direct consequence of this ‘snow-balling’ impact, a country’s stock of knowledge would also grow faster, and, in turn, this may feed back to the firms’ knowledge production function; all these factors should facilitate an even stronger innovation performance by the firms in the future. Globalization therefore facilitates greater knowledge creation. Indeed, this is also consistent with the idea of greater impact of international collaboration in research as pointed by the findings of Chapter 12 by Nagaoka and Tsukada.

Third, keeping in track with ongoing trade liberalization and maintaining a relatively open trade regime is suggested. A high level of domestic market competition always drives firms to engage in innovation-enhancing activities, through the ability of the competition to create a contestable market situation. The findings from Aldaba's study on Philippines manufacturing firms provide some evidence to support this policy suggestion. Having a liberalized trade regime could be even more beneficial if it were put in the framework of the deepened integration of a country in the Southeast and East Asia regions. The case study of Thai manufacturing in this report underlines this in the context of linking firms to the already-established international production networks in these regions. The Thai study finds a positive relationship between participation in the production networks and increased R&D activities by firms.

Fourth, findings from the research suggest that globalization seems also to benefit not only large firms but also SMEs. While this is encouraging, if one considers the affirmative-action type of policy for SMEs in the context of the increased globalization in a country's economy, the more important question perhaps is how one devises policies that could materialize this suggestion. The Australian study in this report suggests that, at least conceptually, the policy should be to gear SMEs to learn more about process innovation – rather than product innovation – from utilizing globalization forces. As pointed out by the study, this policy approach is sensible given the natural disadvantages of SMEs, vis-à-vis their larger counterparts, in terms of financial resources and economies of scale. Further, given the usual 'assistance-type' of policy for SMEs, export promotion policies for SMEs in general would be most effective if they were integrated with policies to promote SMEs innovation activities, which in this case should focus more on process innovation activities.

Notwithstanding the discussion above, it is important to bear in mind that the policy recommendations are at most suggestive in nature. There are indeed other factors that need to be carefully considered for effective policy implementation, in order to maximize the benefit from globalization in terms of innovation. Further, there are a few caveats that policy makers need to always bear in mind for the implementation of these policies. First, it is important not to overdo the competition effect to foster innovation. While a high level of competition can foster progress in innovative activities, one needs to consider the impact on SMEs of having too severe competition. SMEs are financially constrained and have scale disadvantages; therefore, a sensible balanced level of competition may be needed if innovation is guaranteed to progress but, at the same time, SME growth is not constrained.

Second, given the rather strong policy recommendation to support firms' export engagement and performance, it is important that policy makers do not fall in to the trap of providing export subsidies. This is important because such policies will likely be detrimental and counter-productive, since they will, over time, reduce the competitiveness of the exporters. What policy makers can do with this policy is to ensure improvement in trade, as well as investment facilitation measures. For many developing Southeast Asian countries covered by this research, there are still problems – and hence potential for significant improvement – in the area of trade and investment facilitation. This approach in fact is consistent and in line with the objective of regional integration agendas, such as those promoted by ASEAN or APEC.

Finally, it is important to note that different levels of development and/or industry characteristics across countries lead to the need for careful consideration on the implementation of the policy recommendations suggested above. In fact, even within a country, differences across industry could also call for different innovation policy approaches as highlighted by the Australian and Chinese studies in this report.

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CHAPTER 2

Sources of Learning-by-Exporting Effects: Does Exporting Promote Innovation?

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This paper examines whether first-time exporters achieve productivity improvements through learning-by-exporting effects. The results suggest that starting exporting to North America/Europe has a strong positive effect on sales and employment growth, R&D activity, and productivity growth. On the other hand, starting exporting to Asia does not have any strong productivity enhancing effects, although it does tend to raise the growth rates of sales and employment and be associated with an increase in R&D expenditure. However, even for these variables, the positive impact of starting exporting to North America/Europe is much larger. Further analysis shows that export starters to North America/Europe are larger, more productive, more R&D intensive, and more capital intensive than export starters to Asia even before they start exporting, suggesting that the former are potentially better performers than the latter. In other words, the former have greater absorptive capacity, and this absorptive capacity itself may be a source of the larger positive learning-by-exporting effects. Moreover, export starters to North America/Europe become more innovative than export starters to Asia after starting exporting. The results obtained imply that potentially innovative non-exporters should be supported through an export promotion policy. Firms that have the potential to be sufficiently innovative to export to developed regions are likely to benefit from doing so through the positive interaction between exporting and innovation.

Keywords: Exports, Innovation, R&D, Productivity, Learning by exporting, Export destination, Propensity score matching

JEL Classification: D22, D24, L1, L6, O31, F14

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1. Introduction

Globalization clearly affects firms' behavior and performance in various ways, and how to design effective policies to promote economic growth in a globalized economic environment has become a priority subject for many countries around the world. A large body of literature has already investigated the various relationships between globalization and the performance of firms and industries, utilizing a variety of macro- and/or micro-level databases. While a considerable number of empirical studies suggest that firms engaged in international trade and investment perform better than firms not engaged in such activities, the evidence has been less clear-cut on the "learning-by-exporting" hypothesis that exporting firms experience an improvement in productivity by gaining access to technical expertise from export markets.

That being said, there are some studies that do provide evidence of a positive learning-by-exporting effect. One of these is the study by De Loecker (2007), who, moreover, finds that the productivity gains are higher for firms exporting towards high income regions, although he does not provide a detailed discussion of the reasons why learning-by-exporting effects differ depending on the destination of exports. Positive learning-by-exporting effects have also been shown in a number of other empirical studies, but to date, the mechanisms and sources of learning-by-exporting effects have not been adequately investigated, and there is still a long way to go until we have a good understanding of learning-by-exporting effects and can derive appropriate policy recommendations to enhance firms' growth in the globalized economy.

Against this background, this study, utilizing a large-scale firm-level panel dataset on Japanese manufacturing firms, examines the existence of learning-by-exporting effects and investigates how exporting improves the productivity of firms, i.e., it investigates the mechanisms or sources of learning-by-exporting effects. In the case of Japan, several previous studies have already found that firms engaged in international trade and investment outperform non-internationalized firms and that the gap in performance between both types of firms has been widening.[1] Yet, although engaging in international trade and investment has generally raised the performance of individual

[1] See, e.g., Fukao and Kwon (2006), Kimura and Kiyota (2006), Wakasugi *et al*. (2008), and Ito and Lechevalier (2009).

firms, industry-level productivity in Japan has stagnated in many industries and productivity growth at the macro level has remained low during Japan's so-called "Two Lost Decades." This pattern suggests that the majority of Japanese firms have not benefited from globalization and that only a small fraction of firms have enjoyed efficiency gains and growth through international activities. On the other hand, Ito and Lechevalier (2010) found that, compared with European countries, there were a relatively large number of firms in Japan that conducted R&D activities but did not export.[2] In addition, the study found that, in Japan, R&D firms were more likely to see an improvement in productivity by starting to export than non-R&D firms.

These studies indicate that to raise the country's overall economic growth rate, a top priority for the government should be to devise policy schemes to help non-internationalized firms to take advantage of the globalized economy. However, to devise such policy schemes, it is necessary to understand the mechanisms underlying the learning-by-exporting effect, which studies to date have not adequately explored.

Against this background, this paper focuses on the behavior and performance of first-time exporters and investigates how first-time exporters evolve through learning-by-exporting, by exploring the sources of learning from exporting. Specifically, this paper tries to answer to the following questions: (1) Does exporting further promote R&D activities, resulting in further improvements in productivity? (2) Does exporting increase the volume of demand for a firm's products which then raises the firm's productivity through scale effects? And (3) does the learning-by-exporting effect differ across export destinations?

The organization of this paper is as follows. Section 2 provides an overview of related research, while Section 3 describes the dataset used in this paper and explains how first-time exporters are defined. Section 4 then explains the framework of the econometric analysis and presents the results. Finally, Section 5 discusses the policy

2 While this comparison is not based on a rigorous analysis that takes account of differences in the coverage of databases, sizes of domestic economies, industry compositions, barriers to trade, etc., the pattern it suggests is consistent with the results obtained by Nishikawa and Ohashi (2010), who, analyzing the results of the second *National Innovation Survey* conducted by the Japanese government in 2009, find that despite the fact that Japanese firms actively conduct innovative activities in collaboration with R&D organizations within and/or outside the firm, the share of firms which collaborate with overseas organizations or which sell their products in overseas markets is extremely low compared with European firms. Their findings also imply that Japanese firms tend to be less internationalized than firms in European countries.

implications and concludes.

2. Related Literature

Over the last decade, many empirical studies have found evidence in favor of self-selection of more productive firms into exporting, supporting a theoretical prediction by Melitz (2003) and others that heterogeneity in firm productivity affects firms' decision to start exporting. On the other hand, the evidence has been mixed on the "learning-by-exporting" hypothesis that exporting firms experience an improvement in productivity by gaining access to technical expertise from export markets. A few studies, such as Girma *et al*. (2004), De Loecker (2007), and Hahn and Park (2009), have found positive learning-by-exporting effects. However, both the theoretical and the empirical literature say little about the mechanisms involved: the theoretical model on the self-selection effect simply assumes that firms' productivity levels are drawn randomly from a probability distribution without explaining the origin of productivity differences, while the empirical studies do not explore the mechanisms underlying the learning-by-exporting effects.

In recent years, an increasing number of empirical studies have tried to identify the missing link between innovation, performance, and exporting, being aware of the importance of firms' innovative activities for their technological progress and productivity growth, as suggested by theories of firms' growth and endogenous growth theory (Romer 1990, etc.). Particularly in European countries, the interactions between exporting and innovation have been a research topic of major interest. Several studies, using firm-level data, have investigated the innovation-productivity-export link, and some found a positive impact of innovation on productivity and exporting.[3]

[3] For instance, Griffith *et al*. (2006) found that process innovation rather than product innovation positively affects productivity growth. For Spanish firms, Cassiman and Golovko (2007) found evidence of a positive link between innovation and productivity. Moreover, again focusing on Spanish firms, Cassiman *et al*. (2010) found that product innovation, rather than process innovation, was a driver of exports. Similar results were obtained by Becker and Egger (2007) and Bocquet and Musso (2010) for German and French firms, respectively. As for Belgian firms, van Beveren and Vandenbussche (2009) suggest that the combination of product and process innovation, rather than either of the two in isolation, increases a firm's probability to start exporting. On the other hand,

On the other hand, there are at best only a handful of studies that have found evidence in favor of a causal link in the opposite direction, that is, a link from exporting to innovation and productivity. Examples include Damijan *et al*. (2010), who investigated this reverse link using Slovenian firm-level data and found that past exporting status does increase the probability that medium and large firms will become process innovators, but past exporting status does not affect product innovation. Hahn (2010), on the other hand, focusing on the case of Korea, found that exporting has the effect of facilitating new product introduction by those plants that export. Moreover, Hahn's (2010) results suggest that not only exporting activity *per se* but also the absorptive capacity of plants matter in this process. For Japan, Ito and Lechevalier (2010) examined the effects of exporting and R&D activities on productivity growth and found that only firms which have accumulated internal knowledge through R&D activities experience an improvement in productivity after starting to export. Firms without *ex ante* R&D activities did not experience significantly higher productivity growth by starting to export than firms that did not start to export.

These empirical studies provide evidence on the existence of learning-by-exporting. However, the sources of learning-by-exporting have not yet been adequately explored. Damijan *et al*. (2010), for example, concluded that the mechanism underlying learning-by-exporting effects was that it enhanced firms' technical efficiency through process innovation and not that it promoted the introduction of new products. On the other hand, Hahn (2010) suggested that exporting promotes new product introduction, while Ito and Lechevalier (2010) argued that firms' absorptive capacity is important for the realization of learning-by-exporting effects. Finally, Yashiro and Hirano (2009) found that exporting firms realized much faster productivity growth than non-exporting firms during the export boom Japan experienced in 2002-2007. However, they concluded that only large exporting firms showed a higher productivity growth rate while small exporting firms did not show any significant productivity premium vis-à-vis small non-exporting firms.

Therefore, to date, the mechanisms of learning-by-exporting are not yet very clear.

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although they find a positive relationship between innovation and exporters' productivity, Bellone *et al*.(2010) conclude that the contribution of innovative capabilities to exporters' productivity premium is small.

Identifying these mechanisms certainly is not without challenges, given the fact that firms' size, absorptive capacity, product innovation, and process innovation are all endogenous.[4] However, attempting to address these challenges is important in order to gain a better understanding of the mechanisms and dynamics that allow firms to benefit from globalization, and to design effective policies that help firms to do so.

3. Data Description

3.1. Data

The data used for this study is the firm-level panel data underlying the *Basic Survey on Business Structure and Activities (BSBSA)*, collected annually by the Ministry of Economy, Trade and Industry, for the period 1994-2006.[5] The survey covers all firms with at least 50 employees or 30 million yen of paid-in capital in the Japanese manufacturing, mining, and commerce sectors and several other service sectors. The survey contains detailed information on firm-level business activities such as the 3-digit industry in which the firm operates, its number of employees (including a breakdown of the number of employees by firm division), sales, purchases, exports, and imports (including a breakdown of the destination of sales and exports and the origin of purchases and imports),[6] R&D and patents, the number of domestic and overseas subsidiaries, and various other financial data such as costs, profits, investment, and assets. Here, observations for the manufacturing sector are used because the focus of the study is the interaction between R&D and exporting.[7]

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[4] An increasing number of empirical studies on innovation and exporting, including works listed in this literature review, employ propensity score matching to address endogeneity between various firm strategies. Details of propensity score matching are provided in Section 4.

[5] The compilation of the firm-level panel data underlying the *BSBSA* was conducted as part of the project "Japan's Productivity and Economic Growth" at the Research Institute of Economy, Trade and Industry (RIETI).

[6] The survey asks for the amount as well as the destination or origin of exports and imports broken down into seven regions (Asia, Middle East, Europe, North America, Latin America, Africa, and Oceania). Unfortunately, more detailed information on the destination of exports and origin of imports is not available.

[7] Although the survey also asks non-manufacturing firms for information on exports and imports, they are required to provide the amount of trade in goods only. The survey does not cover international transactions in services.

Because firm-level information on product and process innovation is not available, the analysis mainly relies on information on R&D expenditure in the *BSBSA*.[8] Although patent-related information is also used as a proxy for a firm's innovative capabilities for supplementary analyses, a substantial number of firms do not report such information in the *BSBSA*. However, the advantage of the *BSBSA* data is that they are panel-data with more than 10-year time-series observations and that information on the destination of exports and the origin of imports is available.

After cleaning the data, the panel dataset contains approximately 11,000 manufacturing firms each year.[9] Table 1 shows the number of firms by size and by activity. In Table 1, R&D firms are defined as firms that have positive R&D expenditure (the sum of expenditure for in-house R&D and contract R&D) while firms with zero R&D expenditure are defined as non-R&D firms. Similarly, exporting firms are defined as firms that have a positive export value while firms with a zero export value are defined as non-exporting firms.[10] As shown in Table 1, nearly half of the firms do not export and report zero R&D expenditure. However, depending on firm size, between one-quarter and one-third of firms do have positive R&D expenditure but do not export. Especially among small and medium enterprises (SMEs), there are a large number of firms that do have some expenditure on R&D activities but do not export. As for large firms, nearly half are engaged in both exporting and R&D activities. The figures in Table 1 suggest that there is some kind of complementarily between R&D and

[8] The National Institute of Science and Technology Policy (NISTEP) conducted a *National Innovation Survey* in 2003 and 2009 which asked for various types of information related to product and process innovation. According to Kwon *et al*. (2008), the firm-level information taken from the 2003 survey can be linked with the firm-level data in the *BSBSA* for 1,745 manufacturing firms. Although only 15 percent of firms surveyed in the *BSBSA* provide information on innovative activities in the *National Innovation Survey*, such data would be potentially very useful for a future study on innovation and firm performance. Unfortunately, however, gaining access to the data involves extremely time-consuming red tape. Due to time constraints, I would therefore like to leave the analysis utilizing the *National Innovation Survey* for a future study.

[9] Firms for which data on sales, the number of employees, total wages, tangible fixed assets, depreciation, or intermediate inputs are not positive or are missing for at least one year were dropped from the dataset. The list of manufacturing industries analyzed in this paper and the number of firms by industry are shown in Appendix Table 1.

[10] The survey asks for the amount of direct exports and sales by firms' overseas affiliates. There is no information on indirect exports through trading companies and wholesalers. As far as the author knows, all the official surveys in Japan clearly ask for the amount of direct exports only and request not to include indirect exports. Although the fact that only direct exports are included in the data may create some bias in the results, it seems plausible to assume that direct contact to export markets is much more important for learning by exporting than indirect exporting.

exporting. This, in turn, may be a key factor which determines the growth of firms.

Table 1. Distribution of Japanese Manufacturing Firms Engaged in R&D and Export Activities

	No R&D No EXP	R&D only	EXP only	R&D & EXP	Total
All mfg. firms					
1994	4,935	3,502	595	2,308	11,340
	(44%)	(31%)	(5%)	(20%)	(100%)
2006	4,804	2,658	1,009	2,796	11,267
	(43%)	(24%)	(9%)	(25%)	(100%)
SMEs (with 300 or fewer employees)					
1994	4,404	2,502	472	1,068	8,446
	(52%)	(30%)	(6%)	(13%)	(100%)
2006	4,295	1,934	830	1,476	8,535
	(50%)	(23%)	(10%)	(17%)	(100%)
Large firms (with more than 300 employees)					
1994	531	1,000	123	1,240	2,894
	(18%)	(35%)	(4%)	(43%)	(100%)
2006	509	724	179	1,320	2,732
	(19%)	(27%)	(7%)	(48%)	(100%)

Note: The table shows the number of firms in each category. Figures in parentheses are the share of each category in the total. Figures in parentheses are shares of the number of firms for each category.

3.2. First-time Exporters

In order to investigate the mechanisms underlying learning-by-exporting effects, this study focuses on first-time exporters. As the survey does not provide information on the date or year firms first started to export, it is necessary to define first-time exporters based on certain rules. How first-time exporters are indentified is illustrated in Figure 1, which shows hypothetical examples five different patterns of data for exports. Examples 1 and 2 show firms which never exported before the reference year and are therefore defined as export starters in the reference year. On the other hand, if a firm, as shown in Example 3, has a positive export value for the year when it first enters the dataset, it is impossible to indentify whether the firm is an export starter or not. Consequently, export starters cannot be identified for the year 1994 which is the first year of the dataset, because the export status in the previous year is not available. Moreover, it should be noted that there is a greater likelihood of misidentification of export starters for early years in the dataset. Next, export quitters are similarly defined as firms which stopped exporting and subsequently did not start exporting again (Examples 1 and 3). If a firm has a positive export value for the last year in which it appears in the dataset, it is impossible to indentify whether the firm is an export quitter or not (Example 2). The definition of export quitters here also means that export quitters cannot be identified for the year 2006, which is the last year of the dataset. It should also be noted that there is a greater likelihood of misidentification of export quitters for later years in the dataset. Moreover, some firms can be both export starters and quitters (Example 1). Firms which have a positive export value for all years for which observations for them are available in the dataset are defined as firms which always export (Example 4), while firms which have a zero export value for all years for which observations for them are available in the dataset are defined as firms which never export (Example 5).

Figure 1. Examples for Export Starters and Quitters

	Exports (ex.1)		Exports (ex.2)		Exports (ex.3)		Exports (ex.4)		Exports (ex.5)	
1994	0				1		n.a.		n.a.	
1995	0				0		n.a.		n.a.	
1996	0				0		1	ALWAYS	n.a.	
1997	1	STARTER			1		1		0	NEVER
1998	0				0		1		0	
1999	1		0		1		1		0	
2000	0		0		0		1		0	
2001	1		0		1	QUITTER	1		0	
2002	1	QUITTER	1	STARTER	0		1		0	
2003	0		1		0		1		0	
2004	0		1		n.a.		1		0	
2005	0		n.a.		n.a.		1		n.a.	
2006	0		n.a.		n.a.		1		n.a.	

Notes: 1: A positive export value; 0: A zero export value; n.a.: No observation in the dataset.

Table 2 summarizes the number of firms by export status over the period 1995-2005 by industry. The table shows that of the firms in the dataset, 2,408 newly entered export markets during the period 1995-2005. At the same time, a significant number of firms (1,636 firms) stopped exporting and did not start exporting again. In fact, 787 starter firms are also defined as quitters, suggesting that a significant number of export starters quit exporting later.

Table 2. Number of Firms by Industry and by Export Status

		STARTER		QUITTER		ALWAYS		NEVER		Industry total	
		No.	%	No.	%	No.	%	No.	%	No.	%
1	Food products and beverages	159	(6.6)	153	(9.4)	88	(2.5)	2,243	(17.4)	2,601	(12.8)
2	Textiles	116	(4.8)	87	(5.3)	87	(2.4)	950	(7.3)	1,207	(6.0)
3	Lumber and wood products	41	(1.7)	34	(2.1)	22	(0.6)	505	(3.9)	589	(2.9)
4	Pulp, paper and paper products	66	(2.7)	43	(2.6)	29	(0.8)	500	(3.9)	623	(3.1)
5	Printing	43	(1.8)	31	(1.9)	25	(0.7)	804	(6.2)	890	(4.4)
6	Chemicals and chemical fibers	80	(3.3)	45	(2.8)	150	(4.2)	235	(1.8)	509	(2.5)
7	Paint, coating, and grease	30	(1.2)	33	(2.0)	60	(1.7)	75	(0.6)	196	(1.0)
8	Pharmaceutical products	35	(1.5)	29	(1.8)	84	(2.3)	139	(1.1)	291	(1.4)
9	Miscellaneous chemical products	68	(2.8)	49	(3.0)	145	(4.0)	133	(1.0)	391	(1.9)
10	Petroleum and coal products	12	(0.5)	10	(0.6)	20	(0.6)	35	(0.3)	75	(0.4)
11	Plastic products	154	(6.4)	89	(5.4)	137	(3.8)	664	(5.1)	1,023	(5.0)
12	Rubber products	24	(1.0)	18	(1.1)	56	(1.6)	115	(0.9)	213	(1.1)
13	Ceramic, stone and clay products	69	(2.9)	56	(3.4)	107	(3.0)	713	(5.5)	935	(4.6)
14	Iron and steel	89	(3.7)	81	(5.0)	60	(1.7)	411	(3.2)	605	(3.0)
15	Non-ferrous metals	79	(3.3)	52	(3.2)	103	(2.9)	232	(1.8)	460	(2.3)
16	Fabricated metal products	179	(7.4)	114	(7.0)	185	(5.2)	1,002	(7.8)	1,452	(7.2)
17	Metal processing machinery	59	(2.5)	46	(2.8)	137	(3.8)	140	(1.1)	376	(1.9)
18	Special industry machinery	78	(3.2)	58	(3.5)	208	(5.8)	252	(1.9)	612	(3.0)
19	Office and service industry machines	44	(1.8)	26	(1.6)	52	(1.5)	137	(1.1)	251	(1.2)
20	Miscellaneous machinery	179	(7.4)	120	(7.3)	335	(9.3)	479	(3.7)	1,104	(5.4)
21	Electrical machinery and apparatus	84	(3.5)	47	(2.9)	114	(3.2)	355	(2.7)	598	(2.9)
22	Household electric appliances	37	(1.5)	22	(1.3)	63	(1.8)	181	(1.4)	293	(1.4)
23	Communication equipment	52	(2.2)	44	(2.7)	98	(2.7)	225	(1.7)	409	(2.0)
24	Computer and electronic equipment	52	(2.2)	27	(1.7)	101	(2.8)	152	(1.2)	328	(1.6)
25	Electronic parts and devices	160	(6.6)	77	(4.7)	286	(8.0)	529	(4.1)	1,049	(5.2)
26	Miscellaneous electrical machinery	40	(1.7)	22	(1.3)	109	(3.0)	153	(1.2)	324	(1.6)
27	Motor vehicles and parts	211	(8.8)	93	(5.7)	217	(6.1)	795	(6.2)	1,286	(6.3)
28	Other transportation equipment	32	(1.3)	27	(1.7)	73	(2.0)	212	(1.6)	343	(1.7)
29	Precision machinery	75	(3.1)	46	(2.8)	257	(7.2)	191	(1.5)	581	(2.9)
30	Miscellaneous mfg. industries	61	(2.5)	57	(3.5)	175	(4.9)	369	(2.9)	659	(3.3)
1-30	Manufacturing Total	2,408	(100.0)	1,636	(100.0)	3,583	(100.0)	12,926	(100.0)	20,273	(100.0)

Notes: Firms are classified based on the industry reported for the first observation of each firm during the observation period. ALWAYS denotes firms which always exported throughout the sample period while NEVER denotes firms which never exported throughout

Table 3 shows a breakdown of export starters by firm characteristics.[11] It indicates that 74 percent of the 2,408 export starters are SMEs (firms with 300 or fewer employees). This share more or less corresponds to the share of SMEs in the total

[11] The number of export starters by year and the number of export quitters by year are shown in Appendix Table 2.

number of firms in the dataset overall, which is 76 percent. Moreover, as expected, the major export destination for both SMEs and larger firms is Asia.

Table 3. Number of Export Starters by Characteristics (Period Total)

		Total		SMEs		Large firms	
Export Starters		2,408	(100%)	1,780	(74%)	628	(26%)
Breakdown by Export Destination							
Destinations Total		3,142	(100%)	2174	(100%)	968	(100%)
	Asia	1,952	(62%)	1446	(67%)	506	(52%)
	Middle East	64	(2%)	33	(2%)	31	(3%)
	Europe	256	(8%)	165	(8%)	91	(9%)
	North America	617	(20%)	395	(18%)	222	(23%)
	Latin America	85	(3%)	50	(2%)	35	(4%)
	Africa	47	(1%)	23	(1%)	24	(2%)
	Oceania	121	(4%)	62	(3%)	59	(6%)

4. Econometric Analysis

4.1. Propensity Score Matching and DID Estimator

This section explains the econometric strategy employed to investigate the effects of starting to export. Taking account of endogeneity among firms' various strategies and outcomes, propensity score matching is used to examine various outcomes of starting exporting.

First, using logit estimation, the probability of initiating exporting for firms is estimated and then a "propensity score" for each firm calculated. The propensity score is defined as the conditional probability of initiating exporting given a firm's characteristics prior to exporting:

$$P(x) \equiv \Pr\{z = 1|x\} = E\{z|x\} \qquad (1)$$

where z={0,1} indicates whether the firm started exporting in year *t*, and *x* is a vector of observed firm characteristics in year *t-1*, i.e., the year prior to starting to export. For *x*, the productivity level, firm size (proxied by the number of employees), R&D intensity

(R&D expenditure divided by sales), age, the debt-asset ratio, the import-sales ratio, and the FDI ratio (foreign investment divided by assets) are considered.[12] The main productivity measure used here is total factor productivity (TFP) estimated using the Olley-Pakes method. The production function is estimated by industry and the estimated production function coefficients are shown in Appendix Table 3.[13]

Second, after estimating the logit model, firms which did not start exporting in year *t* are matched with firms that had the closest propensity score and that actually did initiate exporting. The matching is conducted separately for each year and industry.

Finally, the causal effect of initiating exporting on various performance variables is examined. As shown in Rosenbaum and Rubin (1983), if the recipient of the treatment (*z* in equation 1) is randomly chosen within cells defined by *x* in equation 1, it is also randomly chosen within cells defined by the values of the single-index variable *P(x)*. Therefore, the Average effect of Treatment on the Treated (ATT) can be estimated as the average difference between the outcome of recipients and non-recipients of the treatment for which propensity scores *P(x)* are identical. In this case, the treatment is the start of exporting. The propensity score matching technique should identify matched firms that satisfy the assumption that, conditional on observables, the non-treated outcomes are independent of the treatment status. Nonetheless, the propensity score is conditional only on a limited number of observable characteristics, implying that unobservable, time-invariant, firm-specific effects may not be fully removed after propensity score matching. Therefore, the growth rate of the performance variables of exporting firms, which is called the difference-in-differences (DID) estimator, is compared between treated and non-treated firms. In this manner, these unobservable effects can be reduced and more robust estimates can be obtained. The DID estimator can be calculated as follows:

$$\widehat{\propto}_{\mathrm{ATT-DID}} = \frac{1}{n}\sum_{1}^{n}(y_{t+s}^{1} - y_{t-1}^{1}) - \frac{1}{n}\sum_{1}^{n}(y_{t+s}^{0} - y_{t-1}^{0}) \qquad (2)$$

[12] Foreign investment here is defined as the amount of investment and/or lending to related firms (either subsidiaries and affiliates of the firm or those of the parent firm) located abroad.

[13] The estimated coefficient of capital input was negative or insignificant in some cases. Therefore, the production function was estimated at a more aggregated industry level. However, there are still some cases where the coefficient of capital input was not statistically significant.

where n denotes the number of observations and y denotes performance variables. For y, productivity (TFP), demand (firm sales), R&D intensity, R&D volume (R&D expenditure and employees in R&D divisions), firm size (employment and capital stock), and skill intensity (R&D employment share) are considered. It is then examined how and whether exporting changes these performance measures.

4.2. Matching Results

In order to examine the determinants of export initiation, observations of firms which did not export before and started exporting for the first time during the sample period are used. Observations of firms which exported throughout and firms which exported but quit exporting before the reference year are excluded. The result of the logit estimation is shown in column (1) of Table 4 and indicates that larger (in terms of employment), more R&D intensive, older, and financially healthier firms are more likely to become exporters. Moreover, the significantly positive coefficients for the import and FDI ratios suggest that having some sort of link with international markets is a key determinant of starting to export. However, the coefficient on productivity is not statistically significant, suggesting that the productivity level is not a relevant determinant of starting to export.[14] Based on the logit estimation, firms are matched separately for each year and industry using the one-to-one nearest neighbor matching method.[15] The balancing property test results are shown in Panel (a) of Appendix Table 4.[16] Table 5 shows the estimated effects of starting to export, with s denoting the year after the treatment (s in equation 2 above). Table 5 suggests that firms that started exporting show significantly higher sales and employment growth rates than firms that did not start exporting (rows (d) and (l)). Moreover, starting to export promotes R&D activities and increases the R&D intensity and R&D volume (rows (e) to (j) and rows

[14] This result is not consistent with the theoretical prediction by Melitz (2003) and others that export starters should be more productive in order to cover the fixed costs involved in starting to export. However, results by Todo (2009) for Japan suggest that productivity has a positive impact on the export decision, although the impact is economically negligible in size. The insignificant coefficient on TFP in Table 4 seems consistent with Todo's results.

[15] The matching procedure is implemented in Stata11 using a modified version of the procedure provided by Leuven and Sianesi (2003).

[16] The balancing property is not adequately satisfied for some cases in Appendix Table 4, though the specification provided the best results in terms of the balancing property tests out of the several specifications tried.

(o) and (p)). The positive effects of exporting on R&D activities continue even four years after the firm started exporting. However, exporting does not have a significantly positive effect on productivity in most cases (rows (a) and (b)). It should be noted that actually a significant number of treated and control firms are dropped from the sample in later years and only surviving firms are included in the ATT and DID analyses. Moreover, a substantial number of treated firms stopped exporting after they started exporting. For some cases, treated firms are retained in the sample while the matched control firms are dropped from the sample, or vice versa, in later years. As can be seen in Table 5, the numbers of treated firms and control firms are not balanced in later years. Because firms which are dropped from the sample or whose export status switches may create some bias in the results, they are excluded when estimating the effects of starting to export.[17] The results are shown in Table 6 and are mostly consistent with those in Table 5. For the estimation shown in Table 6, only treated firms which continued exporting and whose control firms were not dropped from the sample are included. However, as before (Table 5), starting to export has no (or at best a weakly significant) positive effect on productivity.

Table 4. Determinants of Export Initiation

	Logit	Multinomial logit		
	(1)	(2)	(3)	(4)
	STARTER=1	NAEUR=3	ASIA=2	OTHERS=1
lnTFP (OP)	-0.0472	0.2313	-0.1567	-0.6203
	(0.1325)	(0.2318)	(0.1606)	(0.6843)
ln(employment)	0.3879***	0.5366***	0.3152***	0.3056**
	(0.0263)	(0.0422)	(0.0331)	(0.1284)
R&D intensity	10.7083***	14.1406***	8.0768***	10.1582**
	(1.0193)	(1.3279)	(1.3527)	(4.0193)
Age	0.0026***	0.0023*	0.0027***	0.0025
	(0.0007)	(0.0014)	(0.0008)	(0.0048)
Debt-asset ratio	-0.1744*	-0.2806*	-0.1134	-0.5149
	(0.0892)	(0.1608)	(0.1056)	(0.4708)
Import ratio	1.8835***	1.5279***	1.9775***	2.5612***
	(0.1705)	(0.3218)	(0.1937)	(0.6432)

[17] Specifically, a pair of firms is excluded when one of the pair is dropped from the sample or when the treated firm stopped exporting.

Table 4 (continued). Determinants of Export Initiation

	Logit	Multinomial logit		
	(1)	(2)	(3)	(4)
	STARTER=1	NAEUR=3	ASIA=2	OTHERS=1
FDI ratio	8.6690***	8.4402***	8.8450***	6.6518**
	(0.6541)	(1.0077)	(0.7229)	(2.6418)
No. of observations	69,912		69,912	
Chi-squared	1735.51		1997.66	
Pseudo R^2	0.0931		0.0916	
Log likelihood	-8450.0695		-9901.9601	

Note: Standard errors are in parentheses, with ***, **, and * indicating significance at the 1%, 5%, and 10% levels, respectively. The constant term is not reported. All equations include three-digit industry dummy variables and year dummy variables.

Table 5. Estimated Effects of Starting to Export

S	0		1		2		3		4	
No. of observations	4,136		3,528		3,165		2,792		2,448	
Treated	2,068		1,748		1,581		1,413		1,243	
Control	2,068		1,780		1,584		1,379		1,205	
Outcome										
(a) Productivity level (lnTFP_OP)										
	-0.0059		0.0011		-0.0069		-0.0022		0.0047	
	(0.0120)		(0.0104)		(0.0128)		(0.0114)		(0.0124)	
(b) Productivity growth rate: pre-export level (s=-1)										
	0.0032		0.0109	*	0.0038		0.0062		0.0067	
	(0.0052)		(0.0059)		(0.0064)		(0.0076)		(0.0083)	
(c) Sales (lnY)										
	-0.0512		-0.0234		-0.0302		-0.0207		-0.0278	
	(0.0401)		(0.0393)		(0.0488)		(0.0517)		(0.0487)	
(d) Sales growth rate: pre-export level (s=-1)										
	0.0245	***	0.0365	***	0.0388	***	0.0403	***	0.0494	***
	(0.0073)		(0.0091)		(0.0119)		(0.0142)		(0.0177)	
(e) R&D intensity										
	0.0010		0.0021	***	0.0031	***	0.0034	***	0.0032	***
	(0.0007)		(0.0008)		(0.0008)		(0.0009)		(0.0010)	

Table 5 (continued). Estimated Effects of Starting to Export

S	0		1		2		3		4	
(f) Difference in R&D intensity: pre-export level (s=-1)										
	0.0002		0.0015	***	0.0022	***	0.0026	***	0.0019	**
	(0.0006)		(0.0005)		(0.0007)		(0.0007)		(0.0008)	
(g) R&D expenditure (lnR&D exp)										
	1.7512	***	1.9901	***	2.2229	***	2.0099	***	2.1944	***
	(0.3155)		(0.2983)		(0.3805)		(0.3740)		(0.3577)	
(h) R&D expenditure growth rate: pre-export level (s=-1)										
	0.4626	***	0.4845	**	0.7079	***	0.6213	**	0.7254	**
	(0.1689)		(0.2184)		(0.2328)		(0.2736)		(0.3075)	
(i) R&D employment (lnR&D emp)										
	0.2383	***	0.2548	***	0.2819	***	0.3128	***	0.2978	***
	(0.0488)		(0.0549)		(0.0571)		(0.0673)		(0.0587)	
(j) R&D employment growth rate: pre-export level (s=-1)										
	0.0883	***	0.0844	***	0.1026	***	0.1299	***	0.1358	**
	(0.0245)		(0.0283)		(0.0370)		(0.0388)		(0.0536)	
(k) Employment (ln employment)										
	-0.1104	***	-0.0915	**	-0.0910	***	-0.0830	**	-0.0932	**
	(0.0247)		(0.0335)		(0.0321)		(0.0362)		(0.0372)	
(l) Employment growth rate: pre-export level (s=-1)										
	0.0201	***	0.0275	***	0.0337	***	0.0368	***	0.0317	***
	(0.0043)		(0.0057)		(0.0072)		(0.0093)		(0.0106)	
(m) Capital stock (ln K)										
	-0.0606		-0.0365		-0.0018		0.0042		-0.0083	
	(0.0514)		(0.0429)		(0.0521)		(0.0554)		(0.0562)	
(n) Capital stock growth rate: pre-export level (s=-1)										
	0.0190	*	0.0202		0.0386	***	0.0438	**	0.0675	***
	(0.0111)		(0.0125)		(0.0139)		(0.0190)		(0.0234)	
(o) R&D employment share										
	0.0113	***	0.0131	***	0.0134	***	0.0165	***	0.0145	***
	(0.0025)		(0.0024)		(0.0026)		(0.0026)		(0.0033)	
(p) Difference in R&D employment share: pre-export level (s=-1)										
	0.0021		0.0030	*	0.0030		0.0058	***	0.0047	**
	(0.0015)		(0.0018)		(0.0018)		(0.0021)		(0.0024)	

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Estimated Effects of Starting to Export (Excluding Switchers and Quitters)

s	0		1		2		3		4	
No. of observations	4,136		2,260		1,732		1,370		1,136	
Treated	2,068		1,130		866		685		568	
Control	2,068		1,130		866		685		568	
Outcome										
(a) Productivity level (lnTFP_OP)										
	-0.0059		0.0006		-0.0036		-0.0029		0.0001	
	(0.0120)		(0.0149)		(0.0155)		(0.0178)		(0.0177)	
(b) Productivity growth rate: pre-export level (s=-1)										
	0.0032		0.0131	*	0.0166	*	0.0097		0.0095	
	(0.0058)		(0.0071)		(0.0089)		(0.0096)		(0.0101)	
(c) Sales (lnY)										
	-0.0512		-0.0504		-0.0817		-0.0242		-0.0608	
	(0.0355)		(0.0506)		(0.0622)		(0.0691)		(0.0847)	
(d) Sales growth rate: pre-export level (s=-1)										
	0.0245	***	0.0562	***	0.0604	***	0.0746	***	0.0886	***
	(0.0054)		(0.0123)		(0.0151)		(0.0199)		(0.0227)	
(e) R&D intensity										
	0.0010	*	0.0029	***	0.0032	***	0.0033	**	0.0029	
	(0.0006)		(0.0010)		(0.0012)		(0.0016)		(0.0018)	
(f) Difference in R&D intensity: pre-export level (s=-1)										
	0.0002		0.0016	***	0.0022	**	0.0032	***	0.0023	**
	(0.0006)		(0.0006)		(0.0009)		(0.0012)		(0.0011)	
(g) R&D expenditure (lnR&D exp)										
	1.7512	***	2.1893	***	2.1225	***	2.0370	***	1.9617	***
	(0.2893)		(0.3680)		(0.4995)		(0.5369)		(0.5313)	
(h) R&D expenditure growth rate: pre-export level (s=-1)										
	0.4626	**	0.8856	***	0.8358	***	0.9463	**	0.9984	**
	(0.1821)		(0.2737)		(0.3205)		(0.3713)		(0.3856)	
(i) R&D employment (lnR&D emp)										
	0.2383	***	0.2343	***	0.2631	***	0.3624	***	0.3081	***
	(0.0551)		(0.0612)		(0.0841)		(0.0996)		(0.1072)	
(j) R&D employment growth rate: pre-export level (s=-1)										
	0.0883	***	0.0950	**	0.1850	***	0.2741	***	0.1805	**
	(0.0243)		(0.0436)		(0.0538)		(0.0621)		(0.0766)	
(k) Employment (ln employment)										
	-0.1104	***	-0.1024	**	-0.1047	**	-0.0731		-0.0978	*
	(0.0247)		(0.0404)		(0.0407)		(0.0502)		(0.0568)	

Table 6 (continued). Estimated Effects of Starting to Export (Excluding Switchers and Quitters)

s	0		1		2		3		4	
(l) Employment growth rate: pre-export level (s=-1)										
	0.0201	***	0.0340	***	0.0412	***	0.0573	***	0.0573	***
	(0.0043)		(0.0078)		(0.0107)		(0.0130)		(0.0172)	
(m) Capital stock (ln K)										
	-0.0606		-0.0655		-0.0952		-0.0304		-0.0968	
	(0.0514)		(0.0720)		(0.0732)		(0.0812)		(0.0844)	
(n) Capital stock growth rate: pre-export level (s=-1)										
	0.0190	*	0.0156		0.0290		0.0068		0.0447	
	(0.0111)		(0.0171)		(0.0212)		(0.0272)		(0.0300)	
(o) R&D employment share										
	0.0113	***	0.0125	***	0.0135	***	0.0174	***	0.0141	***
	(0.0025)		(0.0038)		(0.0043)		(0.0042)		(0.0051)	
(p) Difference in R&D employment share: pre-export level (s=-1)										
	0.0021		0.0025		0.0056	**	0.0098	***	0.0038	
	(0.0015)		(0.0023)		(0.0026)		(0.0030)		(0.0038)	

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.3. Learning-by-Exporting Effects by Export Destination

In order to further investigate the mechanism of learning-by-exporting, the sample is split according to the destination market and the effect of exporting is estimated separately for firms exporting to high-income regions and low-income regions. Conducting such estimations by region, it is then examined whether the effects of exporting differ across export destinations. Because the survey only asks respondents to name the export region, such as Asia, North America, and Europe, the following four cases are distinguished: (1) firms which do not export; (2) firms which do not export to Asia, North America, or Europe, but do export to other regions; (3) firms which do not export to North America or Europe, but do export to Asia (and other regions); and (4) firms exporting to North America or Europe (and Asia and/or other regions). That is, for example, if a firm exports to both North America and Asia in the initial year of exporting, the firm is classified as falling into the fourth category. Similarly, if a firm exports to both Asia and Oceania in the initial year of exporting, the firm is classified as falling into the third category. And if a firm exports to Europe only, the firm is classified as falling into the fourth category.[18] In order to estimate the determinants of exporting for each category of firms, equation (1) is modified into a multinomial logit model. The indicator of initiating exporting in year *t*, *z*, now takes a value of 0, 1, 2, or 3, corresponding to the four cases. The multinomial logit estimation results are shown in columns (2) to (4) of Table 4.[19] Based on the multinomial logit estimation, firms are matched separately for each year and industry using the one-to-one nearest neighbor matching method. The balancing property test results are shown in Panels (b) to (d) of Appendix Table 4.

Tables 7 to 9 show the estimated effects of starting to export. The results in Table 7 suggest that starting to export to North America or Europe has a strong positive effect on sales and employment growth and R&D activities. Moreover, exporting to these regions improves the productivity growth rate significantly. However, starting to export to Asia does not have any productivity enhancing effects, although it tends to raise the growth rate of sales and increase R&D expenditure (Table 8). Starting to export to other regions has almost no significant effect, though the results may be due to the small sample size (Table 9).

Table 7. Estimated Effects of Starting to Export to North America or Europe

S	0		1		2	3	4
No. of observations	1,260		1,096		967	859	764
Treated	630		551		498	445	389
Control	630		545		469	414	375
Outcome							
(a) Productivity level (lnTFP_OP)							
	0.0116		0.0275		0.0002	-0.0008	0.0066
	(0.0205)		(0.0215)		(0.0187)	(0.0233)	(0.0255)
(b) Productivity growth rate: pre-export level (s=-1)							
	0.0163	**	0.0293	***	0.0183	0.0182	0.0153
	(0.0079)		(0.0104)		(0.0127)	(0.0134)	(0.0149)

[18] The number of firms for each category is shown in Appendix Table 5.

[19] The results in columns (2) to (4) of Table 4 are similar to that in column (1). However, size (as measured by employment) and R&D intensity have a larger impact on the decision to export to North America/Europe than on decision to export to Asia and other regions. As for the productivity level, although the estimated coefficients are not statistically significant, a positive coefficient is estimated only in the case of the decision to export to North America/Europe, suggesting that productivity is a more important determinant for export starters to developed regions than for those to developing regions.

Table 7 (continued). Estimated Effects of Starting to Export to North America or Europe

S	0		1		2		3		4	
(c) Sales (lnY)										
	0.0735		0.0895		0.0818		0.0997		0.1299	
	(0.0787)		(0.0704)		(0.0854)		(0.0874)		(0.0946)	
(d) Sales growth rate: pre-export level (s=-1)										
	0.0672	***	0.0791	***	0.0893	***	0.0787	**	0.0924	***
	(0.0140)		(0.0162)		(0.0214)		(0.0239)		(0.0323)	
(e) R&D intensity										
	0.0026		0.0041	**	0.0057	***	0.0069	***	0.0070	***
	(0.0019)		(0.0020)		(0.0018)		(0.0024)		(0.0022)	
(f) Difference in R&D intensity: pre-export level (s=-1)										
	-0.0007		0.0012		0.0021		0.0034	**	0.0020	
	(0.0012)		(0.0012)		(0.0015)		(0.0016)		(0.0014)	
(g) R&D expenditure (lnR&D exp)										
	3.4182	***	3.4800	***	3.7098	***	3.8470	***	3.9876	***
	(0.4810)		(0.5550)		(0.6499)		(0.6505)		(0.6974)	
(h) R&D expenditure growth rate: pre-export level (s=-1)										
	0.6047	*	0.5624		0.8818	*	1.2263	**	1.0353	*
	(0.3437)		(0.4300)		(0.5251)		(0.5752)		(0.5609)	
(i) R&D employment (lnR&D emp)										
	0.3489	***	0.3903	***	0.4981	***	0.5052	***	0.4992	***
	(0.0903)		(0.1113)		(0.1187)		(0.1138)		(0.1204)	
(j) R&D employment growth rate: pre-export level (s=-1)										
	0.0478		0.0588		0.1934	***	0.2272	***	0.1882	*
	(0.0542)		(0.0661)		(0.0726)		(0.0810)		(0.0992)	
(k) Employment (ln employment)										
	-0.0250		-0.0121		-0.0348		-0.0131		0.0000	
	(0.0567)		(0.0641)		(0.0618)		(0.0717)		(0.0813)	
(l) Employment growth rate: pre-export level (s=-1)										
	0.0364	***	0.0528	***	0.0470	***	0.0517	***	0.0458	**
	(0.0087)		(0.0116)		(0.0158)		(0.0184)		(0.0210)	
(m) Capital stock (ln K)										
	0.1298		0.1178		0.0884		0.1190		0.1391	
	(0.0794)		(0.0851)		(0.1033)		(0.1162)		(0.1140)	
(n) Capital stock growth rate: pre-export level (s=-1)										
	0.0393		0.0351		0.0399		0.0508		0.0997	**
	(0.0257)		(0.0228)		(0.0367)		(0.0398)		(0.0449)	
(o) R&D employment share										
	0.0177	***	0.0178	***	0.0210	***	0.0218	***	0.0219	***
	(0.0052)		(0.0057)		(0.0051)		(0.0057)		(0.0071)	

Table 7 (continued). Estimated Effects of Starting to Export to North America or Europe

S	0	1	2	3	4
(p) Difference in R&D employment share: pre-export level (s=-1)					
	0.0005	-0.0001	0.0035	0.0062	0.0046
	(0.0030)	(0.0032)	(0.0037)	(0.0046)	(0.0053)

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Estimated Effects of Starting to Export to Asia

s	0		1		2		3		4	
No. of observations	2,714		2,283		2,049		1,787		1,565	
Treated	1,357		1,129		1,019		909		798	
Control	1,357		1,154		1,030		878		767	
Outcome										
(a) Productivity level (lnTFP_OP)										
	-0.0076		-0.0062		-0.0050		-0.0111		-0.0055	
	(0.0130)		(0.0141)		(0.0143)		(0.0154)		(0.0169)	
(b) Productivity growth rate: pre-export level (s=-1)										
	-0.0058		-0.0018		-0.0057		-0.0124		-0.0116	
	(0.0060)		(0.0081)		(0.0085)		(0.0089)		(0.0101)	
(c) Sales (lnY)										
	-0.0840	**	-0.0831		-0.1021	*	-0.0798		-0.1001	*
	(0.0403)		(0.0507)		(0.0536)		(0.0530)		(0.0553)	
(d) Sales growth rate: pre-export level (s=-1)										
	0.0101		0.0165		0.0215		0.0214		0.0146	
	(0.0072)		(0.0106)		(0.0140)		(0.0164)		(0.0208)	
(e) R&D intensity										
	-0.0001		0.0010		0.0018	**	0.0018	**	0.0020	**
	(0.0007)		(0.0008)		(0.0009)		(0.0009)		(0.0010)	
(f) Difference in R&D intensity: pre-export level (s=-1)										
	0.0010	**	0.0020	***	0.0028	***	0.0027	***	0.0029	***
	(0.0005)		(0.0005)		(0.0006)		(0.0007)		(0.0008)	
(g) R&D expenditure (lnR&D exp)										
	0.8434	**	1.0986	***	1.3299	***	0.9912	***	1.6074	***
	(0.3728)		(0.3999)		(0.4311)		(0.3591)		(0.4775)	
(h) R&D expenditure growth rate: pre-export level (s=-1)										
	0.2539		0.2348		0.6511	**	0.3137		0.7421	**
	(0.2316)		(0.2913)		(0.2992)		(0.3488)		(0.3660)	

Table 8 (continued). Estimated Effects of Starting to Export to Asia

s	0		1		2		3		4	
(i) R&D employment (lnR&D emp)										
	0.0883		0.1212	*	0.1376	**	0.1334	*	0.1574	*
	(0.0595)		(0.0681)		(0.0569)		(0.0700)		(0.0893)	
(j) R&D employment growth rate: pre-export level (s=-1)										
	0.0414		0.0567	*	0.1041	**	0.0808		0.0924	*
	(0.0336)		(0.0321)		(0.0436)		(0.0561)		(0.0552)	
(k) Employment (ln employment)										
	-0.1389	***	-0.1446	***	-0.1327	***	-0.1398	***	-0.1484	***
	(0.0320)		(0.0355)		(0.0361)		(0.0404)		(0.0439)	
(l) Employment growth rate: pre-export level (s=-1)										
	0.0113	**	0.0094		0.0210	**	0.0127		0.0050	
	(0.0051)		(0.0066)		(0.0095)		(0.0125)		(0.0159)	
(m) Capital stock (ln K)										
	-0.1244	**	-0.1105	*	-0.1102	**	-0.0819		-0.0892	
	(0.0525)		(0.0640)		(0.0518)		(0.0641)		(0.0756)	
(n) Capital stock growth rate: pre-export level (s=-1)										
	0.0113		0.0079		0.0273		0.0350		0.0495	*
	(0.0125)		(0.0146)		(0.0184)		(0.0216)		(0.0272)	
(o) R&D employment share										
	0.0072	***	0.0072	***	0.0088	***	0.0101	***	0.0097	***
	(0.0022)		(0.0027)		(0.0028)		(0.0030)		(0.0033)	
(p) Difference in R&D employment share: pre-export level (s=-1)										
	0.0014		0.0006		0.0030		0.0029		0.0030	
	(0.0015)		(0.0022)		(0.0022)		(0.0027)		(0.0026)	

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 9. Estimated Effects of Starting to Export to Other Regions

s	0	1	2	3	4
No. of observations	162	139	126	116	108
Treated	81	68	64	59	56
Control	81	71	62	57	52
Outcome					
(a) Productivity level (lnTFP_OP)					
	0.0012	-0.0034	-0.0592	-0.0399	-0.0133
	(0.0629)	(0.0599)	(0.0627)	(0.0646)	(0.0639)
(b) Productivity growth rate: pre-export level (s=-1)					
	-0.0016	0.0109	-0.0037	0.0063	0.0181
	(0.0288)	(0.0261)	(0.0283)	(0.0324)	(0.0308)

Table 9 (continued). Estimated Effects of Starting to Export to Other Regions

s	0	1	2	3	4
(c) Sales (lnY)					
	-0.1661	-0.1221	-0.2292	-0.1309	-0.2771
	(0.2107)	(0.2405)	(0.2271)	(0.2733)	(0.2617)
(d) Sales growth rate: pre-export level (s=-1)					
	0.0235	0.0211	0.0220	0.0460	0.0439
	(0.0257)	(0.0455)	(0.0472)	(0.0738)	(0.0854)
(e) R&D intensity					
	-0.0022	-0.0003	0.0004	-0.0014	0.0004
	(0.0024)	(0.0036)	(0.0023)	(0.0034)	(0.0042)
(f) Difference in R&D intensity: pre-export level (s=-1)					
	-0.0035 **	0.0001	-0.0017	-0.0038	-0.0026
	(0.0017)	(0.0026)	(0.0020)	(0.0032)	(0.0027)
(g) R&D expenditure (lnR&D exp)					
	0.9664	-0.1326	1.5564	0.1427	-0.0091
	(1.2480)	(1.6405)	(1.8298)	(1.7239)	(1.7060)
(h) R&D expenditure growth rate: pre-export level (s=-1)					
	0.1393	-0.9247	-0.4689	-2.5038 **	-2.4948 **
	(0.7628)	(0.8846)	(1.1400)	(1.3289)	(1.1326)
(i) R&D employment (lnR&D emp)					
	-0.1133	-0.4866 *	-0.1372	-0.0372	-0.1834
	(0.2434)	(0.2795)	(0.2609)	(0.3065)	(0.3284)
(j) R&D employment growth rate: pre-export level (s=-1)					
	0.2290 *	-0.1179	0.1023	0.0965	-0.0437
	(0.1364)	(0.1875)	(0.1954)	(0.2267)	(0.1722)
(k) Employment (ln employment)					
	-0.2544	-0.2602	-0.3662 **	-0.2869	-0.4188 **
	(0.1639)	(0.2021)	(0.1821)	(0.1776)	(0.2014)
(l) Employment growth rate: pre-export level (s=-1)					
	0.0076	0.0011	0.0036	0.0035	-0.0174
	(0.0173)	(0.0238)	(0.0317)	(0.0511)	(0.0512)
(m) Capital stock (ln K)					
	-0.1134	-0.0802	-0.1415	-0.0394	-0.1564
	(0.2431)	(0.2354)	(0.3030)	(0.2880)	(0.3167)
(n) Capital stock growth rate: pre-export level (s=-1)					
	-0.0400	-0.0811	-0.0343	0.0515	0.0572
	(0.0459)	(0.0710)	(0.0859)	(0.0937)	(0.0952)
(o) R&D employment share					
	0.0051	0.0001	0.0065	0.0167	0.0054
	(0.0089)	(0.0129)	(0.0103)	(0.0158)	(0.0115)
(p) Difference in R&D employment share: pre-export level (s=-1)					
	0.0051	0.0015	0.0005 *	0.0110	-0.0032
	(0.0057)	(0.0106)	(0.0084)	(0.0155)	(0.0065)

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

The results in Tables 7 to 9 are based on observations of firms that survived *s* years after the treatment year regardless of whether the export status of the treated firm changed and of whether one of the pair was dropped from the sample. Therefore, similar to Table 6, Tables 10 to 12 show estimates when these firms are excluded and only treated firms which continued exporting and whose control firms were not dropped from the sample are included. The results are mostly consistent with those in Tables 7 to 9. However, the magnitude of the positive impact is much larger in Tables 10 to 12 than in Tables 7 to 9. The results in Tables 10 to 12 pick up the effects for firms which were able to stay and survive in the export market, and these firms are likely to have enjoyed greater learning effects. That is, the results in Tables 10 to 12 may include a selection effect (better performing firms were able to stay in the export market).

Table 10. Estimated Effects of Starting to Export to North America or Europe (Excluding Switchers and Quitters)

s	0		1		2		3		4	
No. of observations	1,260		802		600		494		410	
Treated	630		401		300		247		205	
Control	630		401		300		247		205	
Outcome										
(a) Productivity level (lnTFP_OP)										
	0.0116		0.0211		0.0217		0.0138		0.0325	
	(0.0209)		(0.0223)		(0.0260)		(0.0265)		(0.0330)	
(b) Productivity growth rate: pre-export level (s=-1)										
	0.0163	*	0.0243	**	0.0384	***	0.0304		0.0414	*
	(0.0095)		(0.0119)		(0.0136)		(0.0195)		(0.0232)	
(c) Sales (lnY)										
	0.0735		0.1216		0.0970		0.1951	*	0.2185	*
	(0.0819)		(0.0975)		(0.1086)		(0.1154)		(0.1180)	
(d) Sales growth rate: pre-export level (s=-1)										
	0.0672	***	0.0966	***	0.1149	***	0.1051	***	0.1223	***
	(0.0128)		(0.0203)		(0.0236)		(0.0329)		(0.0396)	
(e) R&D intensity										
	0.0026		0.0051	**	0.0043	*	0.0033		0.0043	
	(0.0018)		(0.0025)		(0.0024)		(0.0030)		(0.0029)	
(f) Difference in R&D intensity: pre-export level (s=-1)										
	-0.0007		0.0014		0.0023		0.0037		0.0040	**
	(0.0012)		(0.0013)		(0.0019)		(0.0023)		(0.0020)	

Table 10 (continued). Estimated Effects of Starting to Export to North America or Europe (Excluding Switchers and Quitters)

s	0		1		2		3		4	
(g) R&D expenditure (lnR&D exp)										
	3.4182	***	3.8709	***	3.7914	***	3.7351	***	4.2656	***
	(0.5000)		(0.6523)		(0.6731)		(0.8356)		(0.9044)	
(h) R&D expenditure growth rate: pre-export level (s=-1)										
	0.6047	*	0.7230	*	0.9719		1.3370	**	1.3970	*
	(0.3268)		(0.4258)		(0.5905)		(0.6193)		(0.7834)	
(i) R&D employment (lnR&D emp)										
	0.3489	***	0.5129	***	0.5793	***	0.5916	***	0.5461	***
	(0.0809)		(0.1135)		(0.1527)		(0.1698)		(0.1569)	
(j) R&D employment growth rate: pre-export level (s=-1)										
	0.0478		0.1231		0.3092	***	0.3813	***	0.2527	*
	(0.0556)		(0.0852)		(0.1077)		(0.1018)		(0.1320)	
(k) Employment (ln employment)										
	-0.0250		0.0093		-0.0102		0.0529		0.0547	
	(0.0567)		(0.0747)		(0.0809)		(0.0811)		(0.0979)	
(l) Employment growth rate: pre-export level (s=-1)										
	0.0364	***	0.0608	***	0.0574	***	0.0761	***	0.0759	***
	(0.0087)		(0.0127)		(0.0204)		(0.0274)		(0.0280)	
(m) Capital stock (ln K)										
	0.1298		0.0702		0.0335		0.1621		0.1644	
	(0.0794)		(0.1193)		(0.1172)		(0.1206)		(0.1564)	
(n) Capital stock growth rate: pre-export level (s=-1)										
	0.0393		0.0245		0.0530		0.0569		0.0528	
	(0.0257)		(0.0311)		(0.0340)		(0.0399)		(0.0444)	
(o) R&D employment share										
	0.0177	***	0.0227	***	0.0210	***	0.0202	**	0.0163	
	(0.0052)		(0.0073)		(0.0078)		(0.0083)		(0.0107)	
(p) Difference in R&D employment share: pre-export level (s=-1)										
	0.0005		0.0014		0.0043		0.0111	*	0.0026	
	(0.0030)		(0.0038)		(0.0053)		(0.0058)		(0.0068)	

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 11. Estimated Effects of Starting to Export to Asia (Excluding Switchers and Quitters)

s	0		1		2		3		4	
No. of observations	2,714		1,426		1,068		804		688	
Treated	1,357		713		534		402		344	
Control	1,357		713		534		402		344	
Outcome										
(a) Productivity level (lnTFP_OP)										
	-0.0076		-0.0052		-0.0091		-0.0065		-0.0126	
	(0.0128)		(0.0195)		(0.0184)		(0.0243)		(0.0268)	
(b) Productivity growth rate: pre-export level (s=-1)										
	-0.0058		-0.0052		-0.0145		-0.0166		-0.0104	
	(0.0065)		(0.0105)		(0.0111)		(0.0136)		(0.0139)	
(c) Sales (lnY)										
	-0.0840	*	-0.0705		-0.0642		-0.0524		-0.1845	**
	(0.0441)		(0.0679)		(0.0715)		(0.0848)		(0.0934)	
(d) Sales growth rate: pre-export level (s=-1)										
	0.0101		0.0316	**	0.0480	**	0.0645	**	0.0746	***
	(0.0068)		(0.0129)		(0.0188)		(0.0258)		(0.0277)	
(e) R&D intensity										
	-0.0001		0.0009		0.0020	*	0.0017		0.0008	
	(0.0008)		(0.0011)		(0.0012)		(0.0017)		(0.0016)	
(f) Difference in R&D intensity: pre-export level (s=-1)										
	0.0010	*	0.0020	***	0.0033	***	0.0035	***	0.0038	***
	(0.0005)		(0.0007)		(0.0010)		(0.0011)		(0.0012)	
(g) R&D expenditure (lnR&D exp)										
	0.8434	***	0.8088	*	1.3798	**	1.0851	*	0.9615	
	(0.3230)		(0.4490)		(0.5966)		(0.6432)		(0.6581)	
(h) R&D expenditure growth rate: pre-export level (s=-1)										
	0.2539		0.4137		0.8632	**	0.7703		1.3218	**
	(0.2365)		(0.3374)		(0.3770)		(0.4711)		(0.5192)	
(i) R&D employment (lnR&D emp)										
	0.0883		0.0742		0.1203		0.1439		-0.0008	
	(0.0591)		(0.0771)		(0.1028)		(0.1193)		(0.1182)	
(j) R&D employment growth rate: pre-export level (s=-1)										
	0.0414		0.0500		0.1736	***	0.1561	*	0.1251	
	(0.0266)		(0.0479)		(0.0562)		(0.0852)		(0.0958)	
(k) Employment (ln employment)										
	-0.1389	***	-0.1202	**	-0.1030	*	-0.1070		-0.2081	***
	(0.0320)		(0.0505)		(0.0603)		(0.0670)		(0.0694)	

Table 11 (continued). Estimated Effects of Starting to Export to Asia (Excluding Switchers and Quitters)

s	0		1		2		3		4	
(l) Employment growth rate: pre-export level (s=-1)										
	0.0113	**	0.0185	**	0.0270	**	0.0425	**	0.0235	
	(0.0051)		(0.0080)		(0.0127)		(0.0184)		(0.0231)	
(m) Capital stock (ln K)										
	-0.1244	**	-0.0754		-0.0978		-0.0314		-0.1963	*
	(0.0525)		(0.0776)		(0.0843)		(0.0876)		(0.1069)	
(n) Capital stock growth rate: pre-export level (s=-1)										
	0.0113		0.0329	*	0.0394	*	0.0370		0.0607	
	(0.0125)		(0.0185)		(0.0236)		(0.0289)		(0.0398)	
(o) R&D employment share										
	0.0072	***	0.0051		0.0081	*	0.0091	*	0.0034	
	(0.0022)		(0.0036)		(0.0047)		(0.0054)		(0.0059)	
(p) Difference in R&D employment share: pre-export level (s=-1)										
	0.0014		-0.0011		0.0070	**	0.0050		0.0014	
	(0.0015)		(0.0025)		(0.0031)		(0.0042)		(0.0037)	

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 12. Estimated Effects of Starting to Export to Other Regions (Excluding Switchers and Quitters)

s	0		1		2		3		4	
No. of observations	162		46		34		46		38	
Treated	81		23		17		23		19	
Control	81		23		17		23		19	
Outcome										
(a) Productivity level (lnTFP_OP)										
	0.0012		0.0163		-0.0272		0.0232		0.0211	
	(0.0594)		(0.1139)		(0.1055)		(0.0935)		(0.0786)	
(b) Productivity growth rate: pre-export level (s=-1)										
	-0.0016		0.0135		0.0021		0.0374		0.0053	
	(0.0329)		(0.0489)		(0.0466)		(0.0297)		(0.0460)	
(c) Sales (lnY)										
	-0.1661		-0.3473		-0.1230		0.0050		-0.2152	
	(0.1977)		(0.4122)		(0.4522)		(0.4389)		(0.4567)	
(d) Sales growth rate: pre-export level (s=-1)										
	0.0235		-0.0252		0.0810		0.2824	**	0.2364	*
	(0.0242)		(0.0577)		(0.0763)		(0.1275)		(0.1349)	

Table 12 (continued). Estimated Effects of Starting to Export to Other Regions (Excluding Switchers and Quitters)

s	0	1	2	3	4
(e) R&D intensity					
	-0.0022	0.0054	-0.0009	-0.0041	0.0086
	(0.0025)	(0.0086)	(0.0041)	(0.0072)	(0.0082)
(f) Difference in R&D intensity: pre-export level (s=-1)					
	-0.0035 *	0.0035	-0.0027	-0.0080	-0.0018
	(0.0019)	(0.0068)	(0.0029)	(0.0062)	(0.0058)
(g) R&D expenditure (lnR&D exp)					
	0.9664	2.3205	2.9209	4.0153	4.4645
	(1.4966)	(2.5162)	(2.7583)	(3.2764)	(2.8545)
(h) R&D expenditure growth rate: pre-export level (s=-1)					
	0.1393	-0.4879	-2.7956	-2.4023	-2.6873
	(0.7929)	(2.0349)	(2.2592)	(2.4439)	(1.7564)
(i) R&D employment (lnR&D emp)					
	-0.1133	-0.0994	0.0826	0.7269	0.3655
	(0.2487)	(0.5277)	(0.3983)	(0.4602)	(0.5408)
(j) R&D employment growth rate: pre-export level (s=-1)					
	0.2290	0.2214	0.2816	0.6055 *	-0.0702
	(0.1448)	(0.2901)	(0.2791)	(0.3094)	(0.3296)
(k) Employment (ln employment)					
	-0.2544	-0.2539	-0.3234	-0.2386	-0.3643
	(0.1639)	(0.3291)	(0.3419)	(0.3743)	(0.3839)
(l) Employment growth rate: pre-export level (s=-1)					
	0.0076	-0.0052	0.0270	0.1423 *	0.0992
	(0.0173)	(0.0383)	(0.0545)	(0.0744)	(0.1123)
(m) Capital stock (ln K)					
	-0.1134	-0.1511	0.1499	0.0175	-0.2705
	(0.2431)	(0.4549)	(0.5165)	(0.4938)	(0.5603)
(n) Capital stock growth rate: pre-export level (s=-1)					
	-0.0400	-0.3158	-0.0712	-0.0421	0.0574
	(0.0459)	(0.1339)	(0.1682)	(0.1548)	(0.1689)
(o) R&D employment share					
	0.0051	0.0245	0.0260	0.0439	0.0234
	(0.0089)	(0.0334)	(0.0204)	(0.0370)	(0.0253)
(p) Difference in R&D employment share: pre-export level (s=-1)					
	0.0051	0.0199	0.0146	0.0309	-0.0182
	(0.0057)	(0.0248)	(0.0102)	(0.0290)	(0.0170)

Notes: Bootstrapped standard errors are in parentheses (100 repetitions). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

However, the results in Tables 10 to 12 confirm that starting to export to North America/Europe has a larger positive effect on the growth rates of productivity, sales, R&D activity, and employment than starting to export to Asia. Table 13 provides a summary of the differences in the impact two and four years after starting to export to North America/Europe and to Asia. Specifically, the Table shows the difference in the growth rate of various performance indicators of export starters vis-à-vis firms with the closest propensity score that did not export. The figures clearly indicate that starting to export to North America/Europe has a much larger positive impact on sales and employment growth.[20] Moreover, firms show an improvement in productivity only when they start exporting to North America/Europe.

Table 13. Relative Superiority of Exporters (Based on the Results from Tables 10 and 11)

Growth rate from t = -1 to t = 2		
	NA/EUR	ASIA
TFP	3.8pp higher	1.5pplower (n.s.)
Sales	11.5pp higher	4.8pp higher
R&D expenditure	97.2pp higher (n.s.)	86.3pp higher
R&D employment	30.9pp higher	17.4pp higher
Employment	5.7pp higher	2.7pp higher

Growth rate from t = -1 to t = 4		
	NA/EUR	ASIA
TFP	4.1pp higher	1.0pp lower (n.s)
Sales	12.2pp higher	7.5pp higher
R&D expenditure	139pp higher	132pp higher
R&D employment	25.3pp higher	12.5pp higher
Employment	7.6pp higher	2.4pp higher (n.s.)

4.3. Robustness Checks

In order to check the robustness of the above results, the multinomial logit model

[20] As for R&D expenditure, firms starting to export to Asia tend to be smaller in size and are less likely to be firms that conduct R&D before they start exporting. A significant number of firms report zero R&D expenditures before they start exporting but start reporting positive R&D expenditure after they start exporting. The growth rate of R&D expenditure here is calculated as $ln(1+ R\&D\ expenditure)_{t=s} - ln(1 + R\&D\ expenditure)_{t=-1}$. Therefore, firms which increased R&D expenditure from zero to a positive value tend to show a very high growth rate of R&D expenditure.

was also estimated using labor productivity (value added per employee) as a productivity measure and the ATT and the DID estimators calculated using the labor productivity-based propensity score matching.[21] The estimated effects on labor productivity are summarized in Appendix Table 6. For the sample including export switchers and all surviving firms, starting to export to North America/Europe has a strong positive impact on labor productivity growth even two years after initiating exports, while exporting to Asia has a weakly significant positive impact on productivity growth (Panel 1). However, looking at the results based on the balanced sample where export switchers and all pairs where one (or both) of the firms exited are excluded, the strong positive productivity effect disappears three years after starting to export to North America/Europe, while exporting to Asia actually starts to have a strong positive effect on productivity growth after two years (Panel 2).

However, it should be noted that the ATT and DID estimators for later years are subject to serious selection biases. For example, surviving non-exporters may have improved their productivity not by starting to export but by adopting some sort of technology that helps to raise productivity in other ways in later years in order to survive. Moreover, in the case of the balanced sample of treated and control observations (i.e., Panel 2 in Appendix Table 6), productive surviving exporters may have been dropped from the ATT and DID analyses because their matched non-exporters exited, or productive surviving non-exporters may have been dropped from the ATT and DID analyses because their matched exporters exited and/or stopped exporting.

Thus, great care should be taken in interpreting the results particularly for later years. However, as far as earlier years (e.g., up to two years after starting to export) are concerned, starting to export to North America/Europe has a strong positive impact on productivity growth regardless of the choice of productivity measure. Moreover, as for other performance variables, the estimated effects on sales, R&D activity, and employment are mostly consistent with those based on the TFP measure. Therefore, the result that initiating exporting to North America/Asia has a positive and larger impact on firm performance is not driven by the selection of a specific sample of firms and a

[21] The multinomial logit estimation results using labor productivity as the productivity measure are available upon request.

specific measure of productivity.

4.4. Further Investigation and Discussion

The matching results above indicate that firms which started exporting to North America/Europe saw an improvement in the growth rates of productivity, sales, and employment. They also saw a much greater increase in R&D expenditure and R&D employment than firms which did not start exporting. Although firms which started exporting to Asia also registered an increase in sales, employment, and R&D activity, the magnitudes are much smaller than those for firms which started exporting to North America/Europe.

As the multinomial logit estimation results in Table 4 show, firms that are large (as measured by employment), R&D intensive, and financially healthy are more likely to be export starters to North America/Europe than to be export starters to Asia. As for the productivity level, productive firms are more likely to be export starters to North America/Europe, although the coefficient in the estimation is not statistically significant. These results imply that export starters to North America/Europe are potentially better-performing firms than export starters to Asia. In this subsection, for a better understanding and interpretation of the different learning-by-exporting effects across destination regions, differences in various characteristics across groups of firms are examined. In order to do so, the following equation is estimated:

$$\begin{aligned} \mathrm{Y_{ijt}} &= \alpha_0 + \alpha_1 \cdot \mathrm{OTHERS_{ijt}} + \alpha_2 \cdot \mathrm{ASIA_{ijt}} + \alpha_3 \cdot \mathrm{NAEUR_{ijt}} + \alpha_4 \cdot \mathrm{ALWAYS_{ijt}} \\ &\quad + \mu_j + \tau_t + \varepsilon_{ijt} \end{aligned} \tag{3}$$

Various regressions are run using different performance and other firm characteristics as the dependent variable. OTHERS, ASIA, NAEUR, and ALWAYS are dummy variables which indicate firm *i*'s export status. Industry specific and year specific effects are controlled by dummy variables, μ_j and τ_t, respectively. The subscript *j* denotes the industry firm *i* belongs to. The above equation is estimated using ordinary least squares, taking observations at the time of first-time exports for export starters and all observations for firms that always exported (ALWAYS) and firms that never exported (NEVER). The reference case here is NEVER, and we can examine differences in the various characteristics and performance indicators across groups of firms by looking at the estimated coefficients.

The results are shown in Table 14 and indicate that ALWAYS exporters clearly outperform others in terms of size, performance, and capital and R&D intensities. The table also shows the results of F-tests which examine whether two coefficients are significantly different from each other. As can be seen, the two pairs of coefficients examined (ASIA and NAEUR, NAEUR and ALWAYS) are significantly different in most cases. First-time exporters which chose North America/Europe as their export destination were significantly more productive than first-time exporters which chose Asia as their export destination. This implies that the fixed costs of starting to export to North America/Europe are higher than those to Asia and that export starters to North America/Europe need to be more productive than export starters to Asia in order to cover the high fixed costs (self-selection effects). First-time exporters to North America/Europe are superior to first-time exporters to Asia also in terms of size, profitability, wage rates, and capital and R&D intensities. This, in turn, means that they are likely to have greater absorptive capacity, which itself may be a source of the larger positive learning-by-exporting effects.

Moreover, first-time exporters exporting to Asia are more likely to be subcontractors and/or subsidiaries, implying that they are more likely to be small parts suppliers. When looking at trade intensities, the intra-firm export ratio is significantly higher for first-time exporters to Asia than first-time exporters to North America/Europe.[22] These observations suggest that first-time exporters to Asia tend to conduct exporting in order to supply parts and components to related- or non-related Japanese firms in Asia and do not necessarily have to be very innovative.

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[22] In the trade intensity estimations, the reference case is export starters exporting to other regions (OTHERS) and firms that never exported are excluded, for the obvious reason that the export variables would take a value of zero for firms that never exported.

Table 14. Differences in Characteristics by Export Status

	No. of obs.	First-time export destination						ALWAYS		F-test (Asia=NAEUR)		F-test (NAEUR=ALW)	
		OTHERS		ASIA		NAEUR							
ln(employment)	117,026	0.285	***	0.276	***	0.531	***	0.978	***	42.4	***	86.3	***
ln(sales)	117,026	0.496	***	0.420	***	0.756	***	1.312	***	51.5	***	51.5	***
ln(assets)	117,026	0.621	***	0.476	***	0.872	***	1.565	***	55.5	***	44.0	***
lnTFP	117,026	0.013		0.006		0.035	***	0.054	***	21.3	***	14.0	***
lnVAP	117,026	0.099		0.078	***	0.196	***	0.270	***	21.8	***	12.1	***
Profitability	117,026	-0.009		0.002	*	0.011	***	0.014	***	10.4	***	3.5	*
lnWAGE	117,026	0.118	***	0.049	***	0.119	***	0.188	***	19.4	***	28.3	***
ln(KL ratio)	117,026	0.239	**	0.117	***	0.230	***	0.401	***	6.6	**	21.8	***
R&D intensity	117,026	0.002		0.003	***	0.009	***	0.018	***	38.3	***	18.5	***
R&D worker share	117,026	0.014	**	0.011	***	0.026	***	0.040	***	29.4	***	37.7	***
Age	116,382	1.739		3.244	***	2.374	**	8.954	**	1.1		89.3	***
Debt-asset ratio	116,283	-0.030		-0.014	*	-0.036	***	-0.097	***	3.0	*	34.5	***
Subcontracter	98,521	-0.104	**	-0.071	***	-0.119	***	-0.263	***	4.7	**	61.5	***
Co-R&D w/foreign firm	26,671	0.003		0.048		-0.002		0.146	***	0.2		2.9	*
Subsidiary	117,026	-0.047		-0.076	***	-0.090	***	-0.130	***	0.8		9.2	***

Table 14 (continued). Differences in Characteristics by Export Status

	No. of obs.	First-time export destination OTHERS		ASIA		NAEUR		ALWAYS		F-test (Asia=NAEUR)		F-test (NAEUR=ALW)	
Export ratio	29,951	n.a.		-0.185	***	-0.173	***	-0.102	***	2.5		27.8	***
Import ratio	29,912	n.a.		-0.075	***	-0.078	***	-0.046	**	0.1		23.3	***
Intra-firm exp. Ratio	22,809	n.a.		0.141	***	0.082	*	0.102	**	9.7	***	1.5	
Intra-firm imp. Ratio	22,809	n.a.		-0.033	***	-0.026	**	-0.001		1.6		28.0	***

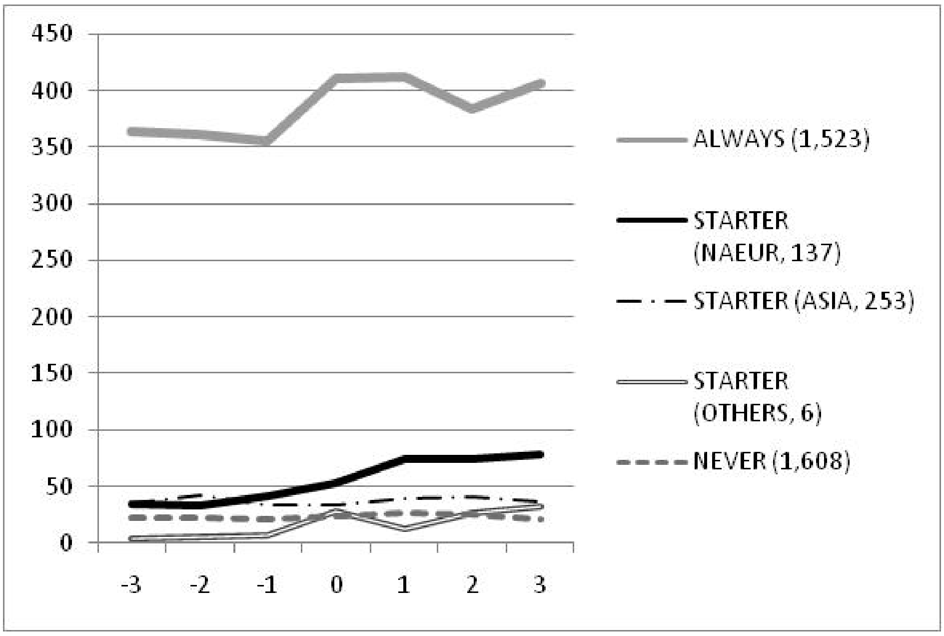
n.a. = not applicable.

Notes: *Profitability*= (Operating profits)/(Sales). *Subcontractor*= A dummy variable which takes 1 if a firm served as a subcontractor in 1994 and/or 1997. *Co-R&D w/foreign firm*= A dummy variable which takes 1 if a firm has a joint R&D project with a foreign firm. *Export (Import) ratio*= Exports (Imports) divided by sales. *Intra-firm exp. (imp.) ratio*= Intra-firm exports (imports) divided by total exports (imports). The survery asks about the subcontractor status only in 1994 and 1997 and about joint R&D projects only in 1997, 2000, and 2003. Therefore, for these two variables, the number of observations is significantly reduced.

In fact, looking at the number of patents owned shows that first-time exporters to North America/Europe recorded an increase in the number of patents owned. Figure 2 shows the trajectory of the average number of patents owned for different groups. For export starters, zero on the horizontal axis represents the year in which firms started to export. For firms that never or always exported throughout the sample period, time zero is 2003. Since consistent patent data are available only for 2000-2006, the patent analysis focuses on this period only. Although firms that always export outperform all other firms in terms of the number of patents, the figure clearly shows that first-time exporters to North America/Europe in the years after starting to export become much more innovative than firms starting to export to Asia or other regions.

Although the DID analysis above indicated that export starters to Asia tend to increase their R&D efforts after starting to export, the patent trajectory analysis here does not suggest that they became more innovative after starting to export. One possible interpretation of these observations is that R&D activities by export starters to Asia may more geared toward product modifications rather than product innovation or the development of new technologies.

Figure 2. Trajectory of Number of Patents Owned



Note: Numbers in parentheses are the average number of observations per year.

5. Policy Implications and Directions for Future Research

The aim of this study was to examine whether first-time exporters achieve productivity improvements through learning-by-exporting effects. According to the results, starting exporting to North America/Europe has larger positive effects on productivity, sales, R&D activities, and employment than starting exporting to Asia. The results also suggest that export starters to North America/Europe are larger, more productive, more R&D intensive, and more capital intensive than export starters to Asia even before they start exporting, suggesting that the former are potentially better performers than the latter. In other words, the former have greater absorptive capacity, and this absorptive capacity itself may be a source of the larger positive learning-by-exporting effects. Moreover, export starters to North America/Europe become more innovative than export starters to Asia after starting exporting.

These observations suggest that export starters to North America/Europe may be able to exploit the positive interplay between exporting, learning from export markets, and the development of innovative capabilities, while export starters to Asia are less likely to have such opportunities. This may be partly because export starters to Asia tend to be smaller parts suppliers to Japanese affiliated firms in Asian countries.

The results of this paper imply that potentially innovative non-exporters should be supported through an export promotion policy. Recently, some policy makers and managers of Japanese firms have emphasized the importance of tapping growing Asian markets and the promotion of exports to Asia. Although the results of this paper confirm that starting exporting to Asia has a positive impact, they also show that exporting only to Asia may not have a strong positive impact in terms of boosting productivity and innovative capabilities. Therefore, firms that have the potential to be sufficiently innovative to export to developed regions are likely to benefit from doing so through the positive interaction between exporting and innovation. Furthermore, firms should target not only developing markets but also developed markets in order to realize stronger learning-by-exporting effects.

Last but not least, several remaining issues should be pointed out. First, this paper confirms the R&D enhancing effect and positive scale effect of starting exporting.

However, the analytical framework of this paper does not allow us to evaluate which effect is more relevant in terms of contributing to productivity improvements. While answering this question presents a challenge, it is important to do so to gain a better understanding of the mechanisms underlying learning-by-exporting effects. However, this would probably require a different analytical framework. One example would be to estimate the relationship among changes in productivity, markups, and scale economies. Although employing such an approach may be a promising avenue, it would require overcoming many difficult data issues. In fact, Melitz and Ottaviano (2008) argue that markups possibly differ across destination markets, while De Loecker and Warzynski (2009) empirically show that firms' markups significantly increase after firms enter export markets. Investigating whether and how the relationships among changes in productivity, markups, and scale economies across destination markets differ between exporters and non-exporters is one possible direction for future research.[23]

Second, a significant number of firms switch their export status. In fact, many export starters stop exporting, while others increase their range of export destinations and, moreover, may become ALWAYS exporters.[24] Given the huge performance gap between ALWAYS exporters and other firms, another important research issue is to examine the determinants of the transition from being an export starter to a firm that always exports. Investigating such dynamics of exporters should provide important indications of how firms grow in the globalized economy and what kind of policy support or other efforts are necessary to facilitate firms' growth.

Third, productivity analyses always face measurement and conceptual challenges. Although changes in export status may be associated with changes in product composition or quality, no productivity measure can fully capture such changes. Moreover, although in practice managers may care more about profitability than productivity, profitability measures tend to be more volatile than productivity measures and measuring the true performance of firms is always very difficult.

[23] De Loecker (2010) argues that initiating exporting changes firms' technology choices and that input decisions are endogenous to firms' export status. Estimating production functions controlling for differences in productivity shocks between exporters and non-exporters, he finds that production function estimates without controlling for differences in productivity shocks produce biased results.
[24] Appendix Table 7 shows transition matrices of export destinations for export starters.

Although we still have a long way to go to open up the productivity-export-innovation black box, this study provides important evidence of learning-by-exporting effects. Particularly, it shows that starting to export does contribute to firms' growth in terms of sales and employment as well as the development of innovative capabilities. Further investigation of the dynamics of firms' behavior in a global market and the growth of firms should help to deepen our understanding of the impact of globalization on firm dynamics at the micro level and countries' economic growth at the macro level.

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Appendix

Table 1. List of Industries and Number of Observations by Industry (After Data Cleaning)

		No. of observations		
		1994	2006	(%)
1-30	Manufacturing Total	11,340	11,267	(100.0)
1	Food products and beverages	1,354	1,396	(12.4)
2	Textiles	788	409	(3.6)
3	Lumber and wood products	318	229	(2.0)
4	Pulp, paper and paper products	397	335	(3.0)
5	Printing	475	525	(4.7)
6	Chemicals and chemical fibers	293	280	(2.5)
7	Paint, coating, and grease	134	117	(1.0)
8	Pharmaceutical products	189	194	(1.7)
9	Miscellaneous chemical products	222	254	(2.3)
10	Petroleum and coal products	35	45	(0.4)
11	Plastic products	557	627	(5.6)
12	Rubber products	133	127	(1.1)
13	Ceramic, stone and clay products	546	412	(3.7)
14	Iron and steel	366	385	(3.4)
15	Non-ferrous metals	294	250	(2.2)
16	Fabricated metal products	856	824	(7.3)
17	Metal processing machinery	221	218	(1.9)
18	Special industry machinery	316	399	(3.5)
19	Office and service industry machines	143	132	(1.2)
20	Miscellaneous machinery	650	689	(6.1)
21	Electrical machinery and apparatus	359	372	(3.3)
22	Household electric appliances	147	101	(0.9)
23	Communication equipment	127	218	(1.9)
24	Computer and electronic equipment	125	164	(1.5)
25	Electronic parts and devices	500	608	(5.4)
26	Miscellaneous electrical machinery	162	231	(2.1)
27	Motor vehicles and parts	825	845	(7.5)
28	Other transportation equipment	201	230	(2.0)
29	Precision machinery	298	319	(2.8)
30	Miscellaneous mfg. industries	309	332	(2.9)

Table 2. Number of Export Starters (First-Time Exporters) and Export Quitters by Year

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total	
Starters	418	278	209	167	156	209	143	190	161	185	142	150	2,408	(100%)
SMEs	280	207	154	110	125	145	109	147	125	145	115	118	1,780	(74%)
Large Firms	138	71	55	57	31	64	34	43	36	40	27	32	628	(26%)
Quitters	99	145	212	115	88	135	102	126	135	122	149	208	1,636	(100%)
SMEs	81	114	138	90	63	103	87	91	92	91	105	150	1,205	(74%)
Large Firms	18	31	74	25	25	32	15	35	43	31	44	58	431	(26%)

Table 3. Estimated Production Function Coefficients (Olley-Pakes Method)

Industry	Labor		Capital		Material		No. of obs.	Sum of coef.
1	0.1013	***	0.0382	***	0.8323	***	16,128	0.9718
2	0.1874	***	0.0238	***	0.7550	***	5,847	0.9663
3	0.1661	***	0.0045		0.8170	***	3,154	0.9876
4 & 5	0.2264	***	0.0062		0.7332	***	10,802	0.9659
6 & 7 & 8 & 9	0.1439	***	0.0161	**	0.8040	***	10,680	0.9641
10 & 11 & 12	0.1358	***	0.0344	***	0.8047	***	9,257	0.9749
13	0.1649	***	0.0281	**	0.7740	***	5,827	0.9670
14 & 15 & 16	0.1843	***	0.0214	***	0.7660	***	17,876	0.9717
17 & 18 & 19 & 20	0.2071	***	0.0191	*	0.7538	***	16,325	0.9800
21	0.2033	***	0.0249	**	0.7766	***	4,049	1.0049
22	0.1725	***	0.0429		0.7918	***	1,473	1.0072
23 & 24	0.1923	***	0.0010		0.8013	***	4,777	0.9947
25	0.1846	***	0.0353	***	0.7617	***	7,212	0.9815
26	0.2206	***	0.0438	***	0.7457	***	2,389	1.0101
27 & 28	0.1905	***	0.0167	*	0.7658	***	13,277	0.9731
29	0.2191	***	0.0464	***	0.7416	***	3,690	1.0071
30	0.1591	***	0.0344	**	0.8062	***	3,346	0.9997

Table 4. Balancing Tests for Matching

(a) Logit model (Column 1 in Table 4)

Variable	Sample	Mean		% bias	% reduct.	t-test	
		Treated	Control		|bias|	t	p>|t|
lnTFP (OP)	Unmatched	2.453	2.445	2.1		0.89	0.375
	Matched	2.453	2.462	-2.3	-10.1	-0.83	0.408
ln(employment)	Unmatched	5.245	4.953	35.4		17.12	0
	Matched	5.252	5.382	-15.8	55.2	-4.59	0
R&D intensity	Unmatched	0.012	0.004	35.4		23.25	0
	Matched	0.012	0.011	4.3	87.9	1.14	0.256
Age	Unmatched	36.938	36.149	4.7		1.98	0.047
	Matched	36.995	36.954	0.2	94.8	0.09	0.931
Debt-asset ratio	Unmatched	0.703	0.719	-6.2		-2.56	0.010
	Matched	0.702	0.690	4.7	23.4	1.64	0.101
Import ratio	Unmatched	0.038	0.010	24.8		16.56	0
	Matched	0.037	0.031	5.7	76.9	1.46	0.143
FDI ratio	Unmatched	0.011	0.002	32.2		23.73	0
	Matched	0.011	0.005	20.8	35.4	6.09	0

(b) Multinomial logit model: First-time exporters to North America or Europe (Column 2 in Table 4)

Variable	Sample	Mean		% bias	% reduct.	t-test	
		Treated	Control		|bias|	t	p>|t|
lnTFP (OP)	Unmatched	2.467	2.445	5.6		1.32	0.186
	Matched	2.467	2.471	-1.2	78.5	-0.24	0.814
ln(employment)	Unmatched	5.435	4.953	54.2		15.78	0
	Matched	5.441	5.503	-6.9	87.2	-1.08	0.278
R&D intensity	Unmatched	0.017	0.004	47.1		23.01	0
	Matched	0.018	0.014	11.9	74.7	1.73	0.084
Age	Unmatched	36.565	36.149	2.4		0.58	0.561
	Matched	36.690	36.492	1.1	52.3	0.22	0.824
Debt-asset ratio	Unmatched	0.689	0.719	-11.9		-2.73	0.006
	Matched	0.688	0.677	4.1	65.9	0.79	0.431
Import ratio	Unmatched	0.031	0.010	20.7		7.3	0
	Matched	0.030	0.029	0.8	96	0.11	0.909
FDI ratio	Unmatched	0.010	0.002	31.6		12.09	0
	Matched	0.010	0.006	16.5	47.7	2.37	0.018

(c) Multinomial logit model: First-time exporters to Asia (Column 3 in Table 4)

Variable	Sample	Mean		% bias	% reduct	t-test	
		Treated	Control		|bias|	t	p>|t|
lnTFP (OP)	Unmatched	2.445	2.445	0.2		0.05	0.956
	Matched	2.445	2.447	-0.5	-194.4	-0.13	0.893
ln(employment)	Unmatched	5.160	4.953	26.3		9.9	0
	Matched	5.168	5.318	-19.2	27.2	-4.58	0
R&D intensity	Unmatched	0.009	0.004	29.4		13.04	0
	Matched	0.009	0.010	-6.4	78.1	-1.39	0.163
Age	Unmatched	37.173	36.149	6.2		2.09	0.036
	Matched	37.186	36.913	1.6	73.3	0.48	0.633
Debt-asset ratio	Unmatched	0.710	0.719	-3.5		-1.19	0.232
	Matched	0.709	0.689	7.8	-118.4	2.2	0.028
Import ratio	Unmatched	0.040	0.010	26.3		14.77	0
	Matched	0.040	0.030	9.5	64	2	0.046
FDI ratio	Unmatched	0.012	0.002	33.2		21.05	0
	Matched	0.011	0.005	20.1	39.4	4.81	0

(d) Multinomial logit model: First-time exporters to other regions (Column 4 in Table 4)

		Mean		% reduct.		t-test	
Variable	Sample	Treated	Control	% bias	|bias|	t	p>|t|
lnTFP (OP)	Unmatched	2.473	2.445	7		0.61	0.54
	Matched	2.471	2.468	0.7	90	0.05	0.963
ln(employment)	Unmatched	5.197	4.953	29		2.87	0.004
	Matched	5.185	5.447	-31.2	-7.7	-1.64	0.103
R&D intensity	Unmatched	0.009	0.004	28.7		3.01	0.003
	Matched	0.009	0.008	8.4	70.8	0.47	0.641
Age	Unmatched	35.915	36.149	-1.4		-0.12	0.906
	Matched	36.160	35.889	1.6	-16	0.12	0.905
Debt-asset ratio	Unmatched	0.702	0.719	-6.4		-0.54	0.591
	Matched	0.703	0.686	6.4	0	0.42	0.673
Import ratio	Unmatched	0.050	0.010	28.5		4.91	0
	Matched	0.050	0.026	17.1	39.9	1	0.319
FDI ratio	Unmatched	0.008	0.002	21.5		3.48	0
	Matched	0.008	0.004	15	30.2	0.92	0.358

Table 5. Number of Export Starters by Boarder Region (Period Total)

	Total		SMEs		Large firms	
Export starters	2,408	(100%)	1,780	(74%)	628	(26%)
Destinations total	2,408	(100%)	1,780	(100%)	628	(100%)
Case 4						
ALL (NA/EUR + Asia + Others)	115	(5%)	53	(3%)	62	(10%)
NA/EUR + Asia	261	(11%)	166	(9%)	95	(15%)
NA/EUR + Others	14	(1%)	9	(1%)	5	(1%)
NA+EUR	25	(1%)	20	(1%)	5	(1%)
NA only	264	(11%)	186	(10%)	78	(12%)
EUR only	67	(3%)	54	(3%)	13	(2%)
Case 3						
Asia only	1,526	(63%)	1185	(67%)	341	(54%)
Asia + Others	50	(2%)	42	(2%)	8	(1%)
Case 2						
Others only	86	(4%)	65	(4%)	21	(3%)
Case 1						
NEVER exporters	12,926	(100%)	11,297	(87%)	1,629	(13%)

Note: The percentage figures in parenthes for cases 2, 3, and 4 denote the share of each destination category in the total number of export starters. The percentage figures in parentheses for export starters and case 1 denote the shares of SMEs and large firms.

Table 6. Robustness Checks

(1) lnVAP specification

s	0		1		2		3	4
Exporting to NA/EUR								
No. of observations	1,260		1,102		985		871	761
Treated	630		551		498		445	389
Control	630		551		487		426	372
(a) Productivity level (lnVAP)								
	0.0450		0.0505		0.0604	**	0.0289	0.0087
	(0.0341)		(0.0376)		(0.0306)		(0.0384)	(0.0423)
(b) Productivity growth rate: pre-export level (s=-1)								
	0.0715	***	0.0700	**	0.1005	***	0.0573	0.0631
	(0.0265)		(0.0312)		(0.0288)		(0.0348)	(0.0411)

Table 6 (Continued). Robustness Checks

(1) lnVAP specification

s	0		1		2		3		4	
Exporting to Asia										
No. of observations	2,714		2,261		2,035		1,795		1,580	
Treated	1,357		1129		1019		909		798	
Control	1,357		1132		1016		886		782	
(a) Productivity level (lnVAP)										
	-0.0272		-0.0196		-0.0066		-0.0061		-0.0081	
	(0.0226)		(0.0237)		(0.0218)		(0.0215)		(0.0277)	
(b) Productivity growth rate: pre-export level (s=-1)										
	0.0074		0.0195		0.0421	*	0.0453	*	0.0410	
	(0.0193)		(0.0196)		(0.0233)		(0.0246)		(0.0282)	

(2) lnVAP specification (Excluding switchers & quitters)

s	0		1		2		3		4	
Exporting to NA/EUR										
No. of observations	1,260		816		626		506		408	
Treated	630		408		313		253		204	
Control	630		408		313		253		204	
(a) Productivity level (lnVAP)										
	0.0450		0.0630		0.0551		0.0210		-0.0571	
	(0.0341)		(0.0396)		(0.0430)		(0.0476)		(0.0608)	
(b) Productivity growth rate: pre-export level (s=-1)										
	0.0715	***	0.0729	**	0.0990	***	0.0155		-0.0318	
	(0.0265)		(0.0363)		(0.0354)		(0.0499)		(0.0649)	
Exporting to Asia										
No. of observations	2,714		1,394		1,072		834		716	
Treated	1,357		697		536		417		358	
Control	1,357		697		536		417		358	
(a) Productivity level (lnVAP)										
	-0.0272		-0.0263		0.0060		0.0039		0.0020	
	(0.0226)		(0.0296)		(0.0334)		(0.0406)		(0.0358)	
(b) Productivity growth rate: pre-export level (s=-1)										
	0.0074		0.0293		0.0645	**	0.0889	**	0.1222	***
	(0.0193)		(0.0259)		(0.0293)		(0.0374)		(0.0393)	

Table 7. Transition of Export Destinations for Export Starters

t=0	1 year after starting exporting (t=1)					Total
	NAEUR	ASIA	OTHERS	Stop	Drop	
NAEUR	453	40	5	125	123	746
	(60.7%)	(5.4%)	(0.7%)	(16.8%)	(16.5%)	(100.0%)
ASIA	65	815	6	390	300	1576
	(4.1%)	(51.7%)	(0.4%)	(24.7%)	(19.0%)	(100.0%)
OTHERS	11	6	13	40	16	86
	(12.8%)	(7.0%)	(15.1%)	(46.5%)	(18.6%)	(100.0%)
t=0	3 years after starting exporting (t=3)					Total
	NAEUR	ASIA	OTHERS	Stop	Drop	
NAEUR	309	41	2	125	269	746
	(41.4%)	(5.5%)	(0.3%)	(16.8%)	(36.1%)	(100.0%)
ASIA	86	487	1	432	570	1576
	(5.5%)	(30.9%)	(0.1%)	(27.4%)	(36.2%)	(100.0%)
OTHERS	15	14	1	32	24	86
	(17.4%)	(16.3%)	(1.2%)	(37.2%)	(27.9%)	(100.0%)
t=0	5 years after starting exporting (t=5)					Total
	NAEUR	ASIA	OTHERS	Stop	Drop	
NAEUR	221	40	2	113	370	746
	(29.6%)	(5.4%)	(0.3%)	(15.1%)	(49.6%)	(100.0%)
ASIA	85	345	5	333	808	1576
	(5.4%)	(21.9%)	(0.3%)	(21.1%)	(51.3%)	(100.0%)
OTHERS	16	8	1	30	31	86
	(18.6%)	(9.3%)	(1.2%)	(34.9%)	(36.0%)	(100.0%)

CHAPTER 3

Direction of Causality in Innovation-Exporting Linkage: Evidence on Korean Manufacturing

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This paper examines various possible bi-directional causal relationships among exporting, innovation, and productivity utilizing plant-level data on Korean manufacturing. Based on both propensity score matching technique and three-variable panel VAR estimation, we find a significantly positive effect of exporting on new product introduction. The effect for the other direction of causality is estimated to be positive but not significant. Panel VAR estimation results suggest that plant productivity has a significantly positive effect on both exporting and new product introduction.

Key Words: Exporting, Innovation, Productivity, Propensity score matching, Panel VAR
JEL Classification: F14, O12, O19

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1. Background and Objective

One of the most robust empirical findings from recent studies on firm' exporting behavior is that exporting firms are more productive than those firms that do not export. A large number of subsequent studies have documented that the productivity premium of exporters, relative to non-exporters, is at least a consequence of self-selection of more productive firms into exporting activity. The evidence in favor of the other direction of causality, i.e., learning-by-exporting, is still considered to be inconclusive. As a reflection of these developments, many theoretical models of heterogeneous firms have featured some form of self-selection mechanism, and analyzed the effects of liberalized trade (e.g., Melitz, 2003; Bernard *et al.,* 2007). According to these models, trade liberalization can raise aggregate productivity by inducing resource reallocation across firms, i.e, the contraction and exit of low-productivity firms and the expansion and entry into export markets of high-productivity firms, even if there is no change in firm-level productivity.

Some authors have noted, however, that one story that is missing from the above productivity-export nexus is that firms may make investments in R&D or undertake innovation activities, which might be systematically related to productivity and to export-market participation. Indeed, in most innovation-based endogenous growth models, firms' innovation activity drives productivity growth as well as the introduction of new products or varieties (e.g., Romer, 1990; Grossman and Helpman, 1991). In an open economy setting, these innovation outcomes affect firms' export market participation behavior. Conversely, exporting can affect the decision to undertake innovation activity. If new knowledge gained through exporting, or larger market size associated with exporting opportunity, raises the profitability of successful innovation, exporting can promote innovation.[3] Given the above potential linkage between innovation and exporting, examining this relationship empirically is likely to give us additional insights into important issues, such as a firm's export-market participation behavior, dynamic effects of trade or trade liberalization, and determinants of innovation. More importantly, it will also help to clarify sources of heterogeneity of firms in productivity, which is assumed to be exogenous in recent heterogeneous-firm-trade models.

This paper also aims to examine empirically a possible bi-directional causal relationship between exporting and innovation, combining plant-level panel data and plant-product matched data in Korean manufacturing. We employ two methodologies: propensity score matching and panel vector auto regression (PVAR) methodologies. The propensity score matching technique in this paper is similar in spirit to the one used by Damijan *et al.* (2008). Here, we examine whether previous exporting (innovation) experience affects whether a plant innovates (exports) or not, controlling the possible selection bias arising from the endogenous-export (innovation) participation. We employ PVAR methodology developed by Holtz-Eakin *et. al*. (1988) and examine the dynamic relationship that exists among three variables at plant level: exporting, innovation, and plant productivity. In this paper, we measure several innovation outcome variables. This paper's focus on innovation outcome is in line with most previous studies on this issue, such as Cassiman and Martinez-Ros (2007), Becker and Egger (2007), Damijan *et al.* (2008), and Hahn (2010). Unlike most previous studies,

[3] Theoretical background behind innovation-export linkage will be discussed below in some more detail.

however, we follow Hahn (2010)[4] to distinguish between two types of product innovation: product innovations that are new to the plant and those that are new to the Korean economy (i.e., products that are domestically produced for the first time). The use of plant-product matched data allows us to measure these two types of product innovations separately, because we can tell whether a new product to the plant is also a new product to the aggregate economy or not.[5] Our conjecture is that, in Korea's context, products that are new to the aggregate economy are likely to capture product-cycle phenomenon or international-knowledge spillovers. By contrast, products that are new only to the plant are likely to reflect imitation by domestic competitors or domestic-knowledge diffusion. Our expectation is that the former is more clearly related to exporting.

This study is similar in spirit to Damijan *et al.* (2008) in that both studies examine the bi-directional causal relationship between innovation and exporting. However, this study differs from Damijan, *et al.* (2008) or most previous related studies in at least two aspects. Firstly, this study explicitly distinguishes between new products to the plants and new products to the aggregate economy, utilizing plant-product matched data. This distinction could shed light on the possibly different roles of those two types of innovation in exporting, and vice versa. Secondly, in contrast to most previous studies, this study utilizes both time-series and cross-sectional variations in the sample in order to test the possibility of bi-directional causality between innovation activity and export-market participation.

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4 Hahn (2010) shows that exporting plants in Korean manufacturing sector are more likely to introduce new products from the viewpoint of the aggregate economy, utilizing propensity score matching technique.

5 By contrast, innovation survey data on product innovation, which are typically used by similar studies, are based on the question whether a certain enterprise introduced products that were new to the firm during the past period.

As mentioned above, this study is expected to give us additional insights into important issues, such as a firm's export market participation behavior, dynamic effects of trade or trade liberalization, and determinants of innovation. Furthermore, it will also help to clarify sources of heterogeneity of firms in productivity, which is assumed to be exogenous in recent heterogeneous firm-trade models. Adequate understanding these issues are necessary to formulate appropriate trade liberalization strategies, as well as appropriate innovation policies in a globalized environment. In particular, the existence of bi-directional causal relationship might suggest not only respective roles of policies to increase the number of exporters and policies to increase the number of innovators, but also a possible complementary relationship between those policies.

This paper is organized as follows. In next section, related studies are briefly reviewed. Section 3 provides a description of the data, our measures of new products, and some preliminary analysis. Section 4 discusses empirical strategy. Section 5 discusses main results. Section 6 provides some robustness checks on our main results. The Final section concludes.

2. Related Literature

2.1. Empirical Literature

This study is directly related to the growing empirical literature examining at least some of the linkages among exporting, innovation, and productivity. There are studies that examine the effect of innovation on exporting: Bernard and Jensen (1999) for U.S. firms, Becker and Egger (2007) for German firms, Cassiman and Martinez-Ros (2007) for Spanish firms, Roper and Love (2002) for the U.K. and German plants, and Ebling and Janz (1999) for German firms.[6] These studies all found a strong positive effect of innovation on exporting. While these studies tend to treat firms' innovation as a exogenous process,[7] Lachenmaier and Wößmann (2006) apply instrumental-variable procedures to account for the potential endogeneity of innovations. They find that innovations increase firm-level exports, and show that exogenous treatment of innovation leads to a downward bias in estimates of the impact of innovations on firm exports. There are also several studies that examine the other direction of causality: from exporting to innovation. Salomon and Shaver (2005) found that exporting promotes innovation in Spanish manufacturing firms, using product innovation counts and patent applications. Hahn (2010) shows that there are strong positive correlations between the exporting status of plants and various measures of product innovation in Korean manufacturing, and also finds some evidence indicating that exporting promotes new product introduction and increases the product scope (number of products produced) of exporting plants. It was only recently that authors began to examine the possible bi-directional causality between exporting and innovation Damijan *et al.* (2008) used a propensity score matching technique and examined the bi-directional causal relationship between innovation and exporting for Slovenian firms, and found that exporting leads to process innovations, while they did not find any evidence for the hypothesis that either product or process innovations increase the probability of becoming an exporter. While the above studies rely on reduced-form approach, Aw *et al.* (2009) estimated a dynamic structural model of a producer's decision to invest in R&D and participate in the export market, using plant-level data on the Taiwanese

[6] Cassiman and Golovko (2007) finds that, for Spanish manufacturing firms, firm innovation status is important in explaining the positive export-productivity nexus documented in previous studies.

[7] Cassiman and Martinez-Ros (2007) treat innovation as predetermined variable and use lagged innovation, instead of contemporary innovation, in the export regressions.

electronics industry. They found that self-selection of high-productivity plants mainly drives the participation in both activities, and also that both R&D and exporting have a positive effect on a plant's future productivity, reinforcing the selection effect. This study is also related to the already large amount of literature examining the productivity-export nexus, which we do not review here.[8] As mentioned above, however, these studies do not consider the role of innovation explicitly.

This study is also related to the growing empirical literature that assesses the effect of trade or trade liberalization on domestic product variety. There are macroeconomic theoretical studies that suggest that trade may contribute to the expansion of domestic varieties and growth, in addition to static efficiency gains (Romer 1990, Grossman and Helpman 1991a, Ch. 9). In these models, trade expands the set of available input varieties, which reduces the R&D cost of creating new domestic varieties.[9] Based on the implications of these endogenous-growth models, as well as more recent theories of heterogenous-firm theories of trade, such as Melitz (2003), Bernard *et al.* (2006), Goldberg *et al.* (2008). All examined empirically whether increased imported variety induced by trade liberalization has generated "domestic-variety-creation" effect. They find evidence that the increase in imported variety following trade reform in India in the early 1990s contributed to the expansion of domestic product variety. Bernard *et al.* (2009) examined product switching behavior of multi-product firms using a firm-product data for the U.S., and showed that multi-product firms are more likely to add or

[8] For a survey of this literature, see Greenaway and Kneller (2007). See also Hahn and Park (2008) and the cited studies for more recent studies.

[9] In these models, growth is viewed as a process of continuous expansion of domestic varieties. Stokey (1988) views growth as a continuous process of creating new products and dropping of old products and constructs an endogenous growth model with learning-by-doing that exhibits these features. Some implications from these theories have been empirically tested by Feenstra *et al.* (1999). Using the data of Korea and Taiwan, they showed that changes in *domestic product variety* have a positive and significant effect on total factor productivity.

drop a product and export. However, neither Goldberg *et al.* (2008) nor Bernard *et al.* (2009) explicitly analyzed the introduction of products that are *new from the view point of the aggregate economy*; they focused on the product-scope decision of firms from the view point of individual firms. For a follower country, such as Korea, one of the most important features of her catch-up growth process is likely to be the introduction of new products from the viewpoint of the aggregate economy: products that came to be produced by domestic firms for the first time. In this regard, examining whether and how the first-time domestic production (or new product introduction) is related to exporting and productivity in Korea's context might be particularly interesting.

2.2. Theoretical Literature

Various theoretical studies suggest that a causal relationship between innovation and exporting is likely to be bi-directional, although the exact mechanism underlying such a relationship might vary somewhat across studies. There two strands of literature which provide a broad theoretical framework behind this study. Firstly, there are open economy endogenous-growth theories, such as Grossman and Helpman (1991b). In their model, the quality competition between Northern innovators and Southern imitators give rise to continual introduction of higher-quality products and, hence, sustained growth for both North and South. One implication of their model is that the causal relationship between innovation and exporting is bi-directional. In their model, firms' innovation (or imitation) activity introduces higher quality products, which then leads to subsequent exporting. So, the causation runs from innovation to exporting. Meanwhile, the larger market size associated with exporting as well as enhanced competition associated with North-South trade strengthens the incentive to innovate, which implies the causation from exporting to innovation.[10]

Secondly, more recent heterogeneous-firm theories of trade and innovation, such as Constantini and Melitz (2008) and Aw *et al.* (2009), also suggest a bi-directional causal relationship between innovation and exporting. Roughly speaking, these theoretical models could be viewed as a combination of the static heterogeneous-firm-trade models, such as Melitz (2003), and the dynamic innovation-based endogenous-growth theories. Specifically, these models could be viewed as efforts to clarify the sources of firm heterogeneity by endogenizing firm-level productivity in heterogeneous-firm-trade models, which is typically assumed to be exogenously determined in those models. Furthermore, unlike the macroeconomic endogenous-growth theories, these theories have clarified the role of firm-level productivity in the innovation-exporting nexus. The role of firm-level productivity can be explained as follows. To begin with, these models view both innovation and exporting as investment activities requiring sunk-entry cost, which generates the feature of productivity-based self-selection into both activities. In addition, these models allow for the possibility that innovation and/or exporting affects firm productivity, which subsequently reinforces the productivity-based self-selection into exporting or innovation.[11] So, the bi-directional relationship between innovation and exporting in these models include the following two step mechanism: exporting (or innovation) improves firm productivity, which subsequently makes that firm more likely

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[10] Grossman and Helpman (1991b) could be viewed as a formalization as well as an extension of an early study Vernon (1966), which is known as "product cycle" theory. According to Vernon (1966), most new goods are developed in the industrialized North, produced there, and exported to South. As the products become standardized, the Northern innovator establishes an offshore production facility via foreign direct investment, or it might license the technology to a local producer in the South, where wage rates are lower. As production location moves from North to South, the direction of trade flow also reverses. In contrast to Vernon (1966), Grossman and Helpman (1991b) focused on immitation by arms-length competitors in the South as a mechanism of international technology transfer.

[11] In contrast with Aw *et al.* (2009), Constantini and Melitz (2008) do not allow for the possibility of learning-by-exporting, the positive effect of exporting on firm productivity.

to self-select into innovation (or exporting). In this study, we conduct the empirical analysis by taking the broad implications from the theoretical studies discussed above.

3. Data and Descriptive Analysis

3.1. Data

This study utilizes two data sets. The first one is the unpublished plant-level census data underlying the *Survey of Mining and Manufacturing* in Korea. The data set covers all plants with five or more employees in 580 manufacturing industries at KSIC (Korean Standard Industrial Classification) five-digit level. It is an unbalanced panel data with about 69,000 to 97,000 plants for each year from 1990 to 1998. For each year, the amount of exports as well as other variables related to production structure of plants, such as production, shipments, the number of production and non-production workers and the tangible fixed investments are available. The exports in this data set include direct exports and shipments to other exporters and wholesalers, but do not include shipments for further manufacture.

The second data set is plant-product data set for the same period. For most plants covered in the plant-level census data (about 80 percent of plants in terms of the number of plants), this data set contains information on the value of shipments of each product produced by plants. It also has information on plant identification number that will be used to link this data set to the plant-level census data. Product is defined at an 8-digit level. The eight-digit product code is constructed using a combination of the eight-digit KSIC (Korea Standard Industrial Classification) code and the three-digit product code which follows the Statistics Office's internal product classification scheme.

3.2. Descriptive Analysis

Table 1.1 - Table 1.3 show the distribution of plants for various years according to their exporting and innovation status. In order to measure the innovation status of a plant, we consider three variables: R&D expenditure, Product Adding, and Product Creation. For each variable, the innovation status of a plant in a certain year is one if that variable takes a positive value in that year, and zero if that variable takes a value of zero. Product Adding is the number of products a plant added for the past one year, while Product Creation is the number of products a plant newly introduced into the economy. So, an added product is a product that is new to the firm, and a created product is a product that is new to the aggregate economy. The latter is also necessarily the former, but not necessarily vice versa.

Table 1.1 shows that from 15 to 20 percent of plants were engaged in R&D, exporting, or both, depending on year. There are more plants which exported than plants which did R&D; from 5.8 to 8.6 percent of plants did R&D while from 11.1 to 16.0 percent of plants did R&D. Plants that did both R&D and exporting accounted for a small proportion of plants—from 2.2 to 3.7 percent of plants. If we measure innovation as Product Adding, then the proportion of plants that added at least one product over the previous year becomes much larger; plants that added some products accounts for between 33.6 and 56.1 percent of all plants with five or more employees (Table 1.2). A large portion of plants added some products but did not export, and a much smaller proportion of plants both added some products and exported. If we measure innovation with our product-creation measure, the percentage of innovator plants drops significantly, which is as expected. Plants which created at least one product account for between 1.6 and 9.4 percent of plants, depending on the year.

Table 1.1. Summary of Exporting and Innovation Activities: R&D Expenditure

Year	Investment Activity			
	No R&D / No Exporting	R&D only	Exporting only	Both R&D and Exporting
1991	53518	2161	8656	1735
	(81.0)	(3.3)	(13.1)	(2.6)
1992	54326	2061	8918	1809
	(80.9)	(3.1)	(13.3)	(2.7)
1993	67715	3299	8590	2073
	(82.9)	(4.0)	(10.5)	(2.5)
1994	70104	3404	8409	2030
	(83.5)	(4.1)	(10.0)	(2.4)
1995	74213	3516	8323	2057
	(84.2)	(4.0)	(9.5)	(2.3)
1996	75799	3567	7989	1977
	(84.9)	(4.0)	(8.9)	(2.2)
1997	71862	3150	8427	2092
	(84.0)	(3.7)	(9.9)	(2.5)
1998	58866	3590	8370	2710
	(80.1)	(4.9)	(11.4)	(3.7)

Table 1.2. Summary of Exporting and Innovation Activities: Product Adding

Year	Investment Activity			
	No Adding / No Exporting	Adding only	Exporting only	Both Adding and Exporting
1991	14814	18357	3704	5281
	(35.1)	(43.6)	(8.8)	(12.5)
1992	21109	12505	5309	4199
	(49.0)	(29.0)	(12.3)	(9.7)
1993	19972	15535	4540	4296
	(45.0)	(35.0)	(10.2)	(9.7)
1994	27327	14617	5814	3451
	(53.4)	(28.5)	(11.4)	(6.7)
1995	25888	15587	5580	3445
	(51.3)	(30.9)	(11.1)	(6.8)
1996	31025	15785	5678	3266
	(55.7)	(28.3)	(10.2)	(5.9)
1997	30604	14806	5808	3614
	(55.8)	(27.0)	(10.6)	(6.6)
1998	21898	16022	5348	4468
	(45.9)	(33.6)	(11.2)	(9.4)

Table 1.3. Summary of Exporting and Innovation Activities: Product Creation

Year	Investment Activity			
	No Creation / No Exporting	Creation only	Exporting only	Both Creation and Exporting
1991	26445	6726	6745	2240
	(62.7)	(16.0)	(16.0)	(5.3)
1992	32372	1242	9028	480
	(75.1)	(2.9)	(20.9)	(1.1)
1993	33320	2187	8208	628
	(75.1)	(4.9)	(18.5)	(1.4)
1994	41322	622	9065	200
	(80.7)	(1.2)	(17.7)	(0.4)
1995	40937	538	8796	229
	(81.1)	(1.1)	(17.4)	(0.5)
1996	46039	771	8759	185
	(82.6)	(1.4)	(15.7)	(0.3)
1997	44225	1185	8886	536
	(80.7)	(2.2)	(16.2)	(1.0)
1998	34294	3626	8943	873
	(71.8)	(7.6)	(18.7)	(1.8)

Table 1.1 - Table 1.3 show various plant characteristics (mean values) according to the exporting and innovation status of plants. Generally speaking, exporters are larger, more productive[12], and more capital- and skill-intensive, which is consistent with many previous studies. However, we cannot say in general that exporters are more R&D-intensive (=R&D/shipments). For example, among the plants that do R&D, exporters have lower R&D intensity than non-exporters (4.7 vs. 9.7 percent in 1991, Table 2.1). Meanwhile, innovator plants are generally larger, more productive, and more capital- and skill-intensive than non-innovator plants, regardless of how we measure innovation. The above results are particularly driven by those plants that both export and innovate. That is, plants that both export and innovate are generally larger, more productive, and

[12] The productivity of a plant is estimated as (a logarithm of) plant TFP following Levinsohn and Petrin (2003).

more capital- and skill-intensive than the other categories of plants by substantive margins.[13]

Table 2.1. Comparison of Plant Characteristics between Exporters and Non-exporters and Innovators and Non-innovators: R&D Expenditure

		Non-exporters		Exporters	
		Non-innovators	**Innovators**	**Non-innovators**	**Innovators**
1991	Shipments(Won)	965.02	6821.52	6718	41447
	Worker(person)	22	74	89	379
	Value added Per Worker	14	20	18	27
	LPlntfp	2.5	2.8	2.8	3.1
	Capital per Worker	14	20	18	46
	Skill intensity	17	31	24	33
	R&D/Production	0.0	9.7	0.0	4.7
1995	Shipment(Won)	1255	5797	10077	71902
	Worker(person)	18	52	71	328
	Value added Per Worker	23	33	34	44
	LPlntfp	2.7	2.9	3.0	3.3
	Capital per Worker	23	34	37	55
	Skill intensity	17	30	26	33
	R&D/Production	0.0	11.1	0.0	4.8
1998	Shipment(Won)	1597	5492	12742	70791
	Worker(person)	16	40	57	222
	Value added Per Worker	29	39	48	59
	LPlntfp	2.7	3.0	3.1	3.3
	Capital per Worker	36	50	59	79
	Skill intensity	18	32	27	35
	R&D/Production	0.0	10.4	0.0	5.0

[13] Again, when we measure innovation with R&D expenditure, plants that both innovate and export are not necessarily those with the highest R&D intensity.

Table 2.2. Comparison of Plant Characteristics between Exporters and Non-exporters and Innovators and Non-innovators: Product Adding

		Non-exporters		Exporters	
		Non-innovators	**Innovators**	**Non-innovators**	**Innovators**
1991	Shipment(Won)	1438	1871	9865	17016
	Worker(person)	24	29	115	178
	Value added Per Worker	16	16	21	20
	LPlntfp	2.5	2.6	2.9	2.9
	Capital per Worker	19	17	21	22
	Skill intensity	19	21	24	27
	R&D/Production	0.2	0.5	0.6	0.8
1995	Shipment(Won)	2258	2084	18452	36095
	Worker(person)	23	24	107	184
	Value added Per Worker	27	27	37	37
	LPlntfp	2.7	2.8	3.1	3.1
	Capital per Worker	32	29	43	45
	Skill intensity	21	22	27	29
	R&D/Production	0.5	0.7	0.7	1.1
1998	Shipment(Won)	2577	2378	18393	43170
	Worker(person)	19	21	82	134
	Value added Per Worker	34	32	50	55
	LPlntfp	2.7	2.8	3.1	3.2
	Capital per Worker	51	41	66	74
	Skill intensity	23	22	28	31
	R&D/Production	0.4	0.7	1.0	1.3

Table 2.3. Comparison of Plant Characteristics between Exporters and Non-exporters and Innovators and Non-innovators: Product Creation

		Non-exporters		Exporters	
		Non-innovators	**Innovators**	**Non-innovators**	**Innovators**
1991	Shipment(Won)	1616	1920	11499	21801
	Worker(person)	26	30	126	231
	Value added Per Worker	16	17	21	19
	LPlntfp	2.5	2.6	2.9	2.8
	Capital per Worker	18	18	22	22
	Skill intensity	20	22	26	26
	R&D/Production	0.3	0.5	0.7	0.8
1995	Shipment(Won)	2188	2530	22540	26839
	Worker(person)	23	27	128	459
	Value added Per Worker	27	27	37	40
	LPlntfp	2.8	2.8	3.1	3.2
	Capital per Worker	31	24	44	46
	Skill intensity	21	23	28	29
	R&D/Production	0.5	1.3	0.8	1.5
1998	Shipment(Won)	2556	1895	26436	62801
	Worker(person)	20	19	100	172
	Value added Per Worker	34	28	52	52
	LPlntfp	2.8	2.8	3.2	3.3
	Capital per Worker	49	28	71	55
	Skill intensity	23	18	29	34
	R&D/Production	0.5	0.6	1.1	1.5

In Table 3.1 - Table 5.2, we examine whether past innovation activity affects the switches from non-exporter to exporter for the three different measures of innovation. With regard to the other direction of causality, we examine whether past exporting activity affects the switches from non-innovator to innovator. Broadly speaking, the tables indicate the possible bi-directional causality between exporting and innovation. Table 3.1 shows that, among the plants that did not do R&D in period t-1, about 4.9 percent of plants switched from non-exporter to exporter. In contrast, among those plants that did R&D in period t-1, 14.5 percent of them switched from non-exporter to exporter. If we allow for the possibility that current innovation decision is also correlated with the current exporting decision, about 18.7 percent (=(176+129+142)/1932) of the switchers from non-exporter to exporter are accounted for by innovators (i.e., those who did R&D). The role of exporting in accounting for switches from non-innovator to innovator is somewhat more pronounced, which is shown at Table 3.2. Among the plants that did not export in period t-1, only 2.4 percent switched from non-innovator at year t-1 to innovator in year t. In contrast, as much as 44.3 percent of plants that exported in year t-1 switched to innovation.

The story is more or less similar when we measure innovation by Product Creation (Table 5.1 and Table 5.2). That is, although we do see some evidence that past or current product creation is important for the switches from non-exporter to exporter, the evidence for the other direction of causality is a little bit more stronger. For example, about 25.3 percent of switchers from non-exporter to exporter were innovators (creators) at year t-1 or t, while about 31.7 percent of switchers from non-innovator to innovator were exporters at year t-1 or t. When we measure innovation by Product Adding, however, the story is somewhat different. Here, the evidence is stronger on the causation from product adding to switching to exporting, rather than the other way around. We caution, however, against any strong conclusion on the causality between innovation and exporting based on the above descriptive analyses.

Table 3.1. Transition Matrix Conditional on Exp_{t-1}=0: R&D Expenditure, 1991-1992

	$Exp_t \mid Exp_{t-1}=0$			
	0		1	
	$R\&D_t = 0$	$R\&D_t = 1$	$R\&D_t = 0$	$R\&D_t = 1$
$R\&D_{t-1}=0$	40281	853	1932	176
	(93.2)	(2.0)	(4.5)	(0.4)
$R\&D_{t-1}=1$	906	698	129	142
	(48.3)	(37.2)	(6.9)	(7.6)

Table 3.2. Transition Matrix Conditional on $R\&D_{t-1}$=0: 1991-1992

	$R\&D_t \mid R\&D_{t-1}=0$			
	0		1	
	$Exp_t = 0$	$Exp_t = 1$	$Exp_t = 0$	$Exp_t = 1$
$Exp_{t-1}=0$	40281	1932	853	176
	(93.2)	(4.5)	(2.0)	(0.4)
$Exp_{t-1}=1$	1557	5340	50	452
	(21.0)	(72.2)	(0.7)	(6.1)

Table 4.1. Transition Matrix Conditional on Exp_{t-1}=0: Product Adding, 1991-1992

	$Exp_t \mid Exp_{t-1}=0$			
	0		1	
	$Adding_t = 0$	$Adding_t = 1$	$Adding_t = 0$	$Adding_t = 1$
$Adding_{t-1}=0$	8733	2715	456	236
	(71.9)	(22.4)	(3.8)	(1.9)
$Adding_{t-1}=1$	7633	5555	507	517
	(53.7)	(39.1)	(3.6)	(3.6)

Table 4.2. Transition Matrix Conditional on $Adding_{t-1}$=0: 1991-1992

	$Adding_t \mid Adding_{t-1}=0$			
	0		1	
	$Exp_t = 0$	$Exp_t = 1$	$Exp_t = 0$	$Exp_t = 1$
Exp_{t-1}=0	8733	456	2715	236
	(71.9)	(3.8)	(22.4)	(1.9)
Exp_{t-1}=1	368	1783	176	875
	(11.5)	(55.7)	(5.5)	(27.3)

Table 5.1. Transition Matrix Conditional on Exp_{t-1}=0: Product Creation, 1991-1992

	$Exp_t \mid Exp_{t-1}=0$			
	0		1	
	$Creation_t = 0$	$Creation_t = 1$	$Creation_t = 0$	$Creation_t = 1$
$Creation_{t-1}$=0	9002	704	1281	54
	(90.3)	(3.3)	(6.1)	(0.3)
$Creation_{t-1}$=1	4717	213	361	20
	(88.8)	(4.0)	(6.8)	(0.4)

Table 5.2. Transition Matrix Conditional on $Creation_{t-1}$=0: 1991-1992

	$Creation_t \mid Creation_{t-1}=0$			
	0		1	
	$Exp_t = 0$	$Exp_t = 1$	$Exp_t = 0$	$Exp_t = 1$
Exp_{t-1}=0	9002	1281	704	54
	(90.3)	(6.1)	(3.3)	(0.3)
Exp_{t-1}=1	982	4524	47	225
	(17.0)	(78.3)	(0.8)	(3.9)

4. Main Empirical Analysis: Propensity Score Matching

4.1. Methodology

We use propensity score matching procedure as explained in Becker and Ichino (2002) to estimate the effect of exporting on innovation and vice versa. The specific procedure used in this paper is adapted from Damijan *et al.* (2010). In this paper, we estimate the average effect of innovation (exporting) at year t-1 on exporting (innovation) status at year t. We use two measures of innovation status: a dummy variable for product adding and a dummy variable for product creation, respectively. As explained before, product adding for a plant at year t is the number of products new to the plant that have been introduced by the plant, and product creation is the number of products new to the economy that have been introduced by the plant, between year t-1 and t. The dummy variable for innovation status takes the value of one if product adding (or creation) is positive, and zero if product adding (or creation) is zero. The dummy variable for exporting status is defined similarly. The treatment variable is innovation status or exporting status at year t-1. The corresponding outcome variable is exporting status or innovation status at year t, respectively.

In order to estimate the effect of innovation to exporting, we match innovators with non-innovators at year t-1 out of non-exporters at year t-1, based on the estimated probability of innovation at year t-1. Similarly, we match exporters with non-exporters at year t-1 out of non-innovators at year t-1, based on the estimated probability of exporting at year t-1 in order to estimate the effect of exporting on innovation. The probability of innovation or exporting is estimated from a probit model, which is specified as follows.

Innovation Probability:

$$\mathrm{Prob}(\mathrm{Innov}_{t-1} = 1) = f(X_{t-1})$$

Exporting Probability

$$\mathrm{Prob}(\mathrm{Exp}_{t-1} = 1) = f(X_{t-1})$$

Here, X is a vector of plant characteristics: plant productivity (log LP-TFP), size (log worker), capital intensity (log capital per worker), and R&D intensity (R&D/Production ratio). The probit model is estimated with year and industry dummy variables. We use nearest neighbor matching with common support restriction.

4.2. Results

Table 6 shows the results, with the upper panel for product adding and the lower panel for product creation. We find that there is a significant positive effect of exporting on product creation. In contrast, the effect of product creation on exporting is estimated to be positive but not significant. Nor do we find any significant effect of exporting (product adding) on product adding (exporting): although the effect of exporting on product adding is estimated to be positive, it is not significant.

This finding is consistent with our previous conjecture that product creation is closely related to the international product-cycle phenomenon, while product adding is related to the process of domestic imitation. If this is in fact the case, we would expect that product creation or introduction of new products from the viewpoint of the Korea's economy is at least more strongly related to the firms' or plants' globalization activities—exporting in this case—than product adding. The empirical results in this study support this view.

Regarding the causality from product creation to exporting, we found a small positive effect, however, it was not significant. Based on a simple theoretical framework of North and South trade and innovation, such as Grossman and Helpman (1991b), we have some reasons to expect a positive and significant effect, since there will be a foreign demand for the product that is newly introduced (imitated) by the

South. However, we do not find evidence for such an effect, at least for the Korean manufacturing sector during the 1990s. One possible reason for this is that newly introduced products are mainly shipped first to the domestic market, but not to foreign markets, under various frictions to trade.

Table 6. The Effects of Lagged Innovation (Exporting) on Current Export (Innovation) Status

	Product Adding		
	ATT	**se**	**Number of treated (controls)**
Adding to Exporting	-0.002	0.002	105967(52453)
Exporting to Adding	0.008	0.005	36085(20335)
	Product Creation		
	ATT	**se**	**Number of treated (controls)**
Creation to Exporting	0.004	0.004	12987(9325)
Exporting to Creation	0.008	0.002	58932(32639)

5. Main Empirical Analysis: Panel VAR

5.1. Methodology

While propensity score matching helps us resolve endogeneity problems through deciphering bi-directional causality among three important variables of interest; innovation, exporting, and productivity[14], it offers little information on complex dynamic inter-dependencies among them. The most important finding from the previous section indicates that exporting activities play a crucial role in stimulating innovation activities, especially when measured by the intensity of new product creation. Similarly, Hahn and Park (2008) shows that the average productivity gains of

[14] In the discussion above, we focused on the bi-directional causality between innovation and exporting only.

exporters is significantly higher than those of non-exporters, which implies that exporting activities may be correlated with subsequent productivity enhancement of exporting firms. However, these findings do not preclude the possibility that the feedback effects from innovation to exporting activities or from productivity gains to exporting activities may occur in subsequent years. In order to examine dynamic inter-relationships among these variables we should take an alternative route, explicitly, by taking dynamic perspectives into consideration. A natural choice would be the vector autoregression (VAR) framework popularized by Sims (1980) in macro-econometric research. Unfortunately, due to the restricted structure of our data set, it is highly doubtful that we would be able to draw a reliable conclusion from the analysis. While VAR requires data series collected from a reasonably long time span, our data set does not seem to include a long enough time span necessary to expect good asymptotic behavior of the estimator. Nonetheless, we may pay attention to the number of cross sectional units observed in our data set as an alternative source of information. Holtz-Eakin *et. al*. (1988) proposed an econometric framework-panel VAR, to derive information on interdependent time paths of economic variables by utilizing sample variations from both time series and cross sectional dimensions. Our data set includes less than 10 time series observations but almost 100,000 cross section units which fit the panel VAR framework pretty well.

Assuming that time-homogeneity of coefficients in the system, we can write the empirical model as;

$$x_{it} = \mu + \sum_{j=1}^{p} \rho_j x_{it-j} + \sum_{j=1}^{p} \tau_j y_{it-j} + \sum_{j=1}^{p} \vartheta_j z_{it-j} + g_i + \varepsilon_{it} \quad (1)$$

$$y_{it} = \alpha + \sum_{j=1}^{p} \beta_j x_{it-j} + \sum_{j=1}^{p} \gamma_j y_{it-j} + \sum_{j=1}^{p} \mu_j z_{it-j} + f_i + u_{it} \quad (2)$$

$$z_{it} = \theta + \sum_{j=1}^{p} \delta_j x_{it-j} + \sum_{j=1}^{p} \pi_j y_{it-j} + \sum_{j=1}^{p} \varphi_j z_{it-j} + h_i + \omega_{it} \quad (3)$$

$$(i = 1, 2, \cdots, N; \;\; t = 1, 2, \cdots, T)$$

where $(x_{it}, y_{it}, z_{it})'$ is a vector of stochastic variables representing exporting status, innovation intensity, and productivity of firm *i* at time *t* and $(g_i, f_i, h_i)'$ is the vector of fixed effects for firm *i*. $(\varepsilon_{it}, u_{it}, \omega_{it})'$ represents statistical disturbances with mean zero and constant variance and none of the disturbance terms is serially correlated but may possess cross-sectional dependencies.

Due to the presence of both individual fixed effects and lagged dependent variables as explanatory variables, it is not possible to obtain a consistent estimator through traditional estimator, such as ordinary least squares in first differences. Holtz-Eakin *et. al*. (1988) suggested a simple IV/GMM-based estimator taking advantage of natural orthogonality conditions given by;

$$E[x_{is}\varepsilon_{it}] = E[y_{is}\varepsilon_{it}] = E[z_{is}\varepsilon_{it}] = E[g_i\varepsilon_{it}] = 0 \quad (s < t) \quad (4)$$

$$E[x_{is}u_{it}] = E[y_{is}u_{it}] = E[z_{is}u_{it}] = E[f_iu_{it}] = 0 \quad (s < t) \quad (5)$$

$$E[x_{is}\omega_{it}] = E[y_{is}\omega_{it}] = E[z_{is}\omega_{it}] = E[h_i\omega_{it}] = 0 \quad (s < t) \quad (6)$$

Iterating GMM procedure utilizing the moment conditions in (4), (5), and (6) and heteroskedasticity and autocorrelation consistent weighting matrix until convergence, we obtain a both consistent and asymptotically efficient estimator.

The structure of the covariance matrix of the error terms in (1), (2), and (3) is crucial in the final estimate of impulse-response function. But it is a rare event that economics imposes restrictions on the covariance matrix enough to derive impulse-response function. Following Sims (1980), we try to identify parameters necessary to derive impulse-response function by assuming lower triangular covariance matrix.

Under the strategy it is of the utmost importance the way we order the variables in the system. With the help of previous studies on the relationship between export, productivity and innovation, we place the variables in the order of exporting activity, innovation intensity, and productivity. In other words, we assume that the exporting activity of a firm is not affected by the contemporaneous shocks to innovation intensity or productivity, and that the innovation intensity of a firm is affected by contemporaneous shocks to exporting activities but not by those to productivity.

Finally, we choose a continuous version of the variables representing exporting activity and innovation intensity to avoid various econometric problems with dichotomous or count variables in VAR analysis. We measure exporting activity of a firm at year t as natural log of the value of exporting product at the year and innovation activity as three-year weighted average of the ratio of the value of shipment of newly created products during the year t to the value of total shipment in the year. Finally, productivity of a firm is calculated as explained in Section 3 and natural log is taken.

5.2. Results

Figure 5.1 illustrates the estimated impulse-response functions along with 95 percent confidence bands calculated by a bootstrapping method[15]. Since a significant proportion of the firms in the sample for a given year are either new entrants or exiting firms, the average time-span of an individual firm is relatively short. In a practical perspective, it does not make much sense to allow many time-lags in the autoregressive part in the regression so that we estimate the model with two time-lags.

[15] Bootstrapping estimates was calculated based on 200 iterations.

Figure 5.1. Impulse Response Functions

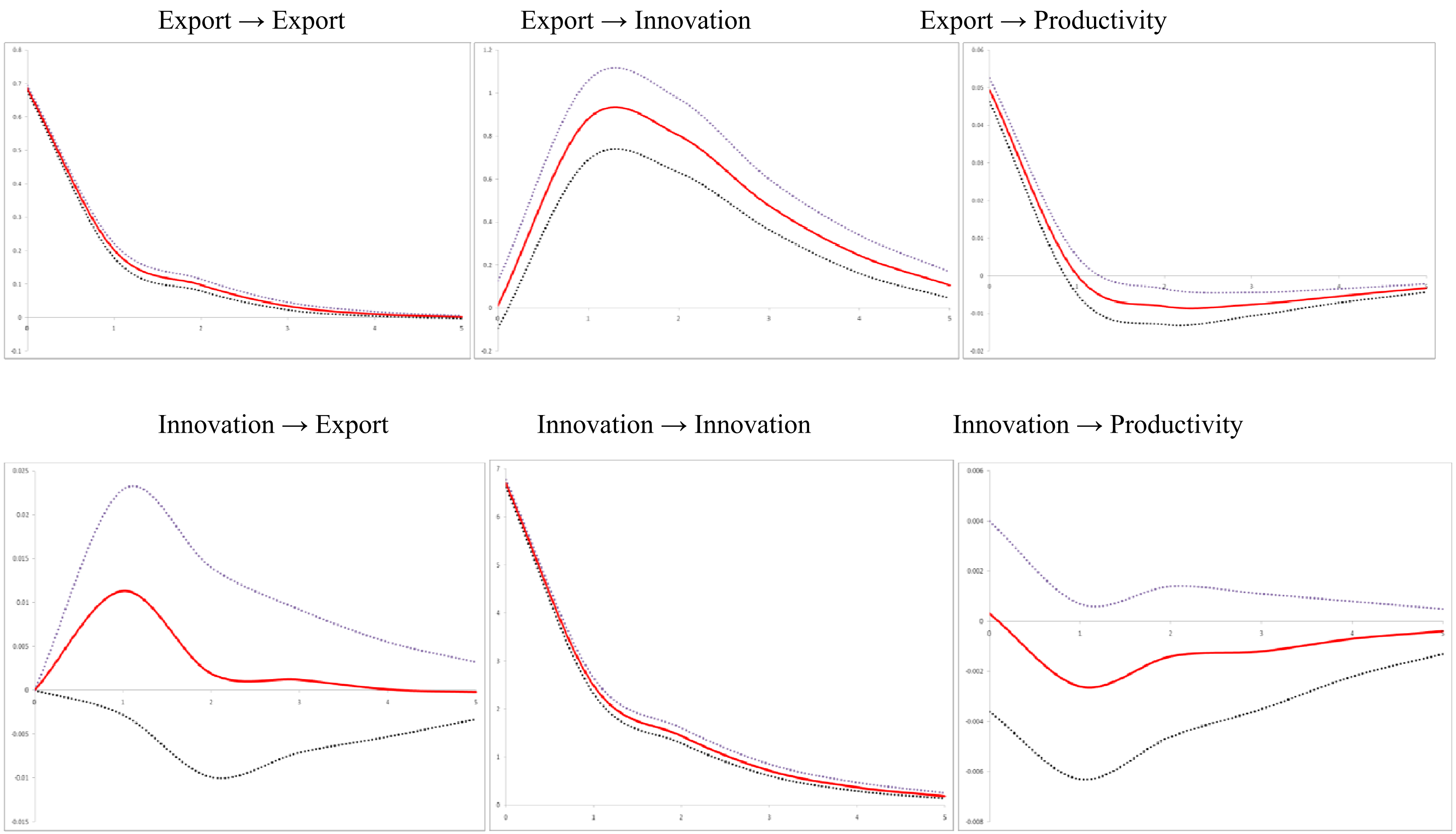
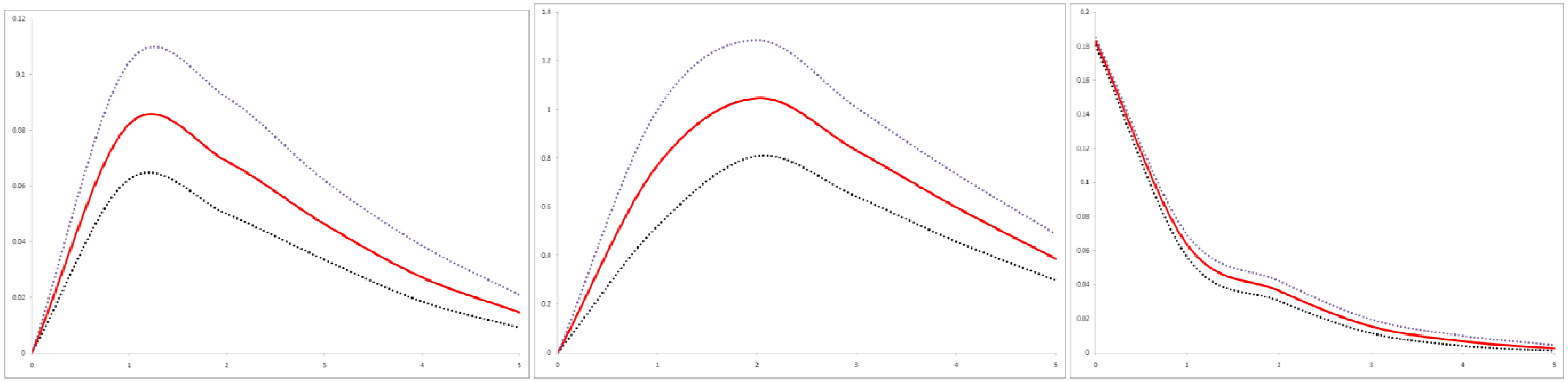


Figure 5.1. Impulse Response Functions (Continued)

Productivity → Export　　Productivity → Innovation　　Productivity → Productivity



Three notable patterns can be pointed out from the analysis. First, a positive exogenous shock to exporting activities seems to stimulate innovation intensity of the firm. Responses to innovation intensity show quite a persistent pattern, that is, it takes more than five years for the impacts of the initial shock to exporting activities to completely die out. The finding that exporting activities may have strong and lasting positive effects on innovation is consistent with earlier research findings that participation in export markets may stimulate innovation in the following year. On the other hand, the initial response of productivity shocks to exporting activity is quite strong but the impacts completely die out after one year.

Second, positive exogenous shocks to innovation intensity affect neither exporting activities nor productivity of a firm. Exporting activities seem to surge immediately in response to exogenous shock to innovation intensity but a 95 percent confidence band indicates that one cannot insist the statistical significance of the pattern. The impacts of innovation shock do not affect productivity of a firm even in the year the initial shock hits the economy.

Third, a positive productivity shock seems to stimulate both exporting activity and innovation intensity of a firm. While two-thirds of the total impact on exporting activity is realized within 2 years, impact on innovation intensity shows more persistent pattern that it can still be detected in a significant magnitude even five years after the initial shock. Therefore, one can infer that the impacts of productivity shocks may be materialized relatively faster in exporting activity than in innovation intensity.

6. Concluding Remarks

In this paper, we examined various possible bi-directional causal relationships among exporting, innovation, and productivity using both propensity score matching technique and panel VAR methodology. We distinguished between two types of product innovation: product adding and new product introduction. Based on propensity score matching technique, we found a significant positive effect of exporting on new product introduction, which is consistent with the similar study by Hahn (2010). The effect from the other direction of causality was estimated to be positive but not significant. This seems to suggest the possibility that when new products are introduced they tend to be first introduced at domestic market level. We could not find any significant effect of exporting on product adding or of the effect the other way around. The three variable panel VAR estimation results are broadly consistent with these results. Exporting has a significantly positive effect on new product introduction and productivity, but new product introduction does not have a significant effect on exporting or productivity. Lastly, plant productivity has a significantly positive effect on both exporting and new product introduction. Overall, this paper suggests an important role of exporting as well as productivity in promoting new product introduction, but no significant role of new product introduction on exporting and productivity.

One of the policy implications of this study is that liberalized trade, at the least, should be seriously considered as a prerequisite when designing an innovation policy framework aimed at new product introduction. Thinking that new product introduction is an outcome of only innovation efforts by both the private and public sectors might be seriously mistaken. Another policy implication of this study is that, even when increasing exports or increasing the number of exporters is a policy objective, introduction of new products or any domestic policies to promote it might not bring about immediate export gains. Finally, the positive effect of becoming an exporter on new product introduction and productivity suggests that there might be some ground for policies to increase the number of exporters. Even within the WTO rules that prohibit export subsidies, policies which facilitate firms to participate in export markets is likely to bring about dynamic benefits over-and-above static gains from trade.

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Appendix

Table A1.1. Transition Matrix Conditional on Exp_{t-3}=0: R&D Expenditure, 1991-1994

	Exp_t|Exp_{t-3}=0			
	0		1	
	$R\&D_t$ = 0	$R\&D_t$ = 1	$R\&D_t$ = 0	$R\&D_t$ = 1
$R\&D_{t-3}$=0	27446	1209	1764	291
	(89.4)	(3.9)	(5.7)	(0.9)
$R\&D_{t-3}$=1	903	324	141	126
	(60.4)	(21.7)	(9.4)	(8.4)

Table A1.2. Transition Matrix Conditional on $R\&D_{t-3}$=0: 1991-1994

	$R\&D_t$|$R\&D_{t-3}$=0			
	0		1	
	Exp_t = 0	Exp_t = 1	Exp_t = 0	Exp_t = 1
Exp_{t-3}=0	27446	1764	1209	291
	(89.4)	(5.7)	(3.9)	(0.9)
Exp_{t-3}=1	1875	3159	144	511
	(33.0)	(55.5)	(2.5)	(9.0)

Table A2.1. Transition Matrix Conditional on Exp_{t-3}=0: Product Adding, 1991-1994

	Exp_t|Exp_{t-3}=0			
	0		1	
	$Adding_t$ = 0	$Adding_t$ = 1	$Adding_t$ = 0	$Adding_t$ = 1
$Adding_{t-3}$=0	6106	1935	511	203
	(69.7)	(22.1)	(5.8)	(2.3)
$Adding_{t-3}$=1	5756	3569	559	464
	(55.6)	(34.5)	(5.4)	(4.5)

Table A2.2. Transition Matrix Conditional on Adding$_{t-3}$=0: 1991-1994

	Adding$_t$|Adding$_{t-3}$=0			
	0		1	
	Exp$_t$ = 0	Exp$_t$ = 1	Exp$_t$ = 0	Exp$_t$ = 1
Exp$_{t-3}$=0	6106	511	1935	203
	(69.7)	(5.8)	(2.1)	(2.3)
Exp$_{t-3}$=1	519	1293	189	519
	(20.6)	(51.3)	(7.5)	(0.6)

Table A3.1. Transition Matrix Conditional on Exp$_{t-3}$=0: Product Creation, 1991-1994

	Exp$_t$|Exp$_{t-3}$=0			
	0		1	
	Creation$_t$ = 0	Creation$_t$ = 1	Creation$_t$ = 0	Creation$_t$ = 1
Creation$_{t-3}$=0	13613	187	1356	31
	(89.6)	(1.2)	(8.9)	(0.2)
Creation$_{t-3}$=1	3479	87	344	6
	(88.8)	(2.2)	(8.8)	(0.2)

Table A3.2. Transition Matrix Conditional on Creation$_{t-3}$=0: 1991-1994

	Creation$_t$|Creation$_{t-3}$=0			
	0		1	
	Exp$_t$ = 0	Exp$_t$ = 1	Exp$_t$ = 0	Exp$_t$ = 1
Exp$_{t-3}$=0	13613	1356	187	31
	(89.6)	(8.9)	(1.2)	(0.2)
Exp$_{t-3}$=1	1315	3145	21	73
	(28.9)	(69.1)	(0.5)	(1.6)

CHAPTER 4

The Link between Innovation and Export: Evidence from Australia's Small and Medium Enterprises

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This paper investigates the direction of causality between export market participation and innovation using firm level data from Australia. Using the propensity score matching approach, the paper asks whether: (i) exporting in the current period is positively correlated with the probability to innovate in the same or the next period, (ii) the relationship in (i) is true for firms who have no export market participation in the previous period, (iii) innovating in the current period leads to export market participation in the same or the next period, and (iv) the relationship in (iv) is true for firms who have no innovation in the previous period. The paper finds a statistically and economically significant positive correlation between export and innovation in the current period. Furthermore, with regards to the direction of causality, there is evidence that it runs both ways for process innovation particularly for the services sector. For product innovation, there is evidence that current product innovator may lead to a higher probability of becoming 'new' exporter in the current period.

Keywords: Innovation; Export; Small and medium enterprises; Propensity score matching
JEL Classification: F14, O12, O14, O31

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1. Introduction

Do exporting firms learn from their participation in foreign markets so that they become more innovative than the firms which focus only on domestic markets (learning-by-exporting hypothesis) or do firm invest in innovative activities in order to become more innovative and productive before they decide to enter foreign markets (self-selection hypothesis)? These are the questions that this paper aims to address. Specifically, this paper is an empirical investigation of the direction of causality between innovation and export market participation using firm level data of Australian small and medium enterprises (SMEs). It asks whether past export market participation explains current innovative performance and whether past innovative performance explains current export market participation.

Understanding the effects of globalisation on economic performance, particularly the performance of firms, is important to ensure that public policy is designed to attain its optimum benefit. One potential benefit of globalisation comes in the form of a productivity improving mechanism via participation in the international market through export. Strong empirical and theoretical evidence seems to indicate that the productivity advantage of exporting firms relative to non-exporting firms come from their pre-export differences in performance.

However, there has been no satisfactory theoretical explanation of how the pre-export differences occur. In addition, recent studies which look at innovation and investment in Research and Development (R&D) provide some evidence that there might be learning effects from participating in the export market. If there is indeed such an effect, then failure to recognize it could lead to suboptimal policy in support of globalisation. This means, any further study that can entangle the causality between globalisation and economic performance which focuses on the role of the intermediate step, that is innovation, would be highly valuable. Hence, the main objective of the proposed study is to contribute to the empirical investigation of the link between export and performance through the effect on innovation using richer data and a better methodology.

This paper extends the existing literature such as the studies by Damijan *et al*. (2010) and Crespi *et al*. (2008) on the evaluation of the competing hypotheses described above. The first contribution of this paper is that the sample of the study consists of firms from all industries instead of just manufacturing. It is quite plausible that lessons from the manufacturing sector may not apply to other sectors. Second, it can identify both process and product innovation, with the former perhaps playing a more important role especially for SMEs and firms in non-manufacturing sectors. Finally, the study focuses on small and medium firms, addressing the limitations in the findings based on large firms.

To some extent, this study and other similar studies which look at the link between innovation and export rather than between productivity and export incorporate an important aspect mentioned by Crespi *et al*. (2008) by linking the way in which export affects innovation directly to the types of source of information used by firms. Thus, while earlier studies only looked at how such information sources were related to export via productivity growth (leaving the details of how the information leads to improved performance inside the black box), our study looks at the more direct relationship between the export market as a potential source of information and the propensity to innovate. For Australia, the proposed study provides further insights to those established by existing studies such as Palangkaraya and Yong (2007; 2011) on the relationship between international trade and productivity by looking at innovation as a likely intermediate step.

The findings of the study provide important information for evaluating the benefits of globalisation to small and medium firms. A confirmation of the learning-by-exporting hypothesis, for example, indicates that export market participation improves a firm's performance through the stimulation of innovations. Thus, the potential benefits of policies designed to improve global market activities (particularly in the export market) would be higher than in the case when there are no learning effects. Furthermore, the findings could also demonstrate how the learning effects are generated both in terms of the types of innovation involved and the roles of the export market activities. Knowing these, governments would be in a better position to design policies that can address any market failure which may lead to suboptimal resource allocation on different types of innovative and export market activities. For developing countries in particular, evidence from studies based on small and medium firm data in developed countries is probably more relevant to draw any policy inference rather than studies based on large corporations, especially when relevant evidence from developing country studies is still rare.

To achieve its objectives, this paper applies the propensity matching score (PSM) approach on firm level Business Longitudinal Database from the Australian Bureau of Statistics from the period of 2004/05 to 2006/07 covering approximately 3000 firms with less than 200 employees. The rest of the paper is structured as follows. Section 2 provides a brief discussion on related studies, Australian SMEs export and innovation activities in general, and two case studies based on an existing study of the Australian wine industry and the characteristics of Australian SMEs which received the Australian Exporter Award from the Australian Government between 2001 and 2010. Section 3 discusses the empirical framework and the data. Section 4 presents and discusses the results. Section 5 summarises the finding and discusses some of their policy implications.

2. Literature Review

2.1. Export and Innovation

The link between export and productivity has been the subject of many different studies over for many years due to its important implications for the benefits of globalisation. As the availability of large, firm-level, longitudinal data has improved over the last fifteen years; the ability to evaluate the two major competing hypotheses (which are not mutually exclusive) behind the export-productivity relationship has also improved in terms of detail and sophistication. The first hypothesis of interest is called the 'self-selection' hypothesis and it is based on the idea that more productive firms self-select into the export market because of the extra (sunken) costs for entering foreign markets. These costs may include, for example, transportation costs, distribution or marketing costs, or the costs to tailor the products to foreign consumers. Because of such entry barriers, firms may exhibit forward-looking behaviour by taking action to improve their productivity before entering any foreign market. As a result, any cross-sectional performance difference between exporters and non-exporters can be explained by the ex ante differences between the two types of firms.

The competing hypothesis, the learning-by-exporting hypothesis, argues that export market participation provides an opportunity for exporters to improve their performance due to a higher level of market competition and the potential for knowledge flows from international consumers. Wagner (2007), for example, surveys more than 40 studies based on firm level data from more than 30 countries and finds that a majority of the studies support the self-selection hypothesis while participation in the export market does not appear to lead to improved productivity.

More recent empirical studies, such as Aw *et al*. (2008), look at the relationship in more detail by incorporating R&D investment or innovation decision and also find evidence for the self-selection hypothesis. The lack of support for the learning-by-exporting hypothesis is further shown by a number of theoretical models which emphasise the role of firm heterogeneity. Other recent studies which also support self-selection include Kirbach and Schmiedeberg (2008) and Chada (2009). The latter is interesting because it finds that innovation can act as a strategic tool to gain market share in the world markets and thus it is important for firms to innovate to enter the export market. Similarly, a recent theoretical study Constantini and Melitz (2008) which, unlike its predecessors, endogenize firm's the decision by firms to export and innovate and show that the export-productivity link can be explained by the decision to innovate before export market entry, consistent with the self-selection hypothesis. Finally, Long *et al*. (2009) explores the effects of trade liberalization on the incentives for firms to innovate and on productivity. They find that trade liberalization's impact is dominated by the selection effect and while the effects on innovation or the incentive to spend in R&D depends in the costs of trade.

Nevertheless, other studies such as Crespi *et al*. (2008), Damijan *et al*. (2010), Girma *et al*. (2008), MacGarvie (2006) and Fernandes and Paunov (2010) provide evidence that globalization may feedback into improved domestic performance through the learning effects on innovation. The last two studies mentioned above show the learning effects through imports while the other studies show the effects through export market participation. What is needed now are further studies employing a similar methodology and similarly rich data from different countries in order to see if the evidence is robust and can be generalized to other settings.

Given the reliance of most of the studies cited above on data from medium and large enterprises and, particularly, from the manufacturing sector, there is a need for a complementary set of evidence drawn from SMEs from across different industries (agriculture and resources, manufacturing, and services). For reasons such as the cost of acquiring legal protection on innovation and its enforcement, it has been argued that SMEs may have a lower propensity to innovate than larger firms.[2] Thus, according to Jensen and Webster (2006), such potential for underinvestment in innovation activity by SMEs and the relatively significant share of SMEs in the economy means that a better understanding of the innovative patterns of SMEs is crucial for an effective innovation policy.

In addition, an analysis of industrial sectors other than manufacturing is also important. First, the extent of market failure in innovation activities varies by industrial sectors and the effectiveness of instruments to combat such market failure including the provision of intellectual property rights (IPRs) protection also varies by sector.[i] Second, the type of innovation activities also varies across industrial sectors because of the multifaceted nature of innovation. Schumpeter (1934), for example, discussed innovation in terms of product innovation, process innovation, organisation innovation and market innovation. Thus, depending on their product or market characteristics, different industries focus more on product innovation while others focus on process innovation. Furthermore, IPRs protection such as patents or trademarks may be more effective for product innovation than process innovation, leading to varying patterns of innovative activity across industrial sectors and dependent upon the size of the firms.

2.2. Australian SMEs' Export And Innovative Activities

Australian SMEs are an interesting case to study the determinants of firm level innovative activities and the link between export and innovation because of the reasons discussed above. In addition, SMEs are important for the Australian economy, accounting for slightly more than 60% of total employment and 50% of value added

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[2] See, for examples, Acs and Audretsch (1988) and Arundel and Kabla (1998).

(ABS, 2001); and, because of these, the SMEs have received specific attention from the Australian government in terms of various policies and incentives directed at them in order to help improve their productive and innovative performance. Naturally, the importance of Australian SMEs varies across industries ranging from, for example, a contribution of as much as 97% of the industry value added in 2006/07 in Agriculture, Forestry and Fishing, to 90% in Rental, Hiring and Real Estate Services, to 75% in Accommodation, Cafes and Restaurant, to 56% in Retail Trade, to 45% in Manufacturing and down to 17% in Information Media and Telecommunication (ABS, 2008).

In terms of export market participation, in 2005-06 SMEs made up approximately 90% of Australia's exporters of goods, but they accounted for less than 10% of the total value of goods exports (ABS, 2006). In terms of export propensity, ABS (2001) indicates that around 15% of SMEs with an employment size 20-199 are exporters whilst less than 5% of SMEs with an employment size 5-19 are exporters. Based on the value of goods export, by 2008-09, Australian SMEs contributed the most in the Construction sector (37%), Transport, postal and warehousing (23%) and Wholesale trade (16%) (ABS, 2010).

For innovative activities, the latest ABS Innovation Survey conducted in December 2005 (ABS, 2007) shows that there were approximately 141,300 businesses[3] operating in Australia and, of this number, around 34% of them undertook innovation in terms of new products, new operational processes and/or new organisational processes.[4] As expected, the extent of innovativeness varies by business size with around 58% of very large businesses (250+ employees), 46-48% of medium businesses (20-99 employees), and 25-34% of small businesses (5-19 employees) reported as innovators. It also varies by industry with industries such as Electricity, gas and water supply (49% of businesses are innovators), Wholesale trade (43%) and Manufacturing (42%) leading the way.

Furthermore, between 2003 and 2005, Accommodation, cafes & restaurants, Mining, and Wholesale trade showed the highest increases in the proportion of innovating businesses. The high growth in innovation incidence among businesses in

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[3] See Mansfield *et al*. (1981) as cited in Jensen and Webster (2006).

[4] Here, 'new' may refer to 'new to businesses' (74% of product innovation), 'new to the industry' (10%), 'new to Australia' (10%), or 'new to the world' (6%).

the Wholesale trade industry, for example, reflects increased incidence of innovation in operational and organisational processes. On the other hand, the growth of innovation activities in Accommodation, cafes & restaurants is due to significant increases in all types of innovation. Finally, some industries appeared to become less innovative between the two periods including Communications services and Finance and insurance.

In terms of the type of innovation, ABS reports that the proportion of Australian businesses with product innovation in 2005 is the lowest at around 19%, followed by operational process and organisational process innovation at around 22 and 25% respectively (ABS, 2007). It is worth noting that in 2003 the proportion of businesses with product innovation is only around 13%. For SMEs, operational process innovation is the most important type of innovation compared to the other two.

Finally, in terms of the contribution to the degree of sales turnover, 65% of innovating businesses reported that less than 10% of their turnover could be attributed to product innovation. This also varies across industries with businesses in most services industry reporting less than 10% attribution while those in Mining and Manufacturing were more likely to attribute between 10% and 50% of their turnover to product innovation. In terms of business size, it is interesting to note that none of the large businesses (100+ employees) reported that their product innovation contributed more than 50% of their turnover. In contrast, 12% of small businesses (5-19 employees) reported that 12% of their turnover could be attributed to product innovation.

2.3. Case Studies

Given the anonymity of firms and the minimal level of details provided by the panel data used in this study, it is probably a good idea to look at a number of case studies on how Australian SMEs conduct their export and innovation activities in practice. This section briefly discusses the case of the Australian wine industry and small and medium businesses in the services sector which have received one form or another of the Australian Exporter Award.[5] The discussion of the wine industry illustrates the

[5] The Australian Export Awards has run for 48 years and provided recognition and honors to exceptional Australian exporters based on the criterion of sustainable export growth achieved

relationship between innovation and export in that industry and is based on the in depth study of Aylward (2004; 2006). Unfortunately, due to a lack of other similarly detailed studies, the services sector discussion can only highlight certain characteristics of select Australian Exporter Award winners between 2001 and 2010.

2.3.1. Australian Wine Industry Australian Exporter Award Winners In Services Sector

According to Aylward (2004; 2006), in 2004 Australia is the 4th largest exporter of wine in terms of value, with 40% exported into the United States. In terms of production, Aylward's study finds that the Australian wine industry consists of two major clusters (South Australia and New South Wales / Victoria). Furthermore, he points out that while the South Australian cluster accounts for only around 25% of wineries, its shares of production and export reach 50% and 60% respectively.

From the interviews that he conducted in his study, Aylward links the South Australian wine cluster's higher productivity and propensity to export to the differences between the two clusters in terms of innovation-related factors. For example, 66% of the firms in South Australia responding to Aylward's interview believed that there was a strong link between innovation and their export performance. In contrast, only 42% of the respondents from the New South Wales / Victoria cluster believed so. Aylward also finds that they differ in how they defined innovation, the extent of collaboration and the use of the wine industry's research and analytical services. Finally, an interesting finding to note from the study is that while there is a negligible difference in how the firms in both clusters define product innovation, they differ rather significantly in how they define process innovation. This last finding points to the possibility that process innovation is probably more important than product innovation in explaining the link between export and innovation.

2.3.2. Australian Exporter Award Winners In Services Sector

In the last 48 years, the Australian government has given awards to businesses deemed as having exceptional performance in the export market every year. The awards are given to businesses belonging to various categories such as agribusiness, arts and

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through innovation and commitment. See http://www.exportawards.gov.au/default.aspx (accessed March 11, 2011) for more details.

entertainment, emerging exporters, and large and advanced manufacturers. For the purpose of this study, two categories of particular interest are the emerging exporter and small and medium-sized businesses in services categories. Between 2001 and 2010, there were 24 businesses which received emerging exporter awards (10 are from the services sector) and 16 businesses which received the small and medium exporter in services awards. In terms of their product characteristics, a majority of these high-performing Australian exporters in the services sector operate in the information technology-related field (10 businesses), highly specialized engineering design and prototype manufacturing operations (8 businesses), or specialized manufacturing and industrial consultancy services for the mining industry (4 businesses). For example, one business in IT related services which employs around 50 consultants is the largest specialist provider of independent information security consulting services in the region, with consumers coming from over 20 countries such as Singapore, Malaysia, South Korea, Japan, the United States, and France. Another business provides maritime simulation, training and consultancy services to the international maritime and defense industries. Perhaps, the most important lesson for this study that can be taken from these award winning exporters, while noting that they may not be representative of the whole services sector, is that most of them rely on being able to continuously come up with better processing technology via skills and technology updating to deliver their services.[6] In other words, it appears that their export performance depends more on process innovation than on product innovation.

3. Empirical Model And Data

3.1. Empirical model

In order to answer the two research questions which require the ability of making causal inference as opposed to simply establishing the (in)existence of correlation, it is necessary to adopt a methodology which allows for an unbiased estimation of the relevant treatment effects (in this case, being an exporter or being an innovator). This

[6] See the case studies for the award winners provided by the Australian Export Awards website mentioned in the previous end note.

study follows Becker and Egger (2010) and Damijan *et al.* (2010) in adopting the propensity score matching methods to arrive at unbiased, robust estimates of the causal effects. As argued by, for example, Deheia and Wahba (2002), the estimation of causal effect through a comparison of a treatment group with a 'nonexperimental' comparison group could suffer from the problem of self-selection or other systematic bias relating to the sample selection. The propensity score-matching methods correct the sample selection bias by pairing treatment and comparison units in terms of their observed characteristics and thus providing a natural weighting scheme that ensures the unbiasedness of the estimated treatment effects.

For the study, there are two treatment effects of interest: innovation effects and exporting effects. Thus, two propensity matching score specifications are specified as follows:

$$\Pr[I_{it} = 1] = f(X_{it-1}) + \varepsilon_{it} \tag{1}$$

and

$$\Pr[E_{it} = 1] = f(Z_{it-1}) + \eta_{it} \tag{2}$$

where, at each period *t*, firm *i*'s propensities to innovate ($\Pr[I_{it} = 1]$) and to export ($\Pr[E_{it} = 1]$) are expressed as a function of observed (exogenous) previous period characteristics such as productivity, size of employment, capital intensity and import status. Based on the estimated propensity to innovate (equation (1)) 'matched' innovators and non-innovators at period *t* are obtained. Similarly, based on the estimated propensity to export we obtain matched exporters and non-exporters.

Based on the resulting matched innovators in period *t*, using a similar approach used by Becker and Egger (2010) and Damijan (2010), we estimate the average treatment effects of innovation on export market participation by comparing their probabilities to become exporters in period *t* and in period *t+1* separately. The latter provides some indication of the direction of causality. We also do the reverse case; that is based on the resulting matched exporters in period *t*, we estimate the average treatment effects of export market participation on innovation by comparing their probabilities to become innovators (product and/or process) in period *t* and in period *t+1* separately. Finally, we repeat the analysis on a restricted sample where we only consider exporters (innovators) at period *t* which were not exporters (innovators) in period *t-1*.

3.2. Data

To estimate the model described above, we use firm level data from the recently released confidentialised unit record file (CURF) Business Longitudinal Database (BLD) from the Australian Bureau of Statistics.[7] This first edition of the BLD CURF includes data for two panels, with 3,000 Australian small and medium businesses with less than 200 employees in each panel – Panel One (2004-05, 2005-06 and 2006-07) and Panel Two (2005-06 and 2006-07). The database contains a rich set of information including firm characteristics (e.g. business structure, markets and competition, financing arrangements; innovation, barriers to business activity, IT use) and financial information (sourced from the Business Activity Statements and Business Income Tax reported to the Australian Tax Office). Finally, in terms of industries, the database covers all of the three broad sectors (primary, manufacturing and services), except for government administration, education, health, and utilities.

The number of businesses covered by the BLD data with useable observations is 1,826 (2004-05), 3,486 (2005-06) and 3,314 (2006-07), for a total of 8,626 firms across years and sectors. The broad sectoral distribution of these firms by type of innovation and the firms' export status is provided in Table 1. From the table, the services sector has the highest number of sampled firms with 4,972. However, this reflects more of the sample design of the BLD database rather than the actual distribution of Australian businesses. Of the 8,626 businesses in the sample, 15% are exporters; and, the proportion of exporters in the sample varies by sector with the manufacturing sector having the highest proportion at around 29%, or double the rate of each of the other sectors.

In terms of innovation, Table 1 shows that overall 30% of the sampled businesses have either product or process innovation (7.8% product innovation only, 10.9% process innovation only, and 11.3% both product and process innovation). Similar to export, the proportion of innovating businesses also varies across sectors. For example, as implied in Table 1, businesses in the manufacturing sector have the highest proportion in terms of innovation with around 40% of them having either product or process innovation. Most importantly, from Table 1, we can see that non-innovators are less

[7] Note that the CURF BLD was supposed to be released in July 2009, but the expected release date has now been postponed to an undetermined date.

likely to be exporters. This is in sharp contrast to what Wakelin (1998) found with UK manufacturing firms, for example, where innovating firms are the ones who are less likely to be exporters. Finally, Table 1 shows that businesses with both product and process innovation are the most likely to be exporters, indicating possible complementary effects between product and process innovation such as the one identified by Van Beveren and Vandenbussche (2010).[8]

Table 1. Distribution of Firms by Sector, Innovation and Export Status (%)

Type of Innovation	Export Status	Sector			
		Primary (n=2,330)	**Manufacturing (n=1,324)**	**Services (n=4,972)**	**Total n=(8,626)**
Product innovation only (7.8)	Non-exporter	82.7	66.9	78.7	77.3
	Exporter	17.3	33.1	21.3	22.7
	Subtotal	100	100	100	
Process innovation only (10.9)	Non-exporter	83.8	66.1	84.1	80.7
	Exporter	16.2	33.9	15.9	19.3
	Subtotal	100	100	100	
Product and process innovation (11.3)	Non-exporter	76.2	54.5	76.7	71.4
	Exporter	23.8	45.5	23.3	28.6
	Subtotal	100	100	100	
No innovation (70.0)	Non-exporter	88.1	77.7	91.7	88.8
	Exporter	11.9	22.3	8.3	11.2
	Subtotal	100	100	100	
Total (100)	Non-exporter	86.7	71.1	88.0	85.0
	Exporter	13.3	28.9	12.0	15.0
	Subtotal	100	100	100	

Note: Primary sector includes agriculture, fishing & forestry and mining. Services sector includes construction, wholesale trade, retail trade, accommodation, cafes & restaurants, transport & storage, communication services, property & business services, cultural & recreational services, and personal & other services.

Source: Processed from pooled panel data 2004/05, 2005/06 and 2006/07 of the CURF Business Longitudinal Database (ABS, 2009) by the author.

After some further data-cleaning steps to ensure that each observation has non-missing values in the relevant variables to estimate the empirical model, the useable sample size is around 1,800 firms for each sample year. A descriptive summary of the clean sample is provided in Table 2. From Table 2, in 2005/06, approximately 20% of

[8] The issue of complementarities between product and process innovation and their link to export participation is not addressed in this paper and is left for future research.

the sampled SMEs are product innovators and 26% are process innovators. The proportion of those with either type of innovation is approximately 34%. Noting that these figures *exclude* innovation in organizational processes, the implied extent of innovativeness among the SMEs in the data sample used in this paper is relatively comparable to that based on the Australian Innovation Survey data discussed in the earlier section. Furthermore, from the same table, the proportion of manufacturing SMEs is approximately 15%, which is about double the proportion of manufacturing SMEs according to the overall figure for Australian SMEs (ABS, 2001). Finally, in terms of the propensity to export, approximately 15% of the SMEs in the clean data reported positive export income. This is similar to the proportion based on the raw BLD data explained above and the overall data of firms with employment size between 20 and 199 as discussed in Section 2.

Table 2. Descriptive Statistics

Variable	Description	t =2005/06			t=2006/07		
		N	Mean	Std. Dev.	N	Mean	Std. Dev.
$PRODINNOV_{t+1}$	=1 if had goods/service innovation at period t+1	3405	0.189	0.391			
$PRODINNOV_{t}$	=1 if had goods/service innovation at period t	3670	0.203	0.402	3365	0.188	0.391
$PRODINNOV_{t-1}$	=1 if had goods/service innovation at period t-1	1826	0.166	0.373	3719	0.204	0.403
$PROCINNOV_{t+1}$	=1 if had operational process innovation at period t+1	3417	0.207	0.406			
$PROCINNOV_{t}$	=1 if had operational process innovation at period t	3688	0.263	0.440	3376	0.209	0.407
$PROCINNOV_{t-1}$	=1 if had operational process innovation at period t-1	1826	0.150	0.357	3737	0.264	0.441
$INNOV_{t+1}$	=1 if had product/process innovation at period t+1	3405	0.289	0.453			
$INNOV_{t}$	=1 if had product/process innovation at period t	3668	0.341	0.474	3365	0.290	0.454
$INNOV_{t-1}$	=1 if had product/process innovation at period t-1	1826	0.227	0.419	3717	0.341	0.474
$EXPORT_{t+1}$	=1 if had any export income at period t	3267	0.146	0.353			

Table 2 (continued). Descriptive Statistics

Variable	Description	t =2005/06			t=2006/07		
		N	Mean	Std. Dev.	N	Mean	Std. Dev.
$EXPORT_t$	=1 if had any export income at period t	3440	0.156	0.363	3229	0.147	0.354
$EXPORT_{t-1}$	=1 if had any export income at period t-1	1826					
$EMPSIZE_{t-1}$	=number of employees at period t	1826	30.10	43.57	3764	31.49	44.74
$LLABPRODVA_{t-1}$	= log of value added (sales less non-capital purchases) per employee at period t	1594	10.25	1.354	3252	10.36	1.343
$LINVINT_{t-1}$	= log of capital purchase per employee in period t-1	1110	7.872	2.141	1559	10.70	1.534
$IMPORT_{t-1}$	= 1 if had any import purchase	1826	0.128	0.334	3476	0.169	0.374
MFG	=1 if industry division is manufacturing	4123	0.152	0.359	3764	0.152	0.359
SERVICE	=1 if industry division is services	4123	0.584	0.493	3764	0.579	0.494

Source: Author.

4. Results

4.1. Propensity to Innovate and to Export

Tables 3 and 4 present the estimated coefficients of the propensity to innovate and to export based on the specified equations 1 and 2 respectively.[9] The estimates are based on pooled sample across years and industrial sectors. In addition, each equation is also estimated with data from each of three major industrial divisions only. These broad sectors are: primary, manufacturing, and services. [10,11]

[9] Unfortunately, due to data access restrictions put in place by the Australian Bureau of Statistic on RADL users, we were not provided with the estimated marginal effects.

[10] Following ANZSIC Version 1993, Primary is A (Agriculture, Forestry & Fishing) and B (Mining), Manufacturing is C (Manufacturing), and Services is E (Construction), F (Wholesale Trade), G (Retail Trade), H (Accommodation, Cafes and Restaurants), I (Transport and Storage), J (Communication Services), L (Property and Business Services), P (Cultural and Recreational Services), and Q = Personal and Other Services.

Overall, the estimated coefficients are statistically significant and of the expected sign; and in all cases they are jointly statistically significant. From Table 3, the propensity to innovate in the current period is positively correlated with the previous period's levels of employment, labour productivity, capital intensity, and whether or not the businesses had any exposure to the import market. Furthermore, the positive relationships with size of employment and labour productivity appear to be non-linear, with diminishing effects. From Tables A.1-A.3 in the Appendix, the estimated coefficients at the sectoral level have similar signs to those based on pooled data across sectors, except for those for primary and manufacturing sectors which are mostly not statistically significant. The only variable that is consistently significant across different specifications is import engagement. One most likely reason for the insignificant coefficient estimates for primary and manufacturing sectors is the drop in the sample size. This needs to be kept in mind when interpreting the results of propensity score matching exercise which will be discussed later.

Table 3. Propensity to Innovate – All Sectors

	Product or process innovation or both $\Pr\left[INNOV_t = 1\right]$		Product innovation $\Pr\left[PRODINNOV_t = 1\right]$		Process Innovation $\Pr\left[PROCINNOV_t = 1\right]$	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
$EMPSIZE_{t-1}$	0.030***	0.009	0.043***	0.010	0.027***	0.001
$(EMPSIZE_{t-1})^2$	-0.000***	0.000	-0.000***	0.000	-0.000***	0.000
$LLABPRODVA_{t-1}$	0.357*	0.195	0.564**	0.276	0.300	0.226
$(LLABPRODVA_{t-1})^2$	-0.019	0.010	-0.029**	0.014	-0.018	0.011
$LINVINT_{t-1}$	0.064***	0.019	0.072***	0.022	0.055*	0.029
$IMPORT_{t-1}$	0.432***	0.087	0.410***	0.104	0.625***	0.106
$YEAR_{2006/07}$	-0.478***	0.087	-0.567***	0.097	-0.396***	0.105
CONST	-3.089***	0.997	-4.391***	0.339	-2.363***	1.144
N. Obs.	1996		1591		1501	
Log pseudo likelihood	-1175.4		-801.4		-720.6	
Pseudo R^2	0.071		0.1067		0.097	

Note: The probit regressions are estimated with 1-digit ANZSIC industry dummy variables when applicable and with robust standard error. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.
Source: Author.

[11] The coefficient estimates of the propensity to innovate equation estimated at the sector level are provided in Tables A.1-A.3 in the Appendix.

For export propensity, the estimates in Table 4 show that only employment and import variables are statistically significant.[12] It should be noted however that any variable constructed using employment size, such as labor productivity and capital intensity with respect to labor, is limited in the sense that the employment size figure is only provided at three discrete intervals: 1-5, 5-19, and 20-99. This might lead to a larger standard error of the estimates than in the case when a more precise measure of employment is available.

Table 4. Propensity to Export

$\Pr\left[Export_t = 1\right]$	All sectors		Primary		Manufacturing		Services	
	Coeff.	Coeff.	Std. Error	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
$EMPSIZE_{t-1}$	0.004***	0.002	0.002	0.001	0.006	0.017	0.004***	0.001
$LLABPRODVA_{t-1}$	0.029	0.002	0.052	0.035	0.071	0.078	0.041	0.056
$LINVINT_{t-1}$	0.016	-0.036	0.045	0.024	0.054	0.055	0.027	0.033
$IMPORT_{t-1}$	1.114***	0.886***	0.214**	0.092	1.091***	0.173	1.178***	0.129
$YEAR_{2006/07}$	-0.121	-0.040	0.178	0.105	-0.106	0.246	-0.206	0.152
CONST	-1.857***	-0.994	0.510	0.425	-2.336***	0.820	-2.112***	0.619
N. Obs.	1993		502		324		1167	
Log pseudo likelihood	-667.2		-174.6		-166.8		-321.9	
Pseudo R^2	0.2178		0.0596		0.1799		0.2480	

Note: The probit regressions are estimated with 1-digit ANZSIC industry dummy variables when applicable and with robust standard error. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.

Source: Author.

4.2. The Effects of Innovative Activities on Export Market Participation

Based on the estimated coefficients summarized in Tables 3-4 (and Tables A.1–A.3) and the resulting innovation propensity score, each SME which innovated in period *t* (the treated firm) is matched to one or more of the non-innovating firms (the untreated firms) using the nearest neighbor and the radius propensity score matching methodologies.[13] To ensure a satisfactory balancing property, the matching is restricted to those observations with common support and to those within the same 1-digit

[12] Unlike the innovation equation, we did not find any non-linearity in the effects of labour productivity and employment size.

[13] We refer to Imbens (2004) and the cited references therein for an excellent survey of the matching methodologies.

ANZSIC classification and year. The resulting matching estimators for average treatments of the treated of the effects of innovation on export market participation are summarized in Tables 5 and 6.[14]

In Table 5, the estimated effects of *current innovation on current export market participation* are presented. While the estimated rate differentials in export market participation are based on matched innovators–non-innovators using previous period conditions, because of their contemporaneous nature these estimates do not indicate any specific direction of causality. Instead, they should be interpreted as unbiased estimates of the nature and strength of the relationship between innovation and export market activities for Australian SMEs as a whole and in each of three major industries.

From the nearest neighbor estimates for all sectors in Table 5, for example, current innovating firms have a 9 - 17 percentage point higher propensity to be in the export market. This effect is also significant in magnitude given that, as discussed earlier, the overall proportion of exporting SMEs in our sample is only around 15%. Also in Table 5, in the last two columns, are estimates based on the radius-matching method. In that case, for each matching analysis, the largest value of radius to ensure that the balancing property test is satisfied. While the overall sector estimates based on the nearest neighbor method have the same sign as those of the radius method, there are dissimilarities in their magnitude. Furthermore, at the sectoral level, the differences between the estimates appear to be more pronounced. However, if we look at the balancing property test results summarized in Table A.4-A7, the balancing property of nearest neighbor matching results seem to be much better. Because of that we focus our discussion of the results on those based on the nearest neighbor method, keeping in mind that the results may not be robust compared to the matching method and should be interpreted with caution.[15]

[14] Tables A.4-A.7 in the Appendix show that the balancing property tests are satisfied for the entire nearest neighbor matching exercises. As can be seen, despite the relatively weak estimates of the propensity models, the results of the matching process appear quite reasonable in identifying valid matched control observations. Furthermore, it appears that the balancing property of the results based on radius matching method is weaker compared to that of the nearest neighbor results.

[15] As indicated earlier, limited sample size may play a role here.

Table 5. Average Treatment Effects of *Innovation*$_t$ on *Pr*[*Export*$_t$]

Outcome: Export *Treatment: Innovation*	**Average Treatment Effects on the Treated by Matching Method**			
	Nearest Neighbor		**Radius**	
ALL SECTORS	ATT	SE	ATT	SE
Innovation type				
Product	0.168*** (334/334)	0.035	0.071** (200/451)	0.032
Process	0.090*** (399/399)	0.034	0.090** (162/226)	0.041
Product/process	0.104*** (655/655)	0.026	0.067* (210/321)	0.035
PRIMARY	ATT	SE	ATT	SE
Innovation type				
Product	0.222*** (45/45)	0.071	0.035 (34/316)	0.062
Process	0.055 (73/73)	0.059	-0.073* (52/276)	0.042
Product/process	0.027 (110/110)	0.061	-0.046 (66/186)	0.038
MANUFACTURING	ATT	SE	ATT	SE
Innovation type				
Product	0.123 (73/73)	0.098	0.021 (21/25)	0.156
Process	0.120 (100/100)	0.091	0.226*** (82/211)	0.072
Product/process	0.140** (143/143)	0.069	0.084 (52/70)	0.092
SERVICES	ATT	SE	ATT	SE
Innovation type				
Product	0.070 (214/214)	0.048	0.088** (110/234)	0.043
Process	0.098** (225/225)	0.040	0.077 (70/92)	0.058
Product/process	0.108*** (397/397)	0.030	0.052* (192/300)	0.030

Note: *,**,*** denote statistically significant at 10%, 5%, and 1% respectively. The standard errors are computed based on Lechner (2001) approximation. In the parentheses are the numbers of treated and matched control (possibly not unique) observations.
Source: Author.

If we look at the sector level and the type of innovation, the estimated co-temporal relationships between innovation and export based on the nearest neighbor matching method summarized in Table 5 seem to support our intuition that the relationship between innovation and export vary across industrial sectors as well as across the different types of innovation. For example, for the primary sector, the relationship between product innovation and export market activities is the strongest, especially if we look only at the nearest neighbor estimators. On the other hand, the relationship between current innovation and export is slightly stronger in terms of process innovation than product innovation. What this means is that the findings of studies which look at the export-innovation link based on data from a certain sector may not generalize to other sectors. It also means that if the sectoral distribution of industrial activities varies across countries, then any study based on data from a certain country may not be generalized to other countries with a different industrial structure.

As mentioned earlier, Table 5's results do not indicate any clear direction causality because of potentially unobserved contemporaneous shocks. In order to investigate the direction of causality in the relationship between innovation and export, we estimate the average treatment effects on the treated in the current period of innovation on the propensity to have any export income in *the next period*. The results of the estimation are provided in Table 6. From the table, most of the estimates are not statistically significant, indicating a lack of evidence that innovation causes export. While most of the estimates have positive signs, they are not statistically significant; possibly due to an increased variance from the smaller sample size. The only exception is process innovation; particularly for firms in the services sector of which current process innovation appears to lead to higher export market participation in the next period. From the table, SMEs in the services sector which have process innovation in the current period have around a 15 percentage point higher probability to have positive export income in the following period. It is interesting to note that the result is also supported by the radius matching method.

Table 6. Average Treatment Effects of *Innovation*$_t$ on *Pr*[*Export*$_{t+1}$]

Outcome: Export ***Treatment: Innovation***	**Average Treatment Effects on the Treated by Matching Method**			
	Nearest Neighbor		**Radius**	
ALL SECTORS	ATT	SE	ATT	SE
Innovation type				
Product	0.131** (153/143)	0.061	0.051 (79/159)	0.057
Process	0.114** (201/200)	0.056	0.085 (58/82)	0.089
Product/process	0.116*** (313/305)	0.043	0.090 (83/120)	0.061
PRIMARY	ATT	SE	ATT	SE
Innovation type				
Product	0.174** (23/24)	0.810	-0.024 (16/115)	0.095
Process	0.144* (42/43)	0.079	0.054 (28/112)	0.074
Product/process	0.083 (60/60)	0.092	0.088 (30/83)	0.061
MANUFACTURING	ATT	SE	ATT	SE
Innovation type				
Product	0.156 (28/22)	0.273	0.143 (7/7)	0.361
Process	0.137 (46/37)	0.208	0.180 (38/54)	0.201
Product/process	0.118 (61/54)	0.160	0.108 (23/21)	0.239
SERVICES	ATT	SE	ATT	SE
Innovation type				
Product	0.022 (104/106)	0.081	0.029 (47/75)	0.094
Process	0.133* (112/111)	0.062	0.234** (27/32)	0.119
Product/process	0.066 (190/186)	0.056	-0.013 (62/75)	0.090

Note: *,**,*** denote statistically significant at 10%, 5%, and 1% respectively. The standard errors are computed based on Lechner (2001) approximation. In the parentheses are the numbers of treated and matched control (possibly not unique) observations.
Source: Author.

4.3. The Effects of Export Market Participation on Innovative Activities

Table 7 and, especially, Table 8 provide matching estimators to investigate the possibility of reversed direction of causality running from export market participation to innovative activities. Using identical matching methodologies based on the estimated propensity to export, we match current exporters (the treated) to current non-exporters (untreated) and estimate the average treatment effects on the treated with regard to their propensity to have product innovation, process innovation, or either type of innovation or both. As before, the estimated effects vary by industry and by type of innovation with process innovation (current and next period), especially for those SMEs in the services sector, appearing to have the strongest and most robust positive relationship with current export market participation.[16] From Table 8, there appears to be evidence that export market participation leads to a higher probability to have process innovation in the services sector.

Table 7. Average Treatment Effects of $Export_t$ on $Pr[Innovation_t = 1]$

Outcome: Innovation *Treatment: Export*	**Average Treatment Effects on the Treated by Matching Method**			
	Nearest Neighbor		**Radius**	
ALL SECTORS	ATT	SE	ATT	SE
Innovation type				
Product	0.122** (219/221)	0.058	0.187** (49/109)	0.077
Process	0.166*** (242/246)	0.054	0.115* (53/100)	0.070
Product/process	0.129** (299/303)	0.053	0.245*** (49/77)	0.082
PRIMARY	ATT	SE*	ATT	SE
Innovation type				
Product	0.043 (46/46)	0.101	0.085 (38/669)	0.063
Process	0.055 (47/50)	0.091	-0.074 (31/111)	0.068
Product/process	0.251*** (54/58)	0.085	0.096 (38/381)	0.078

[16] This is may also be due to services having a much larger sample size.

Table 7 (continued). Average Treatment Effects of *$Export_t$* on *Pr*[*$Innovation_t$* = 1]

Outcome: Innovation *Treatment: Export*	**Average Treatment Effects on the Treated by Matching Method**			
	Nearest Neighbor		**Radius**	
MANUFACTURING	ATT	SE	ATT	SE
Innovation type				
Product	0.065 (70/69)	0.119	0.139 (32/57)	0.112
Process	0.264*** (91/91)	0.094	0.280*** (34/63)	0.109
Product/process	0.062 (104/103)	0.102	0.190* (43/92)	0.097
SERVICES	ATT	SE	ATT	SE
Innovation type				
Product	0.225*** (102/102)	0.080	0.334*** (34/80)	0.099
Process	0.279*** (104/104)	0.078	0.198* (30/104)	0.102
Product/process	0.194** (139/139)	0.077	0.144 (29/65)	0.114

Note: *,**,*** denote statistically significant at 10%, 5%, and 1% respectively. The standard errors are computed based on Lechner (2001) approximation. In the parentheses are the numbers of treated and matched control (possibly not unique) observations.

Source: Author.

Table 8. Average Treatment Effects of *$Export_t$* on *Pr*[*$Innovation_{t+1}$* = 1]

Outcome: Innovation *Treatment: Export*	**Average Treatment Effects on the Treated by Matching Method**			
	Nearest Neighbor		**Radius**	
ALL SECTORS	ATT	SE	ATT	SE
Innovation type				
Product	0.077 (26/24)	0.317	0.000 (15/30)	0.174
Process	0.178* (104/106)	0.105	0.152 (22/42)	0.190
Product/process	0.153 (131/128)	0.110	0.222 (21/27)	0.151

Table 8 (continued). Average Treatment Effects of *Export$_t$* on *Pr*[*Innovation$_{t+1}$* = 1]

Outcome: Innovation *Treatment: Export*	**Average Treatment Effects on the Treated by Matching Method**			
	Nearest Neighbor		**Radius**	
PRIMARY	ATT	SE	ATT	SE
Innovation type				
Product	0.158	0.109	0.044	0.091
	(25/24)		(19/212)	
Process	-0.073	0.159	-0.009	0.125
	(25/24)		(13/35)	
Product/process	0.179	0.131	0.038	0.123
	(28/28)		(18/124)	
MANUFACTURING	ATT	SE	ATT	SE
Innovation type				
Product	0.132	0.245	0.212	0.319
	(39/36)		(11/15)	
Process	0.036	0.271	0.414	0.289
	(39/36)		(11/18)	
Product/process	-0.026	0.256	0.123	0.268
	(39/36)		(14/25)	
SERVICES	ATT	SE	ATT	SE
Innovation type				
Product	0.201	0.145	-0.081	0.317
	(46/47)		(8/17)	
Process	0.303**	0.123	-0.073	0.278
	(47/49)		(10/22)	
Product/process	0.167	0.147	-0.021	0.278
	(62/66)		(11/17)	

Note: *,**,*** denote statistically significant at 10%, 5%, and 1% respectively. The standard errors are computed based on Lechner (2001) approximation. In the parentheses are the numbers of treated and matched control (possibly not unique) observations.
Source: Author.

4.4. New Exporters and New Innovators

In order to investigate further the direction of causality between export and innovation, we also conduct the propensity matching analysis by limiting the sample to 'new' exporters and 'new' innovators. We define 'new' exporters as firms with no export income in period *t-1*. Similarly, we define 'new' innovators as firms without any innovation in the previous period. However, due to the limitation of the sample size, we only conduct the analysis at the overall industry level. The resulting matching estimators of the average treatment effects on the treated are summarized in Tables 9 and 10.

Based on the results in Table 9, we attempt to determine if current innovative activities are correlated with the probability of becoming a 'new' exporter in the current period or in the next period. From the table, it appears that current innovators, especially product innovators, which are non-exporters in the previous period, are more likely to 'become' an exporter in the current period compared to current non-innovators. On the other hand, if we look at the probability of becoming a new exporter in period *t+1*, the relationship is strongest for the process innovators.[17]

Table 9. Average Treatment Effects of $Innovation_t$ on $\Pr[EXPORT_t = 1 | EXPORT_{t-1} = 0]$ and $\Pr[EXPORT_{t+1} = 1 | EXPORT_{t-1} = 0]$

Outcome: Export	Average Treatment Effects on the Treated by Matching Method			
Treatment: Innovation	Nearest Neighbor		Radius	
Innovation type	ATT on period t	SE	ATT on period t	SE
Product	0.054*** (242/242)	0.020	0.030 (61/106)	0.032
Process	0.021 (288/288)	0.020	-0.002 (100/191)	0.029
Product/process	0.027* (490/490)	0.014	-0.005 (90/132)	0.026
	ATT on period t+1	SE	ATT on period t+1	SE
Product	0.007 (114/110)	0.039	0.018 (22/36)	0.070
Process	0.074*** (148/147)	0.025	0.116** (43/70)	0.049
Product/process	0.027 (239/225)	0.027	0.033 (30/41)	0.033

Note: *,**,*** denote statistically significant at 10%, 5%, and 1% respectively. The standard errors are computed based on Lechner (2001) approximation. In the parentheses are the numbers of treated and matched control (possibly not unique) observations.
Source: Author.

Similarly, looking at the results presented in Table 10, we ask if current export participation is associated with a higher probability of becoming a 'new' innovator in

[17] It should be noted again that this study and other studies employing a similar methodology such as Damijan *et al*. (2010) are also sensitive to the matching methods.

the current or the next period. Again, the results appear to be sensitive to the matching method and if we only look at the nearest neighbor estimates, it appears that current exporters are more likely to become new process innovators in the current period. However, when we look at export market participation as the treatment, none of the estimated relationship with the propensity to become a new innovator in period *t+1* is statistically significant.

Table 10. Average Treatment Effects on $Export_t$ on $Pr[Innovation_t = 1 \mid Innovation_{t-1} = 0]$ and $Pr[Innovation_{t+1} = 1 \mid Innovation_{t-1} = 0]$

Outcome: Innovation	Average Treatment Effects on the Treated by Matching Method			
Treatment: Export	Nearest Neighbor		Radius	
Innovation type	ATT on period t	SE*	ATT on period t	SE*
Product	0.052 (129/132)	0.061	0.151*** (65/374)	0.056
Process	0.176*** (143/144)	0.058	0.017 (45/96)	0.058
Product/process	0.155** (157/162)	0.063	0.056 (47/118)	0.075
	ATT on period t+1	SE*	ATT on period t+1	SE*
Product	0.009 (57/59)	0.120	0.153 (26/116)	0.105
Process	0.156 (68/71)	0.111	0.076 (18/33)	0.131
Product/process	0.174 (76/77)	0.114	-0.005 (19/49)	0.129

Note: *,**,*** denote statistically significant at 10%, 5%, and 1% respectively. The standard errors are computed based on Lechner (2001) approximation. In the parentheses are the numbers of treated and matched control (possibly not unique) observations.
Source: Author.

Altogether, the estimated average treatment on the treated effects show a different characterization of the relationship between innovation and export for SMEs from the one for large firms or firms in the manufacturing sector, as reported by most existing studies. For example, it appears that for small firms like Australian SMEs for whom most product innovation involves products which are not new to the world and where most of them are more likely to be financially constrained relative to large firms, the type of innovative activities which appears to matter the most with regards to export market participation is process innovation.

Nevertheless, following the argument in Damijan *et al*. (2010), our results also indicate that the positive effects of current product innovation on the probability of becoming an exporter in the current period shown in Table 11 appear to be consistent with the conclusion of studies such as Cassiman and Golovko (2007), Cassiman and Martinez-Ros (2007) and Becker and Egger (2010) that product innovation is crucial for entering the international market successfully. While the strong positive relationship between current export market activity and the probability of becoming a 'new' process innovator in the current period in Table 12 also appears to be consistent with their conclusion that once in the export market, a firms need to conduct process innovation to stay competitive.

5. Conclusions and Policy Implications

This paper began by asking if exporting firms learned from their participation in the export markets and thus became more innovative than those which focused only on the domestic markets (learning-by-exporting hypothesis) and if firms had invested in innovative activities before they entered foreign markets (self-selection hypothesis). The paper aimed to provide empirical evidence based on firm level data of Australian small and medium enterprises (SMEs) in order to assess if the existing evidence based on medium and large firms and firms in the manufacturing sector can be generalised into smaller firms or firms from the resources and services sector.

The paper attempted to answer the questions by following recent studies in utilizing the propensity score matching methodology to obtain unbiased estimates of the effects of innovation on export market participation and vice versa and in identifying the direction of causality. Despite the various data limitations in terms of the way the data need to be accessed remotely exacerbated by computer programming restrictions that ruled out the use of certain matching estimators and the lack of detailed information such as the provision of information on industrial division at only one digit level or the amount of employment at three grouped intervals, the paper was able to provide some new insights with regard to the relationship between export and innovation. In particular, with regards to the direction of causality, there is evidence that it runs both ways for process innovation, especially for the services sector.[18] That is, the evidence is consistent with the idea that process innovation lead to export market activities which then leads to further process innovation.[19] For product innovation, there is weaker evidence that current product innovation may lead to a higher probability of becoming a 'new' exporter in the current period.

While these findings appear to be sensitive to the matching methodology used and perhaps are not as robust as those of existing studies,[20] they still provide a strong indication that the relationship between innovation and export depends on the size of the firms and the nature of the industry in which the firms operate. For small firms like Australian SMEs for whom most product innovation involves products which are not new to the world and where most of them are more likely to be financially constrained relative to large firms, the type of innovative activity which appears to matter the most with regards to export market participation is process innovation.[21] Not surprisingly, given the importance of the services industry to the Australian economy, the relationship between export market participation and process innovation appears to be the strongest in that industry.

In terms of policy relevance, the findings seem to suggest that government policies aimed at providing SMEs with better access to 'new' and improved operational

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[18] This conclusion may need to be revisited when more data are available to make sure that the insignificant results for non-services sector are not due to sample size. Table A.8 shows the estimates similar to those in table 5 and 6 except for non-services sectors combined and indicates that sample size is possibly the limiting factor.

[19] Or, since it is not clear which comes first, export market participation leads to process innovation which leads to further export market participation.

[20] These are probably due to the limitations of the data as outlined above more than anything else.

[21] Aylward (2004) provides an interesting finding from his case study of the Australian Wine Industry that firms in the more innovative wine clusters in South Australia are more likely to be exporters than firms in Victoria or New South Wales. He finds that the differences between the two groups of firms are negligible in terms of 'new product development but are significant in terms of how they interpret 'production process improvements' and how they implement in-house training and the contraction of skilled labor.

processes or information that could lead to their development by SMEs may be the most effective in leading to higher innovative and export market activities at the same time compared to policies aimed at stimulating the development of new products. This is probably because it is easier for smaller firms in net technology-importing countries such as Australia to enter the international market by becoming a 'better' producer instead of a producer of a 'new' product and, at the same time, it is also easier for them to access new production technologies by becoming more actively involved in the global market in which most of these technologies are developed. In other words, a better export promotion policy would be one that is integrated with policies designed to increase innovation activities. As of now, at least in Australia, innovation policy still appears separate from international trade policy.

Furthermore, the findings also indicate the importance of paying attention to the nature of the industrial sector in which firms operate. In other words, different policies may need to be designed in order to best take advantage of the relationship between product innovation and export market activities among SMEs in the manufacturing sector compared to the policies aimed at SMEs in the services sector which tend to rely more on process innovation. That is, in addition to the need for trade policy and innovation to be more integrated, they also need to be industry specific in order to be the most effective. Finally, while we found indication that there may be complementarities between product and process innovation, we left this issue as well as further analysis with a larger sample of data for future research.

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Appendix

Table A.1. Propensity to Innovate – Primary Sector

	Product or process innovation or both $\Pr\lfloor INNOV_t = 1 \rfloor$		Product innovation $\Pr\lfloor PRODINNOV_t = 1 \rfloor$		Process Innovation $\Pr\lfloor PROCINNOV_t = 1 \rfloor$	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
$EMPSIZE_{t-1}$	0.023	0.017	0.012	0.023	0.027	0.019
$(EMPSIZE_{t-1})^2$	-0.000	0.000	-0.000	0.000	-0.000	0.000
$LLABPRODVA_{t-1}$	0.353	0.339	0.582	0.483	0.123	0.361
$(LLABPRODVA_{t-1})^2$	-0.017	0.018	-0.033	0.025	-0.002	0.019
$LINVINT_{t-1}$	0.036	0.039	0.008	0.050	0.058	0.044
$IMPORT_{t-1}$	0.740***	0.211	0.951***	0.274	0.479*	0.254
$YEAR_{2006/07}$	-0.534***	0.154	-0.263	0.202	-0.654***	0.177
$CONST$	-2.900*	1.662	-0.832	0.692	-2.539	1.828
N. Obs.	493		386		436	
Log pseudo likelihood	-246.3		-129.6		-184.2	
Pseudo R^2	0.068		0.067		0.072	

Note: The probit regressions are estimated with 1-digit ANZSIC industry dummy variables when applicable and with robust standard error. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.

Source: Author.

Table A.2. Propensity to Innovate – Manufacturing Sector

	Product or process innovation or both $\Pr\lfloor INNOV_t = 1 \rfloor$		Product innovation $\Pr\lfloor PRODINNOV_t = 1 \rfloor$		Process Innovation $\Pr\lfloor PROCINNOV_t = 1 \rfloor$	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
$EMPSIZE_{t-1}$	0.025	0.022	0.045	0.028	0.054**	0.027
$(EMPSIZE_{t-1})^2$	-0.000	0.000	-0.000	0.000	-0.000*	0.000
$LLABPRODVA_{t-1}$	0.656	0.688	0.150	0.741	0.654	0.743
$(LLABPRODVA_{t-1})^2$	-0.037	0.034	-0.010	0.037	-0.035	0.037
$LINVINT_{t-1}$	0.059	0.048	0.056	0.063	0.069	0.053
$IMPORT_{t-1}$	0.280*	0.165	0.385*	0.202	0.401**	0.190
$YEAR_{2006/07}$	-0.207	0.164	0.043	0.278	-0.425*	0.241
$CONST$	-3.828	3.494	-1.976	3.763	-4.369	0.241
N. Obs.	326		221		255	
Log pseudo likelihood	-214.7		-134.6		-158.1	
Pseudo R^2	0.044		0.058		0.074	

Note: The probit regressions are estimated with 1-digit ANZSIC industry dummy variables when applicable and with robust standard error. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.

Source: Author.

Table A.3. Propensity to Innovate – Services Sector

	Product or process innovation or both $\Pr[INNOV_t = 1]$		Product innovation $\Pr[PRODINNOV_t = 1]$		Process Innovation $\Pr[PROCINNOV_t = 1]$	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
$EMPSIZE_{t-1}$	0.035***	0.011	0.027**	0.001	0.052***	0.015
$(EMPSIZE_{t-1})^2$	-0.000***	0.000	-0.000**	0.000	-0.000***	0.000
$LLABPRODVA_{t-1}$	0.167	0.286	0.185	0.321	0.672*	0.388
$(LLABPRODVA_{t-1})^2$	-0.009	0.014	-0.012	0.016	-0.035*	0.019
$LINVINT_{t-1}$	0.067***	0.024	0.067**	0.030	0.067**	0.028
$IMPORT_{t-1}$	0.404***	0.117	0.630***	0.138	0.384***	0.144
$YEAR_{2006/07}$	-0.527***	0.110	-0.569***	0.140	-0.554***	0.134
$CONST$	-1.942	0.405	-1.990	1.693	-4.742**	1.986
N. Obs.	1177		894		900	
Log pseudo likelihood	-708.8		-449.7		-455.1	
Pseudo R^2	0.058		0.086		0.1027	

Note: The probit regressions are estimated with 1-digit ANZSIC industry dummy variables when applicable and with robust standard error. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.

Source: Author.

Table A.4. Covariate Balance Tests – All Sectors

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	**t-stat**	**Difference in means**	**t-stat**	**Difference in means**	**t-stat**
Export propensity						
$EMPSIZE_{t-1}$	21.799***	6.947	2.612	0.630	6.034	0.962
$LLABPRODVA_{t-1}$	0.148**	1.949	0.044	0.479	-0.097	-0.520
$LINVINT_{t-1}$	0.131	0.908	-0.306	1.630	-0.246	-0.703
$IMPORT_{t-1}$	0.418***	14.171	0.007	0.162	0.025	0.561
Pseudo R^2 (Radius)	0.218		0.009		0.022 (0.0001)	
Innovation propensity						
$EMPSIZE_{t-1}$	14.641***	6.363	0.733	0.267	6.174	1.546
$LLABPRODVA_{t-1}$	-0.040	0.675	-0.059	0.889	0.003	0.026
$LINVINT_{t-1}$	-0.159	1.459	-0.055	0.429	-0.020	-0.113
$IMPORT_{t-1}$	0.138***	7.278	0.017	0.711	0.008	0.305
Pseudo R^2(Radius)	0.071		0.001		0.017 (0.0009)	

Table A.4 (continued). Covariate Balance Tests – All Sectors

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	t-stat	Difference in means	t-stat	Difference in means	t-stat
Product innovation propensity						
$EMPSIZE_{t-1}$	9.778***	3.339	-0.153	0.410	3.815	0.923
$LLABPRODVA_{t-1}$	-0.024	-0.307	0.069	0.720	0.076	0.770
$LINVINT_{t-1}$	-0.059	-0.417	0.045	0.259	-0.058	-0.337
$IMPORT_{t-1}$	0.209***	7.756	0.027	0.761	0.038	1.572
Pseudo R^2(Radius)	0.097		0.002		0.030 (0.0010)	
Process innovation propensity						
$EMPSIZE_{t-1}$	21.883***	7.709	0.736	0.206	7.462	1.531
$LLABPRODVA_{t-1}$	-0.041	-0.590	-0.041	-0.510	-0.037	-0.295
$LINVINT_{t-1}$	-0.234*	-1.721	-0.038	-0.220	-0.126	-0.587
$IMPORT_{t-1}$	0.144***	6.180	0.015	0.498	0.004	0.1181
Pseudo R^2(Radius)	0.107		0.000		0.017 (0.0006)	

Note: Pseudo R^2 is from the propensity equation regression using observations before and after matching. Radius is the maximum radius to yield statistically insignificant differences in means. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.
Source: Author.

Table A.5. Covariate Balance Tests – Primary Sector

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	t-stat	Difference in means	t-stat	Difference in means	t-stat
Export propensity						
$EMPSIZE_{t-1}$	9.538	1.655	4.814	0.678	7.200	1.464
$LLABPRODVA_{t-1}$	0.021	0.118	-0.082	-0.329	-0.073	0.336
$LINVINT_{t-1}$	-0.273	-1.041	0.003	0.010	-0.157	-0.598
$IMPORT_{t-1}$	0.199***	3.430	0.000	0.000	0.021	0.886
Pseudo R^2(Radius)	0.060		0.003		0.034 (0.0010)	
Innovation propensity						
$EMPSIZE_{t-1}$	8.802**	2.048	-5.255	-0.918	4.860	1.432
$LLABPRODVA_{t-1}$	0.129	0.844	-0.150	-0.878	-0.098	-0.586
$LINVINT_{t-1}$	-0.217	1.080	-0.007	-0.027	-0.402*	1.677
$IMPORT_{t-1}$	0.127***	3.259	0.036	0.744	0.010	0.608
Pseudo R^2(Radius)	0.068		0.010		0.036 (0.0009)	

Table A.5 (continued). Covariate Balance Tests – Primary Sector

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	t-stat	Difference in means	t-stat	Difference in means	t-stat
Product innovation propensity						
$EMPSIZE_{t-1}$	11.421*	1.851	-8.997	-0.800	9.038	1.365
$LLABPRODVA_{t-1}$	-0.099	0.501	0.203	0.685	0.033	0.127
$LINVINT_{t-1}$	-0.369	-1.410	0.070	0.175	-0.045	-0.132
$IMPORT_{t-1}$	0.161***	2.768	0.000	0.000	0.026	0.887
Pseudo R^2(Radius)	0.062		0.008		0.063 (0.0032)	
Process innovation propensity						
$EMPSIZE_{t-1}$	8.700*	1.710	-5.096	-0.726	3.897	0.845
$LLABPRODVA_{t-1}$	0.328*	1.851	-0.154	-0.726	0.054	0.480
$LINVINT_{t-1}$	-0.077	-0.325	0.112	0.311	0.086	0.356
$IMPORT_{t-1}$	0.080*	1.912	0.041	0.814	0.024	0.860
Pseudo R^2	0.072		0.0160		0.050 (0.0029)	

Note: Pseudo R^2 is from the propensity equation regression using observations before and after matching. Radius is the maximum radius to yield statistically insignificant differences in means. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.
Source: Author.

Table A.6. Covariate Balance Tests – Manufacturing Sector

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	t-stat	Difference in means	t-stat	Difference in means	t-stat
Export propensity						
$EMPSIZE_{t-1}$	28.9***	4.927	0.000	0.000	13.988	1.476
$LLABPRODVA_{t-1}$	0.115	0.798	0.054	0.344	0.162	0.773
$LINVINT_{t-1}$	0.296	1.043	0.029	0.010	-0.332	-0.757
$IMPORT_{t-1}$	0.422***	7.766	0.000	0.000	0.082	1.048
Pseudo R^2(Radius)	0.180		0.001		0.028 (0.0020)	
Innovation propensity						
$EMPSIZE_{t-1}$	19.702***	3.561	-3.566	-0.594	5.222	0.583
$LLABPRODVA_{t-1}$	-0.224*	-1.719	0.141	1.067	0.080	0.416
$LINVINT_{t-1}$	0.040	0.155	0.076	0.263	-0.456	-1.004
$IMPORT_{t-1}$	0.127**	2.515	0.042	0.762	0.059	0.899
Pseudo R^2(Radius)	0.044		0.005		0.014 (0.0010)	

Table A.6 (continued). Covariate Balance Tests – Manufacturing Sector

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	t-stat	Difference in means	t-stat	Difference in means	t-stat
Product innovation propensity						
$EMPSIZE_{t-1}$	18.518***	2.624	-5.890	-0.695	-2.922	-0.189
$LLABPRODVA_{t-1}$	-0.227	-1.285	0.489**	2.393	0.531	1.584
$LINVINT_{t-1}$	0.424	1.261	0.370	0.967	-0.034	0.051
$IMPORT_{t-1}$	0.174***	2.655	-0.041	0.509	0.021	0.143
Pseudo R^2(Radius)	0.058		0.039		0.080 (0.0008)	
Process innovation propensity						
$EMPSIZE_{t-1}$	23.330***	3.689	-10.580	-1.503	3.762	0.57
$LLABPRODVA_{t-1}$	-0.166	-1.102	0.009	0.055	0.047	0.356
$LINVINT_{t-1}$	-0.176	-0.575	0.036	0.100	-0.427	-1.353
$IMPORT_{t-1}$	0.174***	2.957	0.040	0.587	0.068	1.152
Pseudo R^2(Radius)	0.074		0.012		0.032 (0.0060)	

Note: Pseudo R^2 is from the propensity equation regression using observations before and after matching. Radius is the maximum radius to yield statistically insignificant differences in means. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.

Source: Author.

Table A.7. Covariate Balance Tests – Services Sector

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	t-stat	Difference in means	t-stat	Difference in means	t-stat
Export propensity						
$EMPSIZE_{t-1}$	18.165***	3.978	3.525	0.578	7.719	1.034
$LLABPRODVA_{t-1}$	0.265**	2.530	0.085	0.666	0.106	0.515
$LINVINT_{t-1}$	0.167	0.764	-0.317	-1.046	-0.668	-1.415
$IMPORT_{t-1}$	0.482***	11.229	0.014	0.241	0.134	1.491
Pseudo R^2(Radius)	0.248		0.012		0.088 (0.0004)	
Innovation propensity						
$EMPSIZE_{t-1}$	10.099***	3.347	0.091	0.026	0.714	0.159
$LLABPRODVA_{t-1}$	-0.045	-0.614	0.042	0.514	0.066	0.634
$LINVINT_{t-1}$	-0.164	-1.125	0.125	0.717	-0.074	-0.362
$IMPORT_{t-1}$	0.119***	4.946	0.030	1.033	0.049	1.646
Pseudo R^2(Radius)	0.058		0.005		0.020 (0.0022)	

Table A.7 (continued). Covariate Balance Tests – Services Sector

Covariate	Before matching		After matching			
			Nearest neighbour		Radius	
	Difference in means	t-stat	Difference in means	t-stat	Difference in means	t-stat
Product innovation propensity						
$EMPSIZE_{t-1}$	1.323	0.361	0.131	0.029	-0.450	-0.084
$LLABPRODVA_{t-1}$	-0.001	-0.014	-0.170	-1.479	0.037	0.305
$LINVINT_{t-1}$	-0.110	-0.603	0.011	0.048	-0.239	-0.951
$IMPORT_{t-1}$	0.193***	5.736	0.033	0.746	0.060	1.561
Pseudo R^2(Radius)	0.086		0.008		0.033 (0.0027)	
Process innovation propensity						
$EMPSIZE_{t-1}$	20.895***	5.454	0.827	0.173	7.820	0.100
$LLABPRODVA_{t-1}$	-0.132	-1.514	-0.062	-0.591	-0.240	-1.479
$LINVINT_{t-1}$	-0.274	-1.455	-0.117	-0.504	-0.207	-0.532
$IMPORT_{t-1}$	0.120***	3.974	0.013	0.343	-0.016	-0.310
Pseudo R^2(Radius)	0.103		0.002		0.028 (0.0020)	

Note: Pseudo R^2 is from the propensity equation regression using observations before and after matching. Radius is the maximum radius to yield statistically insignificant differences in means. ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.
Source: Author.

Table A.8. Average Treatment Effects of $Innovation_t$ on $\Pr[Export_t]$ and $Export_t$ - Manufacturing and Resources

Outcome: Export *Treatment: Innovation*	Average Treatment Effects on the Treated by Matching Method			
	Nearest neighbor		Radius	
	ATT	SE	ATT	SE
$\Pr[Export_t]$				
Innovation type				
Product	0.103 (116/116)	0.069	0.105 (63/128)	0.064
Process	0.104* (173/173)	0.056	0.133** (89/184)	0.054
Product/process	0.109** (258/258)	0.047	0.000 (102/178)	0.049
$\Pr[Export_{t+1}]$				
Innovation type				
Product	0.119 (48/49)	0.133	0.165* (27/49)	0.085
Process	0.099 (88/82)	0.102	0.144* (44/83)	0.075
Product/process	0.086 (123/116)	0.092	0.078 (43/65)	0.083

Note: ***,**,* indicates statistically significant at the 1, 5, and 10% level of significance.
Source: Author.

CHAPTER 5

Multinational Enterprises, Exporting and R&D Activities in Thailand*

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This paper examines the role of MNEs and exporting on R&D activity using the most recent (2006) industrial census of Thai manufacturing with emphasis on providing useful policy suggestions for the promotion of R&D activities in developing countries. The paper's novel feature is that R&D investment is sub-divided into three broad categories, i.e. R&D leading to improved production technology to product development, and to process innovation. In addition, three key globalization forces, namely MNEs, exporting, and global production networks, are examined in a single framework over and above industry and firm-specific factors. Our key finding is that the determinants of each type of R&D are far from identical, suggesting that it is necessary to distinguish between the types of R&D when examining their determinants. The statistical significance of firm-specific factors found in our research suggests that the decision to carry out R&D largely depends on the firm's profitability, and is therefore unlikely to be stimulated by policy-induced incentives. The role of government in this regard should emphasize the availability of infrastructure services and their adequacy for all types of R&D activities. Globalization through exporting and FDI can play a role in encouraging firms to commit to R&D investment. The latter has an indirect effect in encouraging locally-owned firms to engage in R&D investment whereas the former has a direct effect on R&D leading to product development. Another highlighted finding is that participating in a global production network could encourage firms to be even more active in all types of R&D activity. The key policy finding is that our research provides evidence to support ongoing globalization. Firms exposed to global competition through either exporting or participating in global production networks are more likely to make R&D investment, which is a fundamental for sustainable growth.

Key Words: Multinational Enterprises, Exporting and R&D activity

JEL Classification: F23, F10, O30 and O53

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1. Introduction

Research and Development (R&D) has been widely recognized as a key factor in generating industrial development and promoting sustainable economic growth. Governments in most developing Asian countries, including Thailand, have begun to place policy emphasis on R&D activity in order to upgrade the level of technological capability in their manufacturing sector, especially since the competitiveness derived from low labor costs has been eroded over the past decade. In fact, there are two broad ways that technological upgrading could take place, namely technology transmission and technology generation. The former refers to a situation where a firm imports technology from abroad while the latter refers to developing new technology locally through R&D investment. The host-country government generally attaches greater attention to technology generation rather than technology transmission, in the hope that R&D undertaken within the host country will help to lay the foundation for national scientific and technology activity in the country.

In relation to R&D activity, recent interest has been paid to the role of international trade and investment in promoting R&D activity in the host country. In terms of investment, the firm-specific advantages of multinational enterprises (MNEs), which take the form of knowledge-based assets, managerial know-how, quality of the workforce, and marketing and branding, are expected to generate/promote R&D activity in their host countries. Therefore, there has been strong competition among developing countries to attract R&D-intensive foreign direct investment (FDI) through investment promotion campaigns and by offering generous R&D related tax concessions and high-quality infrastructure at subsidized prices (Athukorala and Kohpaiboon, 2010). In terms of the importance of international trade, recent literature points to the role of productivity enhanced by exports in helping to stimulate R&D activity in the exporting country.

Nonetheless, the relationship between MNEs, exports and R&D activity is not straight forward. Some studies (e.g. Daft *et al.*, 1987) argue that the involvement of MNEs may not necessarily lead to the establishment of R&D department/units in the host country. Instead of decentralizing R&D activity, they may keep R&D activity at their headquarters and then export R&D outcomes to their affiliates, mainly to ensure cost efficiency and firm-specific advantages. Some studies (e.g. Lall, 1979) believe that R&D activities established by MNEs are likely to take place in a sequential manner, i.e. the subsidiary begins to set up an R&D activity when they gain more experience in the host country. In terms of exports, some empirical studies (e.g. Hirsch and Bijaoui, 1985; Wakelin, 1998) could not find the positive relationship between exporting and R&D activity. Some studies (e.g. Vernon, 1979 and Salomon and Shaver, 2005) show that exporting would not help firms to learn much about improving production technologies but would help firms to learn more about competing products and customer preferences.

With this unsettled debate, this paper aims to examine the relationship between MNEs; exporting and R&D activity by using the plant-level data of Thai manufacturing as a case study. Thailand is chosen here as the case study for three reasons. First, over the past few years, the Thai government has emphasized technological upgrading and given attention to R&D investment to facilitate the emergence of a new generation of industrial drivers (Yusuf & Nabeshima, 2010; Jongwanich & Kohpaiboon, 2008; ADB 2010) and avoid the 'middle-income trap' i.e. a creeping economic sclerosis (Yusuf & Nabeshima, 2010; Doner, 2009). A number of policy measures have been introduced, especially through the Board of Investment (BOI), to stimulate R&D activity. Second, MNEs have played an important role in Thailand's industrial development, especially since the late 1980s, while Thailand has also pursued an export-oriented industrialization policy as its key strategy since the late 1980s. Third, however, so far, there has been no empirical study examining whether MNE involvement or an exporting strategy would encourage firms, both foreign and domestically-owned firms to set up an R&D activity the country.

This study is distinct from other empirical studies in three ways. First, R&D activity in this study is disaggregated into three categories, namely R&D leading to improved production technology; R&D leading to product development; and R&D leading to process innovation. Most previous empirical studies use total R&D to examine R&D determinants. In fact, MNE involvement and exporting could possibly have a different impact on different types of R&D activities. As argued by Vernon (1979) and Salomon and Shaver (2005), for example, exporting may influence product development more than production technology and process innovation. Thus, disaggregation of R&D activity would help us to clearly examine the role of MNEs and exporting in generating R&D investment. Second, this study examines both a firm's decision to invest in the three types of R&D and their R&D intensity. Examining in both aspects should help us to clearly understand the role of MNEs and exporting activity in influencing these three types of R&D. The selection model and instrument variables techniques are applied here to guard against possible selection bias in R&D intensity and endogeneity problem, respectively.

Finally, this paper examines not only the direct effect of MNEs on R&D activity (both a firm's decision and its intensity), but also the indirect effect of MNEs on the R&D decision and the R&D intensity of locally owned plants, (referred to as R&D spillovers henceforth). Entry of MNEs may help to stimulate domestically-owned firms to set up R&D department/units in order to acquire any advanced technology associated with the former. This would eventually reinforce the imitation (or demonstration) effect as well as increasing competition in the domestic market. A domestically-owned firm's decision in all three types of R&D is examined along with the involvement of MNEs in each industry.

The rest of the paper is organized as follows. Section II briefly looks at R&D activity in Thailand as well as government policy to stimulate R&D activity in the country. Section III provides a literature survey on MNEs, exporting and R&D investment. The Empirical model is set out in Section IV. The data and econometric procedure is discussed in Section V. Section VI discusses empirical results and the final section provides conclusion and policy inferences.

2. R&D Activity and Policy in Thailand: First Look

Data on R&D expenditure as a percentage of GDP are set out in Table 1. World R&D expenditure has increased slightly over the past decade from 2.08% of GDP in 1996-00 to 2.16% in 2006-07. Developed countries and high income countries have dominated R&D activity. For example, R&D expenditure in the US, Japan and the Euro area was 2.66%; 3.42% and 1.95% of GDP, respectively in 2006-07 while R&D expenditure in lower-middle income countries was only 1.19% of GDP. However, the growth rate of R&D expenditure in lower-middle income countries has increased noticeably over the past decade, from only 0.16% of GDP in 1996-00 to 1.19% in 2006-07, and China was one of the key countries contributing to such a noticeable increase.

Table 1. R&D Expenditure (% of GDP)

	1996-00	2001-05	2006-07
World	2.08	2.1	2.16
United States	2.63	2.65	2.66
Euro area	1.81	1.85	1.95
Japan	2.95	3.2	3.42
Lower middle income	0.61	0.9	1.19
Asia			
- China	0.71	1.14	1.45
- Indonesia	0.07	0.05	
- India	0.71	0.74	0.8
- Korea, Rep.	2.38	2.72	3.35
- Malaysia	0.37	0.65	0.64
- Philippines		0.13	
- Singapore	1.69	2.17	2.46
- Thailand	0.18	0.25	0.25
Latin America	0.55	0.58	
Middle East & North Africa		0.96	

Source: World Development Indicator (WDI), available at http://data.worldbank.org/data-catalog, downloaded November 2010.

Not surprisingly, in Asia, most R&D expenditures are contributed by high income countries, especially Newly Industrializing Economies (NIEs). Among lower-middle income countries, China spent almost 1.5% of GDP on R&D activity in 2006-07, compared to less than 1% in other countries. In Thailand, R&D expenditure and its growth rate were relatively low compared to other Asian countries. In 1996-2000, R&D expenditure accounted only for 0.18% of GDP increasing to 0.25% in 2001-05, but there was no growth rate in its expenditure in 2006-07.

This trend and pattern are also found by looking at patents granted by the patent office, broken down by resident and non-resident (Table 2). In high-income countries such as the USA; Japan and Korea, the number of patents granted over the past decade averaged around 150,000 per year while the corresponding figure in developing countries is less than one-tenth of this level. Interestingly, most of the patent registrations in lower-middle income countries were by non-residents, which was in contrast to high-income countries where most of patents granted were registered by residents. China was an exception; the number of patents granted was close to the level found in high-income countries. In 2006-08, registrations reached 73,147, almost half from residents.

In Thailand, there was an increasing trend of patents granted but the level was relatively low, compared to other lower-middle income countries. In 2006-08, the number of patents was only 1,012 on average per year, increasing from 839 patents in 2001-05. This was less in the Philippines and Malaysia where the patents in 2006-08 were 1,274 and 5,273 patents per year respectively. However, all these three countries share the same characteristics- residents contributed only less than 10% of the patents granted.

Table 2. Patent Grants by Patent Office, Broken Down by Resident and Non-resident

Patent_Office	**Applicant_Type**	1991-95	1996-00	2001-05	2006-08
Brazil	Residents	383	340	536	234
	Non Residents	2,020	2,171	3,014	2,225
	Total	2,404	2,510	3,550	2,458
China	Residents	1,704	2,768	12,323	34,537
	Non Residents	2,680	3,612	23,152	38,609
	Total	4,384	6,380	35,474	73,147
Germany	Residents	11,228	11,987	12,608	13,691
	Non Residents	5,566	3,669	3,466	5,003
	Total	16,795	15,655	16,074	18,694
Hong Kong	Residents	16	32	39	52
	Non Residents	1,393	2,245	3,362	4,610
	Total	1,409	2,277	3,401	4,662
India	Residents	368	498	802	1,907
	Non Residents	1,220	1,087	1,448	5,632
	Total	1,588	1,585	2,250	7,539

Table 2 (Continued). Patent Grants by Patent Office, Broken Down by Resident and Non-resident

Patent_Office	Applicant_Type	1991-95	1996-00	2001-05	2006-08
Indonesia	Residents	5	16		
	Non Residents	62	615		
	Total	67	631		
Japan	Residents	70,864	137,910	110,468	141,203
	Non Residents	10,756	18,124	11,650	19,898
	Total	81,620	156,035	122,118	161,101
Malaysia	Residents	18	38	28	230
	Non Residents	1,431	599	1,851	5,043
	Total	1,449	637	1,879	5,273
Mexico	Residents	235	120	134	178
	Non Residents	3,486	3,835	6,482	9,832
	Total	3,722	3,955	6,616	10,010
Philippines	Residents	39	13	10	16
	Non Residents	826	678	1,286	1,258
	Total	865	691	1,296	1,274
Republic of Korea	Residents	4,603	24,995	34,247	80,688
	Non Residents	6,363	14,203	15,049	28,652
	Total	10,967	39,198	49,296	109,339
Singapore	Residents	20	48	309	469
	Non Residents	1,730	3,620	6,188	6,583
	Total	1,750	3,668	6,497	7,052
Thailand	Residents	9	31	54	99
	Non Residents	300	596	785	912
	Total	308	628	839	1,012
USA	Residents	53,696	74,416	84,278	82,284
	Non Residents	45,383	61,610	77,059	80,658
	Total	99,079	136,027	161,338	162,942

Source: World Intellectual Property Organization (WIPO) Statistics Database, December 2009.

Table 3 presents R&D investment in Thailand, disaggregated according to four-digit industries of the International Standard of Industrial Classification (ISIC), compiled from unpublished returns to the Industrial Census 2006- the latest industrial census available-conducted by the National Statistics Office (NSO). On average, the R&D intensity of Thai manufacturing is 3.5 %. This figure seems to be higher than the national average above (0.25%). Given the fact that the R&D definitions used in calculating R&D at the national level and in the industrial census might not be identical, the vast difference would also be due to the sectoral composition. The figure at the national level results from all sectors in the economy combined and the difference suggests even lower R&D intensity in non-manufacturing sectors and the service sector in particular. This finding seems to be consistent with the fact that the service sector accounted for around 50% of the country's GDP and experienced low productivity growth in the past decade (NESDB and World Bank, 2006). This is in a sharp contrast to the manufacturing sectors which experienced considerable positive productivity growth (TDRI 2010, NESDB& World Bank, 2006).

For R&D leading to improved production technology, firms in four industry areas, namely beverages, petroleum and chemical products, textiles and electronics, dominate R&D activity. For example, in the manufacture of malt liquors and malt, more than 70% of total firms invest in R&D leading to improve production technology, followed by manufacture of refined petroleum products (41%) and manufacture of bearings, gears and driving elements (35.5%) (Table 3: A). There is no clear pattern of MNEs, exporting, and R&D investment leading to improved production technology. While firm participation in R&D investment is higher for the manufacture of malt liquors and malt than that for the manufacture of electronic valves and tubes, foreign participation in the latter (i.e. 42%) is far higher than the former (18%). Meanwhile, there are four manufacturing sectors, namely bicycles and invalid carriages; man-made fibers; tanning and dressing of leather; and sugar, where there is no participation by foreign investors but where there is a high percentage of firm participation in R&D activity (20% of total firms, compared to the average of 9%). This pattern is also found in exporting. For example, for both manufacture of malt liquors and malt, and refined petroleum products, export intensity is only 2% each while in manufacture of bearings, gears and driving elements, the export intensity is almost 62% (Table 3: A).

Table 3. R&D Investment, by Industry

A. R&D Leading to Improved Production Technology

ISIC		Total firms	% of firms investing in R&D	R&D intensity	No. of foreign investing in R&D	Age (years)	Sales (million baht)	Export intensity (% of sales)	CR4	Foreign participation
1553	Manufacture of malt liquors and malt	7	71.4	1.8	1	12.6	1326	2	0.53	18
2320	Manufacture of refined petroleum products	61	41	4	5	16	13170	2.1	0.62	5.2
2913	Manufacture of bearings, gears, gearing and driving elements	31	35.5	2.3	2	16	1526	61.4	0.5	10
2423	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	210	25.2	4.3	3	32.1	190.5	10	0.39	3.7
2421	Manufacture of pesticides and other agro-chemical products	44	22.7	1.3	4	23.6	396.3	19	0.39	34.9
2930	Manufacture of domestic appliances n.e.c.	98	22.4	2.4	11	21.1	1307	26.6	0.54	18.6
2411	Manufacture of basic chemicals, except fertilizers and nitrogen compounds	167	22.2	1.9	7	17.7	622.9	16	0.52	8.5
3592	Manufacture of bicycles and invalid carriages	23	21.7	2	0	16.8	593.1	20.2	0.63	0
1532	Manufacture of starches and starch products	67	20.9	4	1	18.3	315.4	20.7	0.6	3.5
2430	Manufacture of man-made fibres	29	20.7	2.8	0	17.8	257.9	14.3	0.44	0
1911	Tanning and dressing of leather	51	19.6	1.2	0	13.7	192.3	51.9	0.46	0
1542	Manufacture of sugar	68	19.1	4.8	1	35.4	1512	52.5	0.41	0.2
2429	Manufacture of other chemical products n.e.c.	121	18.2	1.6	9	13.2	493.9	24.5	0.39	18.2
1533	Manufacture of prepared animal feeds	142	17.6	2.4	4	17.1	982.5	8.8	0.6	3.4
3210	Manufacture of electronic valves and tubes and other electronic components	277	17.3	2.8	27	11.8	1309	44.9	0.39	41.5
Average			9	3.5	2.8	17.6	1052.9	22.7	0.5	13.6
Max			71.4	13.5	27	38	14940	99.3	0.65	100
Min			0	1	0	5	0	0	0.32	0

B. R&D Leading to Product Innovation

ISIC		Total firms	% of firms investing in R&D	R&D intensity	No. of foreign investing in R&D	Age (years)	Sales (million baht)	Export intensity	CR4	Foreign participation
1553	Manufacture of malt liquors and malt	7	42.9	2.3	1	11	534.5	3.3	0.53	30
1911	Tanning and dressing of leather	51	27.5	1.4	0	15.2	250.9	18.6	0.46	0
3592	Manufacture of bicycles and invalid carriages	23	21.7	1.4	0	14	571	20	0.63	0
2320	Manufacture of refined petroleum products	61	21.3	1.2	0	9.3	3506	2.2	0.62	6.1
2411	Manufacture of basic chemicals, except fertilizers and nitrogen compounds	167	19.2	2.6	9	17.7	539.6	12.4	0.52	13.5
2421	Manufacture of pesticides and other agro-chemical products	44	18.2	1.4	2	24.9	350.8	17.5	0.39	18.6
2423	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	210	18.1	2.9	2	29.6	179.9	7.1	0.39	3.9
2429	Manufacture of other chemical products n.e.c.	121	16.5	1.4	10	13.6	243.2	23.3	0.39	27.6
3330	Manufacture of watches and clocks	19	15.8	5.7	2	24.3	2330	99.3	0.58	33.3
1551	Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials	90	15.6	2.4	1	14.9	3356	10.1	0.53	2.8
3210	Manufacture of electronic valves and tubes and other electronic components	277	14.8	2.6	25	11.4	1134	43.2	0.39	43.5
1820	Dressing and dyeing of fur; manufacture of articles of fur	7	14.3	1	0	18	388.1	30	0.5	0
2930	Manufacture of domestic appliances n.e.c.	98	13.3	2.2	6	23.4	1701	21.5	0.54	24.7
2422	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	153	13.1	1.9	2	17	257.2	3.4	0.39	5.6
2109	Manufacture of other articles of paper and paperboard	133	12	1.6	1	19.7	560.3	7.6	0.61	1.6
Average			6.3	3.6	2.1	18.3	1490.5	22.5	0.5	14.3
Max			42.9	25	25	55	24750	99.3	0.69	79.7
Min			0	1	0	5.5	0	0	0.32	0

C. R&D Leading to Process Innovation

ISIC		Total firms	% of firms investing in R&D	R&D intensity	No. of foreign investing in R&D	Age (years)	Sales (million baht)	Export intensity	CR4	Foreign participation
1553	Manufacture of malt liquors and malt	7	42.9	2.3	1	11	534.5	3.3	0.53	30
2423	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	210	36.2	4.6	4	31.9	162.8	8.6	0.39	3.1
2422	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	153	35.3	7.1	11	18.2	269.7	5	0.39	14.7
2421	Manufacture of pesticides and other agro-chemical products	44	31.8	1.1	6	23.8	394.6	14.9	0.39	34.9
2320	Manufacture of wooden containers	61	31.1	2.6	0	12.6	2490	1.5	0.62	2.5
1820	Dressing and dyeing of fur; manufacture of articles of fur	7	28.6	1.5	1	25	1224	32.5	0.5	20
3592	Manufacture of bicycles and invalid carriages	23	26.1	2.3	0	16.8	495.3	16.8	0.63	0
2930	Manufacture of domestic appliances n.e.c.	98	25.5	2.4	8	22.4	2027	18.2	0.54	16.6
1911	Tanning and dressing of leather	51	25.5	2.3	1	12.8	159.5	32.3	0.46	3.8
2411	Manufacture of basic chemicals, except fertilizers and nitrogen compounds	167	24.6	4	13	17.6	554.6	11.4	0.52	15
2429	Manufacture of other chemical products n.e.c.	121	24	2.1	10	12.9	179.6	21.8	0.39	16.3
3330	Manufacture of watches and clocks	19	21.1	12.3	2	22	1887	99.5	0.58	25
3230	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods	64	20.3	3.8	5	15.7	11550	27.5	0.57	37.8
2511	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres	90	20	2.4	8	24.8	1159	43.4	0.52	35.7
3190	Manufacture of other electrical equipment n.e.c.	60	18.3	15.4	3	7.6	140	33.6	0.45	15.2
Average			9.3	5	3.1	18.2	889.9	22.4	0.5	14.2
Max			42.9	31	26	38.5	11550	99.5	0.65	100
Min			0	1	0	7.6	0	0	0.32	0

Note: Age, sales, export intensity, CR4, and foreign participation are different in each types of R&D since firms who invest in R&D are different among these three types of R&Ds.

Source: Authors' compilation from Census 2006.

The percentage of firm participation in R&D leading to product development and process innovation tends to be less than that in R&D leading to improved production technology (Table 3: B and C). The highest percentage of firm participation in both product development and process innovation is around 43% for the manufacture of malt liquors, while the percentage for production technology is 71%. However, the R&D intensity in product development (4.4% of total sales) tends to be higher than that in improved production technology (2.6% of total sales). Meanwhile, industries engaging in product development R&D are more diversified than the other two types of R&D. Electrical equipment and appliances, watches and clocks, rubber tyres and tubes, and paints and printing inks are industries that have a high percentage of firm participation in product development R&D. Note that for both product development and process innovation, there is also no clear pattern of MNEs and exports in determining R&D investment.

2.1. Government Policy in Promoting R&D in Thailand

Policies to promote R&D activity in Thailand are largely implemented through the Broad of Investment (BOI). Until 2000, a double tax deduction on R&D investment was essentially a policy measure to promote R&Ds. From 2000, the government has been more active and has included R&D activities as one of the BOI promoted activities (BOI Notification 1/2543 Section 6.1.2). According to this notification, R&D activity is classified into three broad areas, namely basic research; applied research and experimental development. Basic research means new and original study, either theoretical or empirical, which had no specific target group to use the results. Applied research means new and original study, aimed at generating results a target group. Experimental research means using existing knowledge to improve products and production processes.

To be eligible for BOI privileges, the total R&D investment amount must exceed 1 million baht, not including cost of land. The privileges on offer include (1) tariff exemption for imported machines, regardless of company location (i.e. BOI Zones), (2) tax exemption for corporate income for 8 years, regardless company location; (3) income tax reduction by 50% for another 5 years after the 8 years of income tax exemption when the company is located in the "Thailand Science Park"[1]; (4) being allowed to deduct transportation and utility costs of twice actual expense from its profit for 10 years; (5) being allowed to deduct expenses arising from building, but not more than 25% of total investment, from its profit for 10 years. Note that the company can choose to deduct such expenses from the profit during any years, within the 10 years; (6) other benefits proposed by BOI, varying from location to location.

The government also provides incentive, not only for companies who set up R&D activity for their own business, but also for companies who hire others to conduct R&D for them.[2] Such incentives are provided by the Ministry of Finance in the form of a tax incentive. A company, which hires others to conduct R&D, will be allowed to deduct 100% of its R&D expenditure from corporate income tax, without time frame.

3. Literature Survey: MNES, Exports and R&D

Research and Development (R&D) has been widely accepted as an important factor contributing to innovation, industrial development and sustainable economic growth. R&D leading to *process* innovation could bring more efficient production and management and help firms to cut costs and lower prices. R&D leading to *product* innovation, either through improved production technology or product development, could increase the quality and variety of goods and could open up opportunities for the firm to get higher profits through larger sales volumes and/or price changes. Both innovations could eventually lead to productivity improvement, industrial development, and long-term economic growth.

3.1. MNEs and R&D activity

In contributing to R&D activity, multinational enterprises (MNEs) have a potential role to play in establishing R&D activity in the host country. This would be because multinational firms have firm-specific advantages, which take the form of knowledge-based assets, including proprietary information assets relating to product or process

[1] Thailand Science Park is located in Pathumthani, close to Bangkok.
[2] Recently, 245 companies and government bodies have applied for this incentive.

technology, managerial know-how, quality of the workforce, marketing and branding. However, it is not always the case that multinational firms will establish R&D activity in an investment-receiving country. In fact, the R&D activity of MNEs could take place either at a company's headquarter or could be decentralized to the host country, or both.

There are three key reasons why MNEs keep R&D activity as a headquarter function. First, the establishment of an R&D activity involves high (fixed) costs and uncertainties, and because transportation costs have noticeably declined overtime, MNE affiliates can easily import technology (the so called "technology transmission"), which is developed and produced from their headquarters, instead of establishing R&D activities in the host country. Secondly, the innovatory process essentially involves rich communication and cooperation within a firm, from product design; the production team, marketing and other related key functions. Face-to-face communication, close interdepartmental relationships and highly networked teams transmitting equivocal and uncertain information are very much needed for the development of innovation (Daft *et al.*, 1987 and Athukorala and Kohpaiboon, 2010). Thus, decentralization of R&D activity may be wasteful and may reduce the productivity of R&D effort. Thirdly, the decentralization of R&D also carries the risk of leakage to foreign competitors of proprietary technology, which is the asset created by the R&D process and which determines ownership advantage in international operations. The leakage could occur through either defection of R&D personnel to competitors or simply through the demonstration effect. Thus, to maintain strategic knowledge within the firm, MNEs may decide to keep R&D activity as a headquarter function.

Nevertheless, MNEs may also need to adapt their product design, characteristics of the products and production process to fit properly with the conditions and regulations in the host country. Thus, multinational firms may decide to establish an R&D activity in the host country (the so called "technology generation") to reduce the time lag in adjusting production technique or product characteristics to host country conditions. Improvements in communication technology helps to reduce the difficulty created by distance, although it seems that it cannot perfectly substituted for the physical proximity needed for effective communication in the innovation process (Athukorala and Kohpaiboon, 2010). In addition, MNEs may undertake R&D activity overseas or decentralize their R&D activity to other countries in order to access local technology, local scientists and technicians and to benefit from localized technology spillovers in that location (Serapio and Dalton, 1999; Athukorala and Kohpaiboon, 2010). In contrast to a conventional R&D department established outside headquarters, primarily engaged in adapting products for the local market, modern R&D activities set in developing countries can now also engaged in original product and process development to support the evolution of the core technology of the MNEs.

Some previous empirical literature (e.g. Lall, 1979; Athukorala and Kohpaiboon, 2010) argues that setting up R&D research support by MNE affiliates in the host country is likely to take place in a sequential manner. The process would begin with the establishment of production activity entirely based on technology provided by the parent company. When the subsidiary gains experience in that particular location and sales prospects are promising, the subsidiary begins to set up local R&D support activity. In addition, investment promotion campaigns, e.g. generous R&D related tax concessions and high quality infrastructure at subsidy prices may help to encourage the subsidiary to establish an R&D activity in the host country.

In addition to the direct effect of MNE affiliates establishing R&D activities in the host country, the indirect effect could occur. Here, the entry into the market of MNE affiliates stimulates domestically-owned firms to set up R&D activity. The indirect effect of multinational firms on domestically-owned firms is referred here as "R&D spillovers". There are two key channels through which R&D spillovers could take place. First, domestically-owned firms can benefit from of the entry of MNE affiliates since MNEs can be a source of information, i.e. technologies and management techniques, from which domestically-owned firms can benefit through the processes of demonstration and imitation. This includes providing new technologies and management techniques. MNEs subsidiaries tend to be associated with more advanced production technology than local firms. While such technology associated with foreign firm has also certain qualities of a public good, the localization of the foreign firm cab also potentially generate a positive externality in terms of technological benefit to the local firm. Since the market success of each firm depends on the level of technology it employs, this encourages the local firm to learn the associated superior technology and therefore to set up its own R&D activity.[3]

Secondly, affiliates of foreign firms could affect the decision of domestic firms in setting up R&D activity by increasing the level of competition. Such higher level of competition forces domestic firms to improve their productivity to remain competitive. One of the possible responses by the domestic firms is to conduct certain types of R&D. This process may also help to reinforce the imitation (or demonstration) effect of domestically-owned firms, as it constitutes an incentive to engage in more efficient and leaner production techniques. This would help to stimulate domestically-owned firms to set up and invest in R&D activity. Levin *et al.* (1987) point out that setting up independent R&D near the source of spillover is the most effective way to lean other firms' products and processes, when compared with licensing or the hiring of competitors' R&D employees.

3.2. Exports and R&D Activity

In addition to the potential role of MNEs in supporting R&D activity in the host country, previous studies point to the role of exporting in stimulating innovation, including R&D activity.[4] In fact, the recent theoretical literature suggests a bi-directional relationship between innovation and exports. Aw *et al.* (2008) develop the theoretical model, which can be viewed as a dynamic innovation-based endogenous growth theory. Specifically, the model is a dynamic structural model of a producer's decision to invest in R&D and to participate in export markets. The investment decisions of investing in R&D and participating in export markets depend on the expected future profitability and the fixed and sunk costs[5] incurred with each activity. The model has linked the innovation-export nexus with the role of firm-level productivity. While involvement in R&D and export activities requires entry costs, this generates the feature of productivity-based self-selection into both activities.

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[3] Note that the effort of learning and adapting the associated technology is linked with the dollar amount of cost so that the local firm has to decide its effort to learn associated advanced technology.

[4] See for example, Aw *et al.* (2009); Melitz and ottaviano (2008) and Grossman and Helpman (1991).

[5] That is market research has to be done; option appraisals completed; existing products have to be modified; new distribution networks set up).

Meanwhile, the model suggests that a firm that involves itself in R&D and/or exporting will be able to improve its productivity. Subsequently, this process helps to reinforce the firm's decision to involve itself more into innovation and/or export activities.

All in all, the model points out that the bi-directional relationship between innovation and exporting could occur through changes in a firm's productivity following two step mechanisms. Exporting improves firm productivity, which subsequently makes that firm more likely to self-select into innovation. Or this can occur the other way round, where a firm that involved in innovation activity gains a productivity improvement, which subsequently makes the firm more likely to self-select into export market. Aw *et al*. (2009) apply this model to the Taiwanese electronics industry and find that the self-selection of high productivity plants is the dominant channel driving participation in export market and R&D investment.

"Learning by exporting", which refers to the process where engaging in exporting allows a firm to enhance its productivity and overall competitive position, would be a key link between exporting and innovation. The exporting firms who are exposed to knowledge inputs not available to firms whose operations are confined to the domestic market are likely to be able to amass market and technological information (Salomon and Shaver, 2005). Specifically, exporters could benefit from the technological expertise of their buyers or receive valuable information about consumer preferences and competing products. Improving its productivity could help a firm to involve itself more in R&D activity.

The international competition could be another channel that links exports and innovation activity. As pointed out by Aw *et al.* (2009); Clerides *et al.* (1998) and Greenaway *et al*. (2004), entering export markets incurs sunk costs so that a firm must reach a certain level of productivity to cover such sunk costs. However, to maintain or expand its market position under intense global competition, the firm must keep improving product and/or process innovation, stimulating it to more R&D activity.

However, the theoretical bi-directional relationship between innovation and exports is not always supported by empirical studies. Most of the studies find only the impact of a firm's productivity on exports but not the other way round (e.g. Hirsch and Bijaoui, 1985; Wakelin, 1998). Vernon (1979) and Salomon and Shaver (2005) point out that in export markets exporters would learn more about competing products and customer preferences from export intermediaries; customer feedback and other foreign agents, than they would learn about process technologies. Thus, information passed from the foreign customer might help firms tailor their product to meet the specific needs of foreign customers but have a negligible impact on improving productivity. Meanwhile, Salomon and Shaver (2005) point out that the lack of empirical support for "learning by exporting" could be because of researcher' use of productivity as a measure of learning. Since gains from incorporating the technological information in a firm's production function take time to result in productivity gains, it is difficult to find a statistical relationship between exports and productivity. Interestingly, when Salomon and Shaver (2005) use patent applications (instead of productivity) as a proxy for learning, and use number of new product launched to proxy product innovation, they find a positive relationship between these two variables. They conclude that exporting is associated with innovation.

4. Empirical Model

The empirical model in this paper is based on the analytical framework developed in Section II, to examine the relationship between MNEs, exporting and R&D investment in Thai manufacturing. There are three alternative kinds of R&D investment, i.e. the dependent variable in this study, namely R&D leading to improved production technology (*RDTech*), R&D leading to product development (product innovation) (*RDProduct*) and R&D leading to improved process and management systems (process innovation) (*RDProcess*). Separating R&D investment into these three alternatives allows us to clearly examine the possibly different impact of MNEs and exporting on R&D investment.

In this study, we examine the impacts of MNEs and exporting on R&D in three stages. The first stage examines the impacts of MNE involvement and exporting on a firm's decision to carry out R&D investment. In this stage, R&D activity is measured in terms of a binary dummy variable, where '0' refers to a firm that is not involved in

R&D activity and '1' refers to a firm that is involved.[6] The second stage is to examine the impacts of MNEs and exports on R&D expenditure/R&D intensity (*RDTechEx*; *RDProductEx*; *RDProcessEx*). R&D investment is measured as a of percentage of sales. In this stage, sample selection bias may arise. This refers to problems where the dependent variable is observed only for a restricted, nonrandom sample. In this respect, R&D expenditure can be observed only if the firm decides to invest in R&D. The sample-selection model is applied to redress the bias that may arise from a restricted and nonrandom sample of the dependent variables. This issue is discussed in detail in the next section.

In the first two stages, the MNEs variable (*MNE*) is measured by the proportion of foreign shareholding in a firm while exporting (*EX*) is measured by export propensity, i.e. the share of exports in total sales. Alternatively, the binary dummy variables for MNEs, which take value '1' for firms that has involved with MNEs and '0' otherwise, and for exports, i.e. '1' for firms that has involved with export market and '0' otherwise, are also used to check for the robustness of the model.

Note that all plants with an FDI connection (regardless of the magnitude of the foreign share in capital stock) are considered to be foreign plants for the identification of local firms ('1' for dummy variable). The cutting point (i.e. 0%) seems to be slightly higher than what is widely used by the International Monetary Fund (IMF) and other institutions such as the Organization for Economic Co-operation and Development (OECD), the US Department of Commence as well as several scholars studying multinational firms (e.g. Lipsey, 2001), i.e. 10%. However, the choice is dictated by data availability since information on foreign ownership in the census is reported with a wide range.

The third stage is to examine whether MNEs could generate R&D spillover to domestically-owned firms. As mentioned in the previous section, MNE affiliates can stimulate domestically-owned firms to invest in R&D activity through the processes of demonstration and imitation as well as through more intense competition. To examine such impacts, the model specification in the first and second stages is modified. In the spillover equation the sample includes only domestically owned firms. The MNE

[6] Note that this includes a company that hires other companies to conduct R&D activity.

variable needs to be modified. Instead of using firm level information on MNEs, the variable is replaced by the share of foreign firm in total capital stock at industry level (*FOR*). If the coefficient associated with *FOR* is positive, it shows that MNEs could positively influence the domestically-owned firm's R&D investment decision.

In addition to MNEs and exporting, firm and industry specific variables based on the previous literature on R&D determinants are included in the model. The first firm specific variable is firm size (*Size*). Schumpeter (1942) points out that firm size matters to innovation activity by showing the qualitative differences between the nature of innovation activity undertaken by small firms, which have no formal R&D units, and the large firms, which have formal R&D laboratories. Many scholars (e.g. Pavitt, 1987; Vaona and Pianta, 2008) test Schumpeter's hypothesis and find a positive relationship between firm size and innovation. Such a positive relationship could arise for two key reasons. First, due to the imperfection in the capital market, large firms, which have stability and internally generated funds can afford to invest in (risky) R&D. Second, with large sales, the returns from R&D are higher, i.e. the fixed costs arising from investing in R&D can be recovered faster from a large sale volume. However, there are some studies (e.g. Acs and Audretsch, 1987 and Dorfman, 1987) arguing that the efficiency in R&D could be undermined by loss of managerial control when a firm grows large so that the incentives of scientists and engineers become attenuated. They argue that industry conditions and market structures seem to be more crucial than firm size while a non-linear relationship between firm size and R&D investment is possible.[7]

In this study, firm size (*size*) is measured by the firm's total sales. To capture the possible non-linear relationship between firm size and R&D investment we include the squared term of size $(size^2)$ in the model. Because exporters and MNE affiliates tend to

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[7] Our paper also examines the role of market structure on R&D activity. The concentration ratio (CR4) is calculated using data on large corporations from Business On-Line 2008, supplemented by a large number of related sources, to estimate sales of the largest four firms in each industry. However, as found in many previous studies such as Mishra (2007) and Cohen and Levin (1989) and works cited therein, this variable is statistically insignificant in directly determining R&D investment (See our results when we include concentration ratio in *Appendix I*). However, Jongwanich and Kohpaiboon (2008) found that market concentration has a negative and significant effect on exports. This implies that market structure could directly influence a firm's R&D decision and R&D intensity through export channel. This is supported by most previous empirical studies, i.e. when exports is included in the R&D determinant model, market structure (concentration ratio or Herfindahl index) cannot be included in the model (e.g. Aw *et al*., 2009; Meyer, 2009; Salomon and Shaver, 2005).

be larger firms than non-exporters and non-MNE firm, by omitting this variable (size), the effect of exporting and MNEs might capture a spurious effect based on firm size.

In addition to firm size, the model includes firm age (*Age*), another firm specific factor. The sign of firm age is inconclusive since older firms, on the one hand, may be more traditional than younger firms and therefore less inclined to change the operating process and adopt new technologies. On the other hand, older firms may have more experience in changing production processes and adopting new technologies. The need to adopt new technology may be higher than for younger firms since their technologies are outdated so the likelihood that they will have to involve themselves in R&D investment is higher. In addition, firms would accumulate knowledge through experience (the "learning by doing" argument, Barrios *et al*., 2003) so that older firms tend to be more efficient and perform better in terms of export activity than younger firms. Meyer (2009) finds that firm age has a positive effect in determining technology adoption in German firms. To capture this effect, this study proxies *Age* by periods where a firm has been operated in an industry. The squared term of *Age* is also included to capture the possible non-linear relationship between age and R&D investment.

A firm's productivity (*PROD*) is also included in the model. As argued by Aw *et al* (2008, 2009), changes in a firm's productivity could influence a firm's decision to invest in R&D in two ways. It could directly affect the prospects of the firm's future profit, thereby encouraging the firm to invest more in R&D, and indirectly through the exporting channel as mentioned earlier. Thus, it is relevant to include a firm's productivity as another control variable. We use value added per worker as a proxy in measuring this variable.

Government policy to promote R&D investment is included in the empirical model. The sign of government policy is ambiguous. Some studies find a positive relationship between government policy and R&D investment. Yoon (2000) finds that the government subsidy program in Korea helps to stimulate the R&D activity in the IT industry; Lee and Hwang (2003) find that the government subsidy helps to promote R&D activity only for the IT industry but not for non-IT industry. The negative impact of government policy, especially subsidy, and R&D may result from the moral hazard and burden that could arise from a result-sharing agreement connected with the subsidy. This could discourage a company from conducting R&D. To capture the effect of government policy, we include a binary dummy variable, which takes the value '1' for a plant that receives investment (R&D) promotion from the Board of Investment (BOI) and '0' otherwise. It is important to note that the BOI is included only in the selection model (i.e. a firm's decision to invest in R&D) but not in the R&D intensity. This is not only to redress the problem of model identification when applying the selection model, but also to reflect the fact that privileges provided by the BOI are not varied by amount of R&D expenditure. Thus, the BOI policy is likely to affect the decision of a firm to invest in R&D, but not its intensity.

To capture possible effects of both regional-specific factors and infrastructure, the model includes the location of the plant (*region*) as another explanatory variable. Infrastructure could influence a firm's R&D decision and facilitate higher R&D intensity. Infrastructure in Thailand tends to be best developed in the central part of the country, in Bangkok, its vicinity, and in the Central region. We therefore include a binary dummy variable, which takes the value of '1' for a plant that is established in these areas, and '0' otherwise.

The model also controls for capital-labor ratio (*KL*). Newark (1983) points out that the capital intensity of firms/industries could influence their R&D activity. More specifically, a firm in capital-intensive industries such as telecommunication generally requires bigger budgets for R&D activity than those in labor-intensive industries. A positive relationship between the capital-labor ratio and R&D activity is expected.

Finally, the model also includes a proxy of 'international production network' (*Network*). Rapid advances in production technology and technological innovations in transportation and communications have allowed companies to "unbundle" the stages of production so that different tasks can be performed in different places. These dynamics have resulted in the increasing importance of international production fragmentation—the cross-border dispersion of component production/assembly within vertically integrated production processes—and a shift in the composition of exports toward intermediate goods (parts and components). Industry that has involved more in the environment of a production network tends to be more dynamic such as the electronics and electrical appliance industry. Thus the need to invest in R&D activity in industries that are integrated into production networks, is expected to be higher than in other industries.

We use trade data to capture the aspect of international production networks (*Network*), we measure the ratio of parts and components (P&C) trade (the sum of imports and exports) to total goods trade. The listing of P&C is the result of a careful disaggregation of trade data based on Revision 3 of the Standard International Trade Classification (SITC, Rev 3) extracted from the United Nations trade data reporting system (UN Comtrade database). Note that the Comtrade database does not provide for the construction of data series covering the entire range of fragmentation-based trade. The lists of parts used here is from Kohpaiboon (2010) and Jongwanich (2011) where there are 319 items classified as parts and components in which 256 products are in SITC7 and 63 products are in SITC8.[8]

In total, the empirical model of a firm's decision to invest in R&D activity, and its R&D expenditure can be summarized as follows[9]:

1. $$RDTech_{ij} = f\left(MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij},\ Network_j\right) \quad (1.1)$$

$$RDTechEx_{ij} = f\left(MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij},\ KL_{ij},\ region_{ij},\ Network_j\right) \quad (1.2)$$

2. $$RDProduct_{ij} = f\left(MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij},\ Network_j\right) \quad (2.1)$$

$$RDProductEx_{ij} = f\left(MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij},\ KL_{ij},\ region_{ij},\ Network_j\right) \quad (2.2)$$

3. $$RDProcess_{ij} = f\left(MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij},\ Network_j\right) \quad (3.1)$$

$$RDProcessEx_{ij} = f\left(MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij},\ KL_{ij},\ region_{ij},\ Network_j\right) \quad (3.2)$$

where,

$RDTech_{ij}$ = A firm's decision to invest in R&D improved technology

$RDTechEx_{ij}$ = R&D expenditure in improving production technology (% of total sales)

$RDProduct_{ij}$ = A firm's decision to invest in R&D (development of product)

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8 Note that this list is an extended version of Athukorala and Kohpaiboon (2009) using lists of parts in Board Economics Classification (BEC) 42 and 53 as a point of departure.

9 Note that in our empirical model, we also include an interaction term between MNEs and exports, MNEs and production network, MNEs and age to capture the indirect effect that may occur between domestic-oriented MNEs and export-oriented MNEs, between MNEs in and out production network, and MNEs of different ages, but the results are statistically insignificant. See Appendix II for the results.

$RDProductEx_{ij}$ = R&D expenditure in product development (% of total sales)

$RDProcess_{ij}$ = A firm's decision to invest in R&D (process innovation)

$RDProcessEx_{ij}$ = R&D expenditure in process innovation (% of total sales)

MNE_{ij} = Proportion of foreign share holding in a firm i

Ex_{ij} = Propensity to exports

$Size_{ij}$ = Size of firm i in industry j

Age_{ij} = years ofoperation of firm i in industry j

$PROD_{ij}$ = Productivity of firm i in industry j

KL_{ij} = Capital-labor ratio

BOI_{ij} = Investment (R&D) promotion from Board of Investment (BOI)

$region_{ij}$ = Location of plant
(1 for Bankok, vicinity and central region and 0 otherwise)

$Network_j$ = International production network in industry j

For the R&D spillovers, R&D and foreign ownership variables in equations (1.1, 2.1 and 3.1) are modified as follows:

$$RDTech_{ij,d} = f\left(FOR_j,\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij}, Network_j\right) \quad (4)$$

$$RDProduct_{ij,d} = f\left(FOR_j,\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij}, KL_{ij},\ BOI_{ij}, region_{ij}, Network_j\right) \quad (5)$$

$$RDProcess_{ij,d} = f\left(FOR_j,\ Ex_{ij},\ Size_{ij},\ Size^2_{ij},\ Age_{ij},\ Age^2_{ij},\ PROD_{ij}, KL_{ij},\ BOI_{ij}, region_{ij}, Network_j\right) \quad (6)$$

where

$RDTech_{ij,d}$; $RDProduct_{ij,d}$; $RDProcess_{ij,d}$ include only domestically-own firms and

FOR_j = the presence of multinational firms in industry j

5. Data and Econometric Procedure

Data for the study are compiled from unpublished returns to the Industrial Census 2006, the latest industrial census available, conducted by the National Statistics Office (NSO). A well-known limitation of any cross-sectional data set, with each industry representing a single data point, is that it is difficult to control for unobserved industry specific differences. Long-term averages tend to ignore changes that may have occurred over time in the same country. These limitations can be avoided by using a panel data set compiled by pooling cross-industry and time-series data. Particularly, in the case of technology spillover involving a time-consuming process, panel data are more appropriate. Unfortunately, given the nature of data availability in this case, this preferred data choice is not possible. So far there are two industrial census sets, i.e. 1996 and 2006, both are establishment-level data. Even though both of them provide an establishment identification number, the number was not assigned systematically. Thus for a given ID No., an establishment in 1996 is not necessarily the same as that in 2006.

The census covers 73,931 plants, classified according to the four-digit industries of the International Standard of Industrial Classification (ISIC). The census was cleaned up first by checking for duplicated samples. As occurred in the 1996 industrial census, there are some duplicated records in the survey return, presumably because plants belonging to the same firm filled in the questionnaire using the same records. The procedure followed in dealing with this problem was to treat records reporting the same value for the eight key variables of interest in this study as one record. The eight variables are registered capital, number of male workers, number of female workers, sale value, values of (initial and ending periods) capital stocks, value of intermediates and initial stock of raw materials. There are 8,645 such cases so that the final sample drops to 65,286 plants. In addition, we deleted establishments which had not responded to one or more the key questions such as sales value or, output and which had provided seemingly unrealistic information such as negative output value or an initial capital stock of less than 5,000 baht (less than $200).[10]

[10] If we alter initial capital to 10,000 baht the number to be dropped increased to 1,289 samples (another 500 samples dropped).

The 2006 census contains a large number of micro-enterprises defined as plants with fewer than 10 workers. There are 37,042 establishments in the sample which employ less than 10 workers, 52% of which are micro enterprises which do not hire paid workers (zero paid workers). The problem of self-employed samples is less severe when considering the samples with more than 10 workers. Hence, our analysis focuses on establishments with more than 10 workers net of self-employed firms. Seven industries are excluded. These either serve niches in the domestic market (e.g. processing of nuclear fuel, manufacture of weapons and ammunition), in the service sector (e.g. building and repairing of ships, manufacture of aircraft and spacecraft, and recycling) or are explicitly preserved for local enterprises (e.g. manufacture of ovens, furnaces and furnace burners, manufacture of coke oven products). In total the remaining establishments accounted for 75% of Thailand's manufacturing gross output and 62% of manufacturing value added in 2006.

Trade data are compiled from UN Comtrade and the standard concordance between ISIC and HS code is used. Concentration ratio (*CR4*), which is used as an instrument variable for exports, is obtained from Kophaiboon and Ramstetter (2008) in which the concentration is measured at the more aggregate level (e.g. many measured at the 4-digit whereas some at the 3-digit ISIC classification). This guards against possible problems arising from the fact that two reasonably substitutable goods are treated as two different industries according to the conventional industrial classification at a high level of disaggregation.[11] Tables 4 and 5 provide a statistical summary as well as a correlation matrix of all relevant variables in this analysis.

[11] Effective rate of protection is also used as alternative instrument variable for exports. It is calculated based on official data provided by Customs Department, Ministry of Finance (see Jongwanich and Kohpaiboon,, 2007). However, the model using concentration ratio as an instrument performs better in terms of diagnostic tests.

Table 4. Statistics Summary of Variables

	Observations	Mean	Std. Dev.	Min	Max
MNE, Share of foreign firms (%)	27,358	0.08	0.27	0	1
MNE, foreign participation (dummy 0 and 1)	27,358	4.65	18.33	0	100
Ex, Export share in total sales (%)	27,358	8.29	23.86	0	100
Ex, export participation (dummy 0 and 1)	27,358	0.16	0.37	0	1
Age, Firm age (Years)	27,358	12.17	9.92	1	99
PROD, Firm's productivity (million baht/worker)	26,125	4.2	2.26	0	191
Sales, Firm size (million baht)	27,358	195	2240	0	279000
KL, capital-labor ratio (million baht/person)	27,358	0.57	6.43	0	670
Network, international production network (P&C trade to total trade)	27,358	0.02	0.09	0	1
RDTech, Decision to invest in R&D production technology (dummy 0 and 1)	27,358	0.06	0.23	0	1
RDTechEx, R&D production technology intensity (% of total sales)	27,358	0.2	1.87	0	100
RDProduct, Decision to invest in R&D production innovation (dummy 0 and 1)	27,358	0.06	0.24	0	1
RDProductEx, R&D production innovation (% of total sales)	27,358	0.29	2.82	0	100
RDProcess, Decision to invest in R&D process innovation (dummy 0 and 1)	27,358	0.04	0.2	0	1
RDProcessEx, R&D process innovation (% of total sales)	27,358	0.14	1.56	0	100
Concentration ratio	27,358	0.46	0.09	0.32	0.69
ERP, Effective rate of protection	27,358	0.12	0.35	-1.58	0.62

Source: Authors' Compilation.

Table 5. Correlation Coefficient Matrix

A. A Firm's Decision to Invest in R&D

	$RDTech_{ij}$	$RDProduct_{ij}$	$RDProcess_{ij}$	Age_{ij}	$Size_{ij}$	Kl_{ij}	Ex_{ij}	MNE_{ij}	BOI_{ij}	$Network_{ij}$	$Region_{ij}$	$Productivity_{ij}$
$RDTech_{ij}$	1											
$RDProduct_{ij}$	0.68	1										
$RDProcess_{ij}$	0.64	0.64	1									
Age_{ij}	0.14	0.16	0.13	1								
$Size_{ij}$	0.24	0.25	0.21	0.37	1							
Kl_{ij}	0.18	0.18	0.15	0.36	0.53	1						
Ex_{ij}	0.17	0.16	0.11	0.13	0.32	0.18	1					
MNE_{ij}	0.12	0.12	0.1	0.08	0.28	0.21	0.36	1				
BOI_{ij}	0.24	0.23	0.18	0.18	0.4	0.26	0.73	0.4	1			
$Network_{ij}$	0.05	0.03	0.03	0.05	0.15	0.1	0.11	0.17	0.12	1		
$Region_{ij}$	0.14	0.18	0.14	0.28	0.42	0.47	0.17	0.19	0.23	0.14	1	
$Productivity_{ij}$	0.17	0.21	0.2	0.39	0.84	0.69	0.23	0.24	0.31	0.13	0.53	1

B. R&D Intensity (Improved Production Technology)

	RDTechexij	Ageij	Sizeij	Klij	Exij	MNEij	BOIij	Networkj	Regionij	Productivityij
RDTechexij	1									
Ageij	0.0089	1								
Sizeij	-0.1123	0.2577	1							
Klij	-0.0503	0.0229	0.2748	1						
Exij	-0.061	-0.0164	0.2175	-0.1136	1					
MNEij	-0.041	0.014	0.2733	0.0871	0.2452	1				
BOIij	-0.0532	0.0893	0.3332	0.0185	0.6448	0.2527	1			
Networkj	0.0913	-0.0306	0.0631	-0.0526	0.0743	0.19	0.0321	1		
Regionij	-0.0953	0.1159	0.3069	0.0794	0.0311	0.1088	0.1275	0.0528	1	
Productivityij	-0.0299	0.3923	0.8788	0.6895	0.2264	0.2381	0.3091	0.1293	0.5376	1

Note: Observations for the correlation are 1,046.

C. R&D Intensity (Product Innovation)

	RDProductExij	Ageij	Sizeij	Klij	Exij	MNEij	BOIij	Networkj	Regionij	Productivityij
RDProductExij	1									
Ageij	-0.0376	1								
Sizeij	-0.0899	0.2823	1							
Klij	-0.0856	0.0346	0.2956	1						
Exij	-0.0207	0.0296	0.2292	-0.0529	1					
MNEij	-0.0327	0.0318	0.2514	0.1424	0.2635	1				
BOIij	-0.0188	0.1085	0.3267	0.0306	0.6181	0.2521	1			
Networkj	0.0706	-0.025	0.0431	-0.0376	0.0619	0.0963	-0.0009	1		
Regionij	-0.1457	0.0993	0.2811	0.1044	0.0192	0.0782	0.0724	0.0337	1	
Productivityij	-0.0293	0.1884	0.6414	0.4186	-0.0256	0.2349	0.1333	0.2885	0.2885	1

Note: Observations for the correlation are 1,218.

D. R&D Intensity (Process Innovation)

	RDProcessExij	Ageij	Sizeij	Klij	Exij	MNEij	BOIij	Networkj	Regionij	Productivityij
RDProcessExij	1									
Ageij	0.005	1								
Sizeij	-0.0939	0.2587	1							
Klij	-0.0786	0.0187	0.2795	1						
Exij	-0.0452	0.0859	0.2345	-0.0915	1					
MNEij	-0.0298	0.0446	0.2757	0.0919	0.2749	1				
BOIij	-0.0503	0.1212	0.3499	0.0387	0.6147	0.2139	1			
Networkj	0.0774	-0.0264	0.0852	-0.0356	0.0771	0.1554	0.0053	1		
Regionij	-0.1061	0.0696	0.2413	0.0647	-0.032	0.0959	0.0751	0.0549	1	
Productivityij	-0.0791	0.1226	0.6314	0.4423	-0.0506	0.2268	0.0918	0.0408	0.0408	1

Note: Observations for the correlation are 762.

5.1. Econometric Procedure

To examine a firm's R&D decision and R&D spillovers (equations 1.1; 2.1; 3.1; 4; 5; 6), the probit model is applied. There are two key problems relating to OLS estimation under a binary dependent variable, i.e. 1 for firms that export and 0 otherwise. First, the predicted value of a dependent variable under OLS could be higher than 1 or could become negative. Secondly, linear relationship between dependent and independent variables are generally assumed. However, the relationship between the probability of investing in R&D and explanatory variables could be non-linear. To limit the predicted value of a dependent variable so that it lies between 0 and 1, the Probit model is applied. The Probit model is as follows:

$$g_{ij}^{*} = x_{ij}\beta_i + e_{ij} \qquad (7)$$

where g_{ij}^{*} is the binary dummy variable (i.e. taking the value of 0 and 1) to reflect a firm's R&D's decision, x_{ij} represents the explanatory variables listed in Section IV and e_{ij} is the error term.

To deal with the endogeneity issue, especially for exports, the instrumental variable method is applied with the probit model (IV probit) (Criscuolo *et al.*, 2005). Instrument variables are those that statistically affect/determine exports but are not statistically significant in determining R&D. The effective rate of protection (ERP) and the concentration ratio (CR4) are used as instrumental variables.[12] Based on diagnostic tests, we found that the concentration ratio performs better as an instrument variable than the effective rate of protection. Thus, we use concentration as a key instrument variable in this study.

To estimate a firm's R&D expenditure (equation 1.2; 2.2; 3.2), the sample selection model is applied since the dependent variable (i.e. R&D expenditure) is observed only when a firm makes the decision to invest in R&D (i.e. could be observed only for a restricted, nonrandom sample). There are two key equations in the model. The first equation (equation (8)) explains whether an observation is in the sample or not while the

[12] See Jongwanich and Kohpaiboon (2008) for analytical and empirical studies of how the effective rate of protection and market structure (the concentration ratio) affect a firm's exports.

second equation (equation (9)) determines the value of Y. Note that Y is the outcome variable, which is only observed when a variable Z is positive.

$$Z_i^* = w_i^* \alpha + e_i$$

$$\left.\begin{array}{l} Z_i = 0 \quad if \quad Z_i^* \leq 0 \\ Z_i = 1 \quad if \quad Z_i^* > 0 \end{array}\right\} \qquad (8)$$

$$Y_i^* = x_i^{'} \beta + \mu_i$$

$$\left.\begin{array}{l} Y_i = Y_i^* \quad if \quad Z_i = 1 \\ Y_i \text{ not observed} \quad if \quad Z_i = 0 \end{array}\right\} \qquad (9)$$

When equations (8) and (9) are solved together, the expected value of the variable Y is the conditional expectation of Y_i^* conditioned on it being observed (Z_i = 1).

$$\begin{aligned} E\left(Y_i / x_i, w_i\right) = E\left(Y_i^* / d_i = 1, x_i, w_i\right) &= x_i^{'} \beta + \rho \sigma_\varepsilon \frac{\phi\left(w_i^{'} \alpha\right)}{\Phi\left(w_i^{'} \alpha\right)} \\ &= x_i^{'} \beta + \rho \sigma_\varepsilon \lambda\left(w_i^{'} \alpha\right) \end{aligned} \qquad (10)$$

where $\lambda\left(w_i^{'} \alpha\right) \equiv \phi\left(w_i^{'} \alpha\right) / \Phi\left(w_i^{'} \alpha\right)$ is the inverse Mills ratio. It is important to note that $E\left(Y_i / x_i, w_i\right) = x_i^{'} \beta$ if the two error terms are uncorrelated, i.e. $\rho = 0$. In other words, if two error terms are correlated, the simple OLS approach is inefficient and biased to explain Y, so that we need to take into account the inverse Mills ratio by applying either the Maximum Likelihood method (simultaneously estimating equations (8) and (9)) or Heckman two-step estimation.

In this study, we apply two-step estimation since the model needs to take into account the possible endogeneity problem that could arise, especially for the export variable. The estimation procedure is as follows. First, we construct the inverse Mills ratio from the probit model (IVprobit model) for each type of R&D (equation 7) and then estimate equations 1.2; 2.2; 3.2, using a cross-sectional model and include the inverse Mills ratio as additional regressor. Note that instrumental variable method is also applied at this stage.

6. Results

Tables 6, 7 and 8 report the results of a firm's R&D investment in improved production technology, product development, and process innovation, respectively. In each table, there are two columns. Columns A present the determinants of a firm's R&D decision, which take a value of '1' for a firm engaging in R&D activity and '0' otherwise, whereas columns B show determinants of a firm's R&D intensity. Table 9 presents the determinants of R&D spillover for improved production technology (column A), product development (column B), and process innovation (column C).

The model shows the negative and statistically significant relationship between multinational firms (MNEs) and a firm's decision to invest in R&D leading to improved production technology and leading to product development, but not in R&D leading to process innovation. Given the fact that nearly half of world R&D expenditure was undertaken by MNEs (UNCTAD, 2005), the negative and statistically significant coefficient implies that most MNE affiliates are unlikely to invest in R&D in the host country (Thailand), but instead they are likely to import technology (technology transmission) from their parent company. In terms of improved production technology, this is plausible since R&D investment in such activity involves high fixed costs, at a time when transportation costs have become cheaper, so that it tends to be more efficient to invest in R&D activity at their headquarters and import technology to the host country. In addition, the decentralization of R&D activity relating to production technology has a high risk of leakage of propriety assets, which is important to MNEs wishing to retain their ownership advantage in international operation.

Table 6. Estimation Results of R&D Leading to Improved Production Technology (Both Domestic and Foreign Firms)

	Column A A firm's decision to invest in R&D		Column B R&D intensity (% of sales)	
	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-12.37	-9.81*	-5.6	-0.57
MNE_{ij}	-11.12	-1.58**	75.57	0.48
Ex_{ij}	0.95	1.38	-3.29	-0.52
Age_{ij}	0.07	2.69*	-0.13	-0.35
$Age_{ij}^{\wedge 2}$	-	-	-	-
$PROD_{ij}$	-0.08	-3.51*	-0.16	-0.44
$Size_{ij}$	0.99	7.61*	1.06	0.61
$Size_{ij}^{\wedge 2}$	-0.02	-5.99*	-0.03	-0.66
KL_{ij}	0.07	4.67*	-0.21	-0.55
BOI_{ij}	-0.12	-0.37	-	-
$region_{ij}$	0.02	0.41	-0.45	-0.72
$Network_{j}$	0.46	2.48*	1.23	1.43
Inversed mill ratio	-		2.24	0.52
No. of obs	17,427		1018	
Log likelihood	5274.8		Root MSE = 1.40	
Wald chi2	1257.19 (Prob>chi2 = 0.00)			
Wald-test for exogeneity	1.37 (Prob>chi2 = 0.24)			

Note: (1) Column A is estimated by IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by 2SLS and sample-selection model. Logarithm is used for Age; Size; KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively, and

(3) Industrial dummy variables are included (according to ISIC) in the estimation.

Source: Authors' estimations.

In terms of product development, the innovatory process involves rich communication and cooperation within a firm, between product design, the production team, marketing etc, and a face to face communication. In other words, close interdepartmental relationships and teamwork are required for the development of innovation. Thus, it would be more efficient for the MNEs to develop/innovate new and core products in their headquarters, instead of decentralizing such activity to their MNE affiliates. This is especially true in the context of small and long-open developing economies like Thailand. However, MNEs still listen and gather information from their affiliates to ensure that the innovated products can match well with consumer preference in different locations.

The statistical insignificance found in R&D leading to process innovation implies that some MNEs began to invest in R&D leading to process innovation in the host country, including introducing “lean processing” and “just in time” methods, but their likelihood of conducting such R&Ds is not statistically different from that of their local firms.

Table 7. Estimation Results of R&D Product Development (Both Domestic and Foreign Firms)

	Column A A firm’s decision to invest in R&D		Column B R&D intensity (% of sales)	
	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-11.64	-9.38*	-0.94	-0.4
MNE_{ij}	-16.28	-2.52	6.32	0.21
Ex_{ij}	1.9	3.15*	-0.44	-0.31
Age_{ij}	0.12	4.89*	-0.04	-0.4
$Age_{ij}{}^{\wedge 2}$	-	-	-	-
$PROD_{ij}$	-0.09	-4.10*	0.06	0.86
$Size_{ij}$	1	8.04*	0.25	0.81
$Size_{ij}{}^{\wedge 2}$	-0.02	-6.53*	-0.008	-1.04
KL_{ij}	0.04	3.18*	-0.06	-1.31
BOI_{ij}	-0.6	-2.15*	-	-
$region_{ij}$	0.25	5.19*	-0.44	-2.28*
$Network_{j}$	0.5	2.87*	0.7	2.22*
Inverse mill ratio	-		0.1	0.22
No. of obs	17,951		1,191	
Log likelihood	5045.81		Root MSE = 0.980	
Wald chi2	1797.91 (prob>chi2 = 0.00)			
Wald-test for exogeneity	0.33 (prob>chi2 = 0.56)			

Note: (1) Column A is estimated by IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by 2SLS and sample-selection model. Logarithm is used for Age; Size; KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively and

(3) Industrial dummy variables are included (according to ISIC) in the estimation.

Source: Authors’ estimations.

Table 8: Estimation Results of R&D Process Innovation (Both Domestic and Foreign Firms)

	Column A A firm's decision to invest in R&D		Column B R&D intensity (% of sales)	
	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-11.9	-8.74*	2.87	0.49
MNE_{ij}	-8.68	-1.1	-10.56	-0.25
Ex_{ij}	0.2	0.25	0.48	0.23
Age_{ij}	0.35	2.49*	0.04	0.12
$Age_{ij}^{\wedge 2}$	-0.04	-1.56**	0.002	0.04
$PROD_{ij}$	-0.12	-4.49*	0.02	0.15
$Size_{ij}$	0.91	6.37*	-0.2	-0.27
$Size_{ij}^{\wedge 2}$	-0.02	-4.69*	0.004	0.21
KL_{ij}	0.05	2.97*	-0.009	-0.13
BOI_{ij}	0.06	0.17	-	-
$region_{ij}$	0.13	2.22*	-0.13	-0.48
$Network_j$	0.07	0.34	0.65	1.82**
Inverse mill ratio	-		0.02	0.05
No. of obs	17,998		748	
Log likelihood	5945.38		Root MSE = 0.92	
Wald chi2	1028 (prob>chi2 = 0.00)			
Wald-test for exogeneity	0.00 (prob>chi2 = 0.95)			

Note: (1) Column A is estimated by IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by 2SLS and sample-selection model. Logarithm is used for Age; Size; KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively, and

(3) Industrial dummy variables are included (according to ISIC) in the estimation.

Source: Authors' estimations.

In contrast to MNEs, a positive sign is found for the exporting variable. However, the model shows the *positive*, but *statistically insignificant*, relationship between exporting and a firm's decision to invest in R&D leading to improved production technology and leading to process innovation (Tables 6 and 8). The statistical insignificance implies that the probability of firms to investing in R&D for improving production technology and for process innovation is not affected by market destination, i.e. either domestic or export markets. By contrast, we find a positive and *statistically significant* relationship between exports and a firm's decision to invest in product development R&D (Table 7), reflecting the idea that exporters tend to learn more about competing products and customer preferences in international markets, but the information gained relating to improving production technology and process innovation is limited. The information on competing products and customer preferences could come from customer feedback, export intermediaries and other foreign agents. Thus, information passed from foreign customers helps firms innovate/tailor their products to meet the specific needs of international markets. It is noteworthy that although the relationship of exports and the other two R&D activities is statistically insignificant, the positive sign of this variable could, to some extent, reflect the idea intense global competition may begin to stimulate firms to invest in R&D leading to improved production technology and processes.

The model also shows that firm age and firm size have a positive and significant impact in determining a firm's decision to invest in R&D for improved production technology and R&D product development. The positive sign of firm age in these two R&D equations supports the argument that older firms tend to be more likely to change production processes and adopt new technologies than younger firms. Interestingly, for R&D process innovation, we find that ($Age^{\wedge 2}$) is negative, while there is statistical significance, along with a significantly positive sign for *Age*. This implies that the incentive for firms to invest in process innovation grows at a diminishing rate and becomes negative when the firms reach a certain years of age. In this study, we find that when firm age is over 70 years, the probability of firms investing in R&D for process innovation becomes negative (Table 8). Note that the negative signs of $Age^{\wedge 2}$ are also found in R&D for improved production technology and R&D for product development, but that these signs are statistically insignificance (See Appendix I for this result).

A non-linear relationship between firm size ($Size_{ij}$) and a decision of a firm to invest in R&D activity is also found in this study. The positive sign for firm size reflects the fact that R&D activity involves high fixed costs. However the capital market is imperfect so that larger firms, which are likely to have stable funding access are able to afford R&D investment as opposed to smaller firms. However, the negative sign for $Size^{\wedge 2}$ shows that this factor would become less important in affecting a firm's decision to invest in all three types of R&Ds when it reaches a certain level. In other words, after the firm reaches its break-even point, other factors would become more important for the firm's decision making. In this study, such a level of firm size, measured by annual sales, would be around 126 billion baht.

In addition to firm age and firm size, our study finds a negative and statistically significant relationship between a firm's productivity ($PROD_{ij}$) and its decision to invest in all three types of R&D. This result is in contrast to the expected positive sign, which is mentioned in Section IV. The negative relationship found in this study implies that the probability of a firm with lower productivity investing in all types of R&D would be higher than for a firm with high productivity. This tends to reflect a possible *catching up* process among firms, not only to improve their own productivity, but also to survive in an intensely competitive environment. The coefficient corresponding to this variable is the highest for R&D leading to process innovation, followed by R&D leading to product development and improved production technology. This may reflect the fact that where a firm's productivity improvement is concerned, the process innovation mode seems to be prioritized before improving production technology, with its relatively higher fixed costs.

The model also shows that firms in a more capital-intensive industry have a higher probability of involvement in all three types of R&D activities, confirming that the nature of its industry could influence a firm's decision to invest in R&D. While the possible causality between R&D and the industry's capital intensity can occur in theory, it is unlikely in reality because it takes time for R&D investment to result in capital deepening. This argument is in line with what Aw *et al*. (2008) which used lagged instead of current R&D investments in the productivity equation. This study also finds that infrastructure tends to be one of the crucial factors that positively influence a firm's decision to invest in all three types of R&Ds. This is reflected by the positive relationship of "*region*" to a firm's decision to invest in R&Ds.

A statistically insignificant relationship between government policy (BOI) and a firm's R&D decision is found in R&D leading to improved production technology and leading to process innovation.[13] This result could, to some extent, reflect the thought that government policy so far has not been effective enough to influence a firm's

[13] Note that the insignificance of this variable may arise from the fact that the available measurement of government policy used here could not capture well the overall policies implemented by the government. Disaggregated details of government policy in each industry, which so far are not available, may help to improve accuracy of our model.

decision to set up an R&D activity. By contrast, other fundamental variables, such as firm age, firm size, firm productivity, and other industrial characteristics, play more crucial roles in influencing the firm's decision making. However, when we consider only domestically-owned firm in R&D spillover (see more detail below), government policy (BOI) positively increases the probability of a firm investing in R&D, especially in terms of improved production technology. Thus, the insignificant effect of BOI found here tends to be dominated by foreign firms, most of whose decisions are influenced by their parent companies (i.e. by firm specific factors), and for whom government policy is less relevant. Government policy, by contrast, tends to affect more the decisions of domestically-owned firms in setting up R&D activities, since most are disadvantaged in terms of proprietary assets and need more support from government.

Another interesting result is the 'network' variable. The positive relationship of "network" and a firm's decision to invest in R&D supports the importance of international production networks in promoting a firm's R&D decision. The dynamism of industries involved in production networks is likely to require more R&D investment to keep the industry upbeat and competitive in the international market. "Network" is also statistically significant and positive not only for a firm's basic R&D decisions, but also for intensity for all three types of R&D. This implies that the higher the importance of the international production network to a firm, the greater the R&D expenditure expected. The robust econometric evidence here encourages developing countries to participate in MNE production networks.

Except for "network", other variables are statistically insignificant in the R&D intensity equations (equations 1.2; 2.2 and 3.2). The inability to capture well their relationship could be due to the smaller sample size of firms who are involved in R&D activity. In addition, the variation of R&D expenditures is limited among these firms. For example, in R&D for improved production technology there are only 1,558 firms who decided to set up an R&D activity and the R&D expenditures are mostly set by less than, or equal to, 10% of total expenditure. The low variation of R&D expenditure makes it rather difficult to reveal the relationship statistically.

6.1. R&D spillovers

Interestingly, although there is evidence that most multinational firms tend to import technology, instead of establishing R&D activity in the host country (i.e. statistical insignificance between a firm's decision to invest in R&D and MNEs), multinational firms do tend to stimulate domestically-owned firms to invest more in R&D activity (i.e. spillovers). Such evidence is supported by the positive sign and statistical significance of the share of foreign ownership at the industry level (*FOR*j) and a domestically-owned firm's R&D decision (Table 9). Among the three types of R&D activity, the spillover tends to be strong in product development, followed by process innovation, while there is statistical insignificance in the case of product technology. The strong spillovers in product development and process innovation support the idea of the important process of demonstration and imitation in generating R&D spillovers. Intense competition from the entry of MNEs might play some role in generating spillover and encouraging domestic firms to invest in R&D and reduce costs. However, the statistical insignificance of *FOR* in the R&D improved production technology equation could be because of the relatively high fixed costs of such investment. This may limit the possible positive effect that could arise from demonstration and imitation effects.

Table 9. Estimation Results of R&D Spillovers (The Domestically-owned Firms' Decision to Invest in R&D)

	Column A R&D improved technology		Column B R&D product development		Column C R&D process innovation	
	Coefficient	T-statistics	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-14.01	-10.85*	-12.23	-8.90*	-12.78	-11.03*
FOR_j	0.004	1.38	0.004	1.70**	0.003	1.76**
Ex_{ij}	-1.23	-1.18	1.34	1.45***	-2.02	-1.2
Age_{ij}	0.05	1.66**	0.1	3.64*	0.17	1.56**
$Age_{ij}^{\wedge 2}$	-	-	-	-	-0.02	-0.81
$PROD_{ij}$	-0.14	-5.61*	-0.14	-5.48*	-0.14	-6.59*
$Size_{ij}$	1.06	7.19*	1.02	7.29*	0.92	6.51*
$Size_{ij}^{\wedge 2}$	-0.02	-5.39*	-0.02	-5.64*	-0.02	-4.60*
KL_{ij}	0.1	5.90*	0.06	4.24*	0.07	4.71*
BOI_{ij}	0.88	1.97*	-0.29	-0.7	1.08	1.49***
$region_{ij}$	-0.02	-0.41	0.22	4.24*	0.06	1.19
$Network_j$	0.4	1.64**	0.64	2.92*	-	-
No. of obs	16,245		16,245		16,289	
Log likelihood	7344.29		7095.7		10290.9	
Wald chi2	1157.4 (prob>chi2 = 0.00)		1370.4 (prob>chi2 = 0.00)		1 (prob>chi2 = 0.00)	
Wald-test for exogeneity	1.63 (prob>chi2 = 0.20)		1.77 (prob>chi2 = 0.18)		1.04 (prob>chi2 = 0.31)	

Note: (1) Column A is estimated by IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by 2SLS and sample-selection model. Logarithm is used for Age; Size; KL while the ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).
(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively, and
(3) Industrial dummy variables are included (according to ISIC) in the estimation.

Source: Authors' estimations.

The model shows the mild significance of exporting on the firm's decision to invest in R&D leading to product development while there is no positive and significant effect of exports on firm's its decision to invest in R&D leading to production technology and process innovations. This is consistent with the above finding when we include both domestic and foreign firms, i.e. entering export markets tends to help firms get/learn more information about products and consumer preferences than about production technology and process innovation. However, the smaller coefficient of this variable, compared to the situation where we consider both foreign and domestic firms, reflects the fact that domestic firms still have limited knowledge of world market, especially in terms of networking, compared to foreign firms. In addition, despite statistical insignificance, the negative relationship between exporting and a firm's decision to invest in R&D for production technology might reflect the fact that domestically-owned firms which export could access/update new production technology easier than other domestic firms so that they are likely to import production technology, instead of involving themselves in 'technology generation'.

Regardless of foreign ownership, however, firm age, firm size, capital intensity and location are all significant in affecting the decisions of domestically-owned firms in investing in all types of R&D activity. Positive relationships of these variables and the firm's R&D decision are found. In particular, the non-linear relationship between firm size and the firm's R&D decision is revealed in all three types of R&D activity. The catching up effect is still found in the case of domestically-owned firms, as suggested by the negative sign and statistical significance of coefficients corresponding to a firm's productivity variable. A production network (*network*) tends to positively and significantly affect the probability of a domestic firm investing in R&D for product development and production technology, but there is no such evidence for R&D process innovation.

7. Conclusion and Policy Inferences

This paper examines the role of multinational enterprises (MNEs) and exporting on R&D activity, using the most recent (2006) industrial census of Thai manufacturing, with emphasis on providing useful policy suggestions for promoting R&D activities in developing countries. The paper is distinguished from the existing literature in two ways. First, R&D investment is categorized into three broad types, i.e. R&D leading to improved production technology, product development, and process innovation. To the best of our knowledge, this is one of the few studies undertaking research into possible heterogeneity in firms' decision toward on each type of R&D. Secondly, three key globalization forces, namely MNEs, exporting, and global production networks, are examined in a single framework over and above industry and firm-specific factors.

Our key findings suggest that the determinants of each R&D are far from identical. For example, MNE affiliates would prefer to undertake process innovation-related R&D locally but not R&D for production technology and product development. Another example is the propensity for, and intensity of product development R&D which can be positively affected by exporting. Hence, our conclusion that separating the types of R&D when examining its determinants is a necessary step in gaining a better understanding of firms' R&D activities.

Globalization through exporting and FDI can play a role in encouraging firms to commit to R&D investment. Note that the role played by exporting seems to be different from that played by FDI. We found a lower R&D propensity for MNE affiliates than for locally-owned firms, pointing to the fact that MNEs prefer importing technology from their parent companies to developing new technology in host countries. Nonetheless, this does not indicate that there is no effect from MNE presence on R&D propensity and intensity. In fact, their presence could stimulate locally-owned firms to undertake R&D activities. The latter might set up in-house R&D facilities in order to reap potential and possible technological benefits from the MNE presence in a given industry. In addition, firms participating in global production networks are more active in all types of R&D activity than those not participating. Considered together with their relative importance in the global production networks, this result would be another indirect contribution by MNEs and globalization.

Exporting, the other globalized force, tends to have a positive and significant impact, but its impact is limited to R&D leading to product development, and it does not impact the other two types of R&D. This implies that entering export markets tends to help firms to learn more about competing products and customer preferences, but information relating to improving the technology of production, and process innovation, is still limited.

From the policymakers' perspective, three policy suggestions can be drawn from our study. The first concerns the role of government policy. Supply-side capability, such as infrastructure services, is highlighted in this study. Improving infrastructure could eventually attract more foreign direct investment into the host country, generating spillover impacts on domestically-owned firms. In addition to infrastructure, government should improve other aspects of the business environment, including trade facilitation, to further promote FDI so that the indirect impacts of MNEs on R&D activity in the host country could be increased. Our study raises concerns about relying heavily on policy-induced incentives such as tax exemptions, to spur R&D activity. The effectiveness of these policy measures is not always apparent. Secondly, our findings provide evidence to support ongoing globalization. Firms exposed to global competition through either exporting or participating in global production networks are more likely to commit to R&D investment. The net effect of MNEs on R&D activities cannot be measured solely by whether MNEs conduct R&D activities in the host country. Even though MNE affiliates do not invest in R&D locally, their presence still stimulates local firms to become more active in R&D. Finally, the role of global production networks and the relative importance of infrastructure services in this study point to the area where plurilateral organizations such as ASEAN can play a role in spurring R&D activities. Cooperation in infrastructure services among member countries would facilitate the entry of MNEs seeking to utilize the specialization of the the region in their global production networks, and could help locally owned firms to become more likely to participate in global production networks. This eventually results in an increase in R&D intensity.

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APPENDIX 1

Example of Full Estimation Results of R&D Leading to Improved Production Technology (both Domestic and Foreign Firms)

	Column A A firm's decision to invest in R&D		Column B A firm's decision to invest in R&D	
	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-12.36	-9.78*	-11.68	-2.29*
MNE_{ij}	-11.01	-1.57**	-13.98	-0.66
Ex_{ij}	0.95	1.37	1.49	0.40
Age_{ij}	0.01	0.12	0.007	0.06
$Age_{ij}^{\wedge 2}$	0.13	0.55	0.01	0.57
$PROD_{ij}$	-0.08	-3.48*	-0.08	-1.39
$Size_{ij}$	1.00	7.62*	0.97	4.10*
$Size_{ij}^{\wedge 2}$	-0.02	-6.01*	-0.02	-4.15*
KL_{ij}	0.07	4.67*	0.07	3.97*
*CR4*j	-	-	-0.38	-0.14
BOI_{ij}	-0.12	-0.37	-0.36	-0.21
$region_{ij}$	0.02	0.39	0.02	0.43
$Network_{j}$	0.46	2.49*	0.56	0.73
No. of obs	17,427		17,427	
Log likelihood	5277.86		5284.09	
Wald chi2	1257.7 (Prob>chi2 = 0.00)		1315.3 (Prob>chi2 = 0.00)	
Wald-test for exogeneity	1.36 (Prob>chi2 = 0.24)		0.13 (Prob>chi2 = 0.72)	

Note: (1) Column A is estimated by an IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by *including* concentration ratio as one of the independent variables, and using the effective rate of protection as the instrument variable for exports. Logarithm is used for Age, Size and KL, while a ratio is applied for MNE (the share of foreign firms), EX (the share of exports to total sales) and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively; and

(3) Industrial dummy variables are included (according to ISIC) in included in the estimation.

Source Authors' estimate.

Example of Full Estimation Results of R&D Leading to Product Development (both Domestic and Foreign Firms)

	Column A A firm's decision to invest in R&D		Column B A firm's decision to invest in R&D	
	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-11.62	-9.35*	-9.71	-1.71**
MNE_{ij}	-16.17	-2.50*	-22.09	-1.37
Ex_{ij}	1.90	3.15*	3.01	1.04
Age_{ij}	0.07	0.68	0.05	0.48
$Age_{ij}^{\wedge 2}$	0.01	0.53	0.01	0.66
$PROD_{ij}$	-0.09	-4.07*	-0.07	-1.26
$Size_{ij}$	1.00	8.04*	0.91	2.90*
$Size_{ij}^{\wedge 2}$	-0.02	-6.53*	-0.02	-3.05*
KL_{ij}	0.04	3.18*	0.04	2.45*
*CR4*j	-	-	-0.86	-0.36
BOI_{ij}	-0.60	-2.14*	-1.10	-0.83
$region_{ij}$	0.25	5.17*	0.25	4.19*
$Network_{j}$	0.50	2.87*	0.72	1.18
No. of obs	17,427		17,427	
Log likelihood	5020.19		5026.70	
Wald chi2	1640.4 (Prob>chi2 = 0.00)		2027.0 (Prob>chi2 = 0.00)	
Wald-test for exogeneity	0.01 (Prob>chi2 = 0.94)		0.75 (Prob>chi2 = 0.39)	

Note: (1) Column A is estimated by an IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by *including* concentration ratio as one of the independent variables, and using effective rate of protection as the instrument variable for exports. Logarithm is used for Age, Size and KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively; and

(3) Industrial dummy variables are included (according to ISIC) in included in the estimation.

Source: Authors' estimations.

Example of Full Estimation Results of R&D Leading to Process Innovation (both Domestic and Foreign Firms)

	Column A A firm's decision to invest in R&D		Column B A firm's decision to invest in R&D	
	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-11.90	-8.74*	-3.52	-0.83
MNE_{ij}	-8.67	-1.10	-33.24	-4.22*
Ex_{ij}	0.20	0.25	4.91	3.52*
Age_{ij}	0.35	2.49*	0.18	1.31
$Age_{ij}^{\wedge 2}$	-0.04	-1.56**	-0.02	-0.61
$PROD_{ij}$	-0.12	-4.49*	-0.03	-0.59
$Size_{ij}$	0.91	6.37*	0.50	1.89**
$Size_{ij}^{\wedge 2}$	-0.02	-4.69*	-0.01	-1.97*
KL_{ij}	0.05	2.97*	0.03	1.88**
*CR4*j	-	-	-3.35	-0.09
BOI_{ij}	0.06	0.17	-2.07	-3.18*
$region_{ij}$	0.13	2.22*	0.12	2.54*
$Network_{j}$	0.07	0.34	1.05	3.14*
No. of obs	17,473		17,473	
Log likelihood	5851.4		5859.1	
Wald chi2	909.1 (Prob>chi2 = 0.00)		3062.0 (Prob>chi2 = 0.00)	
Wald-test for exogeneity	0.14 (Prob>chi2 = 0.71)		4.15 (Prob>chi2 = 0.05)	

Note: (1) Column A is estimated by an IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by *including* concentration ratio as one of the independent variables and using effective rate of protection as the instrument variable for exports. Logarithm is used for Age, Size and KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively, and

(3) Industrial dummy variables are included (according to ISIC) in included in the estimation.

Source: Authors' estimations.

APPENDIX II

Example of Full Estimation Results of R&D Leading to Improved Production Technology (Interaction Terms) (both Domestic and Foreign Firms)

A firm's decision to invest in R&D	Column A		Column B		Column B	
	Coefficient	T-statistics	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-12.90	-11.21*	-12.89	-11.19*	-12.83	-11.10*
MNE_{ij}	-0.10	-0.01	-5.68	-0.94	-25.38	-1.31
Ex_{ij}	0.35	1.80**	0.14	1.72**	0.14	1.74**
Age_{ij}	0.07	2.65*	0.07	2.66*	-0.02	-0.20
$Age_{ij}^{\wedge 2}$	-	-	-	-	-	-
$PROD_{ij}$	-0.09	-4.06*	-0.09	-4.06*	-0.09	-4.09*
$Size_{ij}$	1.01	7.79*	1.01	7.80*	1.02	7.88*
$Size_{ij}^{\wedge 2}$	-0.02	-6.02*	-0.02	-6.03*	-0.02	-6.12*
KL_{ij}	0.07	4.55*	0.07	4.58*	0.07	4.62*
BOI_{ij}	0.24	4.16*	0.25	4.35*	0.25	4.35*
$region_{ij}$	0.01	0.27	0.02	0.32	0.02	0.34
$Network_{j}$	0.38	2.19*	0.45	0.95	0.38	2.18*
MNEij*Exij	-16.41	1.20	-	-	-	-
MNEij*Networkj	-	-	-4.84	-0.15	-	-
MNEij*Ageij	-	-	-	-	7.57	1.05
No. of obs	17,427		17,951		17,427	
Log likelihood	21241.43		5327.04		5343	
Wald chi2	1674.88 (Prob>chi2 = 0.00)		1433.58 (Prob>chi2 = 0.00)		1434.55 (Prob>chi2 = 0.00)	
Wald-test for exogeneity	0.64 (Prob>chi2 = 0.42)		0.49 (Prob>chi2 = 0.48)		0.17 (Prob>chi2 = 0.68)	

Note: (1) Column A is estimated by an IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by *including* concentration ratio as one of the independent variables and using effective rate of protection as the instrument variable for exports. Logarithm is used for Age, Size and KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively, and

(3) Industrial dummy variables are included (according to ISIC) in included in the estimation.

Source: Authors' estimations.

Example of Full Estimation Results of R&D Leading to Product Development (Interaction Terms) (both Domestic and Foreign Firms)

A firm's decision to invest in R&D	Column A		Column B		Column B	
	Coefficient	T-statistics	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-13.06	-11.97*	-12.96	-11.90*	-12.90	-11.75*
MNE_{ij}	-0.35	-0.05	*-0.09*	*-0.02*	-48.02	-2.47*
Ex_{ij}	0.34	1.75**	0.14	1.80**	0.15	1.86*
Age_{ij}	0.12	4.86*	0.12	4.87*	*-0.07*	*-0.77*
$Age_{ij}^{\wedge 2}$	-	-	-	-	-	-
$PROD_{ij}$	-0.12	-5.26*	-0.12	-5.27*	-0.12	-5.31*
$Size_{ij}$	1.06	8.61*	1.04	8.50*	1.10	8.85*
$Size_{ij}^{\wedge 2}$	-0.02	-6.71*	-0.02	-6.58*	-0.02	-6.96*
KL_{ij}	0.04	3.00*	0.04	2.96*	0.04	3.07*
BOI_{ij}	0.19	3.36*	0.20	3.57*	0.19	3.55*
$region_{ij}$	0.25	4.97*	0.25	4.97*	0.25	5.03*
$Network_j$	0.34	1.99*	1.51	3.27*	0.34	1.96*
MNEij*Exij	-14.72	-1.09	-	-	-	-
MNEij*Networkj	-	-	-85.85	-2.66*	-	-
MNEij*Ageij	-	-	-	-	16.53	2.29*
No. of obs	17,427		17,427		17,427	
Log likelihood	3142.15		3327.04		3292.29	
Wald chi2	2321.01 (Prob>chi2 = 0.00)		2328.89 (Prob>chi2 = 0.00)		2320 (Prob>chi2 = 0.00)	
Wald-test for exogeneity	0.64 (Prob>chi2 = 0.42)		0.49 (Prob>chi2 = 0.48)		0.17 (Prob>chi2 = 0.68)	

Note: (1) Column A is estimated by an IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by *including* concentration ratio as one of the independent variables and using effective rate of protection as the instrument variable for exports. Logarithm is used for Age, Size and KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively, and

(3) Industrial dummy variables are included (according to ISIC) in included in the estimation.

Source: Authors' estimations.

Example of Full Estimation Results of R&D Leading to Process Innovation (Interaction Terms) (both Domestic and Foreign Firms)

A firm's decision to invest in R&D	Column A		Column B		Column B	
	Coefficient	T-statistics	Coefficient	T-statistics	Coefficient	T-statistics
Intercept	-12.10	-9.05*	-11.90	-8.74*	-11.70	-8.47*
MNE_{ij}	51.14	0.33	-7.35	-0.87	-54.27	-2.15*
Ex_{ij}	2.85	0.37	0.18	0.23	0.18	0.23
Age_{ij}	0.35	2.46*	0.35	2.49*	*0.16*	*0.92*
$Age_{ij}^{\wedge 2}$	-0.04	-1.56**	-0.04	-1.56**	-0.05	-1.60**
$PROD_{ij}$	-0.11	-3.06*	-0.12	-4.50*	-0.12	-4.56*
$Size_{ij}$	0.90	5.38*	0.91	6.35*	0.95	6.55*
$Size_{ij}^{\wedge 2}$	-0.02	-4.66*	-0.02	-4.66*	-0.02	-4.88*
KL_{ij}	0.05	2.47*	0.05	2.95*	0.05	3.04*
BOI_{ij}	-0.12	-0.15	0.07	0.19	0.07	0.20
$region_{ij}$	0.11	1.57**	0.13	2.21*	0.13	2.24*
$Network_j$	0.07	0.32	0.34	0.62	0.06	0.30
MNEij*Exij	-189.5	-0.38	-	-	-	-
MNEij*Networkj	-	-	-19.04	-0.52	-	-
MNEij*Ageij	-	-	-	-	17.38	1.99*
No. of obs	17,473		17,473		17,473	
Log likelihood	21334.12		5852.86		5861.31	
Wald chi2	962.55 (Prob>chi2 = 0.00)		909.55 (Prob>chi2 = 0.00)		914.68 (Prob>chi2 = 0.00)	
Wald-test for exogeneity	0.14 (Prob>chi2 = 0.71)		0.12 (Prob>chi2 = 0.73)		0.12 (Prob>chi2 = 0.73)	

Note: (1) Column A is estimated by an IVProbit model using concentration ratio as the instrument for exports and Column B is estimated by *including* concentration ratio as one of the independent variables and using effective rate of protection as the instrument variable for exports. Logarithm is used for Age, Size and KL while a ratio is applied for MNE (the share of foreign firms); EX (the share of exports to total sales); and Network (the share of trade in parts and components to total trade).

(2) *, **, and *** indicate the significance level at 5, 10 and 15%, respectively, and

(3) Industrial dummy variables are included (according to ISIC) in included in the estimation.

Source: Authors' estimations.

CHAPTER 6

Globalization and Innovation in Indonesia: Evidence from Micro-Data on Medium and Large Manufacturing Establishments

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In this paper we examine the impact of globalization on innovation in the Indonesian manufacturing sector. The lack of innovation data in the manufacturing survey has necessitated the use of R&D expenditure as an input in the innovation production function. Globalization is represented by being exporters, FDI and effective rate of protection (EPR). The model is set up such that within the concept of R&D as conditional input demand function, allowing labor productivity to have impact on R&D. In this case we find that less productive firms are less likely to venture into R&D activities. In terms of globalization variables we find that being exporters is important determinant of R&D. Meanwhile the impact of FDI firms on domestic R&D is only on the incidence not on the intensity of R&D. It will require a critical mass of firm within a location or an agglomeration to have a meaningful impact. Also lower ERP would induce firms to spend more on R&D. So lowering protection or trade barriers will have positive impact on R&D.

Keywords: Indonesian manufacturing, Research and Development

JEL Classification: D21, O31, O12

1. Introduction

Globalization is a process whereby countries become more integrated via movements of goods, capital, labor and ideas (Bloom, 2002). From the economic policy standpoint, how globalization is transmitted into the domestic economy is manifested in many ways, but is usually focused in the realm of trade and investment liberalization. Decreasing trade barriers allow increasing exchange of goods and services between countries. This process is facilitated by advances in information and communication technology. In this setting new ideas are quickly brought to fruition and new technologies are developed and superseded faster than at any other time in history. More important than any other time in the past, knowledge has now become an increasingly important determinant of the wealth of nations.

The importance of knowledge has revived attention on innovation systems and research institutions. The process of globalization has made innovation more important than before - even poor countries can no longer neglect the development of innovation systems. Innovation systems as creators, adaptors and disseminators of knowledge can be used as a vital tool for developing countries to benefit from globalization.

Firms now have to compete domestically and internationally. A Fast changing business environment is a fact of life that has to be faced by corporations in the globalization. From the organizational standpoint it requires firms to adjust quickly with changing market demand immediately and for this they need to innovate.

The purpose of this study is to examine the impact of globalization on innovation at the firm level in the Indonesian large and medium manufacturing. This study, using the Indonesian micro data on large and medium size manufacturing establishment, attempts to provide contribution to resolve the debate whether globalization is innovation enhancing or innovation reducing. The key question is whether government policies to liberalize trade and investment regime will boost innovations. If that the case then the policy to open up the economy to global competition is desirable. It will allow developing countries or more specifically Indonesia to jump up the learning curve by bypassing the expensive process of invention. The government then after a series of trade and investment liberalization policies could focus on policies to facilitate firms to exploit the benefits of globalization.

The relationship between globalization and innovation is a complex one. Increasing imports and inward foreign direct investment (FDI) brought about by decreasing trade barriers would intensify competition in the domestic market and erode the domestic firms' profitability. This would force domestic firms to produce efficiently (Berthschek , 1995). One way of staying competitive in business one way is to increase innovation activity. So globalization and innovation may be positively related.

On the other hand, others have argued that the above relationship may be just the opposite (Braga and Wilmore, 1991). Because firms have to spend handsomely on R&D to create new product and new production processes while its return is highly uncertain, they tend to be very conservative on innovation - focusing only on the assimilation of imported technology to local conditions. Hence, the relationship between globalization and innovation may be negative.

Between these two opposing views some prefer to adopt the middle ground stance that globalization allows developing countries to jump up the learning curve without having to undergo the lengthy and expensive process of discovery, by accessing ideas and technologies developed elsewhere and putting them into practice after some modification (Bloom, 2002).

Although the term "globalization" is well understood, translating it into more 'operational' variables for an empirical exercise is another matter. First globalization can be considered as a regime change from a relatively highly regulated and protected economy to a more open and deregulated one. Any economic reform that involves trade and/or investment liberalization will suit into this definition. In this respect, the period of analysis will be divided into before and after liberalization to examine the impact of regime change on any defined outcomes, for example its impact on the number of innovations conducted by firms.

The second way is more microeconomic in nature (i.e. at the firm or industry level). As a result of the dismantling trade barriers, a firm has options to enter export markets, operating as FDI, licensing or some or all combinations of the above. This applies to all firms irrespective of their countries of origin (Bertschek, 1995). One implication is that export activities, the presence of FDI and/or licensing can be used to signify the extent of globalization at the firm, industry and national levels – depending on how disaggregated is the analysis. One example is to use the ratio of exported output at the firm level (Kuncoro, 2002). Meanwhile the presence of FDI firms is often used to capture the impact of globalization on firms (Kuncoro, 2007). Therefore globalization is treated as an exogenous factor – the possibility that firms learn through R&D to become more productive so that they can go global as in Damijan *et al*. (2010), Crespi *et al.* (2008) and MacGarvie (2006) is completely abstracted from.

For innovation the measurement is more straightforward. There are two aspects of innovations, namely product technology or product innovation and process technology or process innovation. Product innovation is a substantial improvement of a current product or development and manufacture of a new product. Kraemer and Dedrick (2000) for example, used the number of new products introduced over the last three years to capture product innovation. Process innovation on the other hand involves substantially improved or new production process through the introduction of new process equipment or re-engineering of operational process. For example if a firm in a specific period of time do the following; to set up new production line, to put in new production system and to put in new computerized system to upgrade production facilities, then they can be categorized as undertaking process innovation. This also applies to the purchase of new capital equipment if it involves new production process or at least brings improvement in production process.

The concept of 'knowledge' production function allows us to estimate directly the determinants of innovation provided that the data are available. One important feature of innovation data is that they consist of integer number and zero counts. This necessitates the modification of distributional assumption when it comes to estimate innovation function. The simplest is the Poisson distribution (Crepon and Duguet, 1997)

In subsequent development, Andersen (1970) extends the basic model to allow estimation of fixed effects where the heterogeneity term u_i is no longer assumed to be independent of right hand side variables. So potentially one can allow individual or industry effect such as different operating skills, appropriate condition and technological opportunities in the innovation relationship.[1] The pioneering work applying the Poisson regression or count data model to the relationship between innovation and R&D was conducted by Hausman *et al.* (1984).

One important contribution of this study is methodological – how to deal with the situation when the innovation data are very rudimentary. Both types of innovation are simply not available in BPS (Indonesian Statistical Agency) large and medium manufacturing surveys. The only observed outcome from innovation activities is R&D expenditure in which all product and process innovations are lumped together. To overcome this problem instead using the knowledge production function directly, using economic theory one can derive R&D expenditure as a product of the cost minimization process where total cost of production which includes R&D expenditure is minimized subject to a certain level of targeted output. In other words by relying on the concept of innovation or the knowledge production function R&D expenditures are interpreted as preceding activities prior to actual innovations. The attempt to endogenize R&D decision is in line with Constantini and Melitz (2008) while export remains exogenous.

2. R&D Activities & Globalization in Indonesian Manufacturing

Before we proceed to the conceptual model guiding our empirical research, we examine the main data sets – the annual survey of large and medium manufacturing firms. The biggest problem is that the data do not contain the count of innovation, what is available R&D expenditure. Under this condition, one way to get around the problem is to model R&D expenditure as a conditional input-demand function representing innovation generating activity.

The manufacturing data sets mentioned above are available from 1980 to 2007. So potentially one can construct a long panel data to study the dynamic of R&D activities. Unfortunately R&D expenditure is only recorded intermittently for the years 1995, 1996, 1997, 1999, 2000 and 2006. There is no R&D data prior to 1995.[2] Although

[1] This effect can be either fixed or random.
[2] 1996 was eventually dropped from our regression sample due to the fact that it misses one crucial variable for our modeling set up, namely new investment in machinery.

potentially one can construct a balanced panel data set, the main hurdle is to link data sets before 2000 to that of 2006. We find that the firm identifiers are unreliable to link the same firms from different years. So at best one can use the data sets in a pooled fashion. Another problem is that R&D events are such rarities that from the total combined sample from 1995 to 2006 the overall percentage of firms doing R&D rarely exceeds 8 percent, which happened only in 1997 and 2006 (**Table 1**). On this consideration, a lot more can be learned from firms' decision to undertake R&D or not by using a pooled sample.

Table 1. R&D versus no R&D

Year	No R&D (%)	R&D (%)	Number of firms
1995	92.4	7.4	21530
1996	92.8	7.2	22969
1997	91.7	8.3	22355
1999	94.7	5.3	20445
2000	93.9	6.1	21762
2006	91.2	8.8	29421

Source: calculated from the Annual Manufacturing Surveys

Our observation on data sets will also help in determining the direction of the modeling. In particular we want to know the main motivation behind carrying out R&D. It is known that at the present stage of technology maturity, R&D has not been an important factor in affecting the competitiveness (Kuncoro, 2002). Even if R&D activities do exist, mostly they take the form of process innovation. Process innovation involves substantially improved or new production process through the introduction of new process equipment or re-engineering of operational process. There are three situations where process innovation may take place: setting up a new production line, putting in a new production system and installing new computer or information technology components to upgrade production facilities (Kraemer and Dedrick, 2000).

The purchase of new capital equipment can be categorized as process innovation if it involves a new production process or at least brings improvement in production process. So a common occurrence is R&D activities taking place after new machinery is installed. To examine this, we tabulate new machinery investment and the incidence of R&D. The results are presented in **Table 2**.

Table 2. Firms Investing in New Machinery and R&D

Year	No New Machinery Investment		New Investment in Machinery	
	% Firms doing R&D	Number of Firms	% Firms doing R&D	Number of Firms
1995	5.4	18246 (84.7%)	19.6	3284 (15.3%)
1997	6.5	19401 (86.6%)	20.3	2954 (13.4%)
1999	3.5	17347 (85.2%)	15.1	3007 (14.8%)
2000	4.5	18622 (85.8%)	15.3	3100 (14.2%)
2006	5.6	25342 (86.1%)	10.4	4079 (13.9%)

Source: Calculated from the Annual Manufacturing Surveys.

For all years under observation firms making new investments in machinery have higher likelihood of conducting R&D. In 1995 for example only 5.4 percent firms with no new machinery investment carried out R&D. The corresponding figure for firm with new machinery investment is almost four times higher. For both investing and non-investing firms, the Asian economic crises have obviously had significant impact on R&D activities. For investing firms the propensity to do R&D declined ever since and it has yet recovered in 2006. On the contrary it reached its lowest figure of 10.4 percent in that year. The figures for non investing firms are virtually flat – suggesting that there is no relationship between R&D and machinery investment.[3] The decision to invest in new machinery is not an easy one. Since the investment cost is sunk a careful consideration must be made by a firm taking account business uncertainty and future profits, in effect it makes investment in machinery more volatile. Whatever the trend of the likelihood of engaging R&D, **Table 2** suggests that there is a relationship between new investment in machinery and R&D.

As mentioned above, we hypothesize that an increase in competition from arising globalization may induce firms to do more R&D. For this we replicate the above simple analysis to two variables representing globalization, namely going into export market and the presence of FDI firms (**Table 3** and **Table 4**).

[3] If there is no relationship between new machinery investment and R&D – the existence of R&D must be driven by something else like packaging, sales and so on.

Table 3. FDI Firms and R&D

Year	Non FDI Firms		FDI Firms	
	% Firms doing R&D	Total Number of non FDI Firms	% Firms doing R&D	Total Number of FDI Firms
1995	7.1	20657 (95.9%)	18.6	873 (4.1%)
1996	6.7	21988 (95.7%)	18.7	980 (4.3%)
1997	6.7	21254 (95.1%)	20.9	1101 (4.9%)
1999	7.7	18926 (93.0%)	10.6	1428 (7.0%)
2000	4.8	20028 (92.0%)	13.1	1734 (8.0%)
2006	8.7	27252 (92.8%)	10.1	2169 (7.2%)

Source: Calculated from the Annual Manufacturing Surveys.

FDI firms are almost three times more likely to engage in R&D. In 1995 the percentage of FDI firms recording R&D is 18.6 percent in contrast to 7.1 percent for non FDI. The percentage of FDI firms carrying out R&D reaches its peak in 1997 just a year before the Asian Crisis. As a mimic to observed pattern in the new machinery investment before the likelihood of FDI firms engaging in R&D dropped after the Asian crisis almost by half (**Table 3**). Interestingly the figures for non FDI firms show a drop only in 2000 – the number is virtually stable for all other years. One plausible explanation is that since R&D is tied to new machinery investment, the number is less volatile for those that are less likely to make such investment namely non FDI firms.

Table 4 shows how exporting is related to R&D activities. Manufacturing is dominated by non-exporters, which account for about 80 percent of total firms. Exporting firms are clearly more likely to do R&D. But as in the previous analysis, the likelihood to carry out R&D diminishes after the crisis and by 2006 it has still to recover. To summarize there are three factors that may drive firms to engage in R&D: making new machinery investment, being FDI enterprises and being exporters, all of which may be interrelated. To disentangle this we have to wait for a formal econometric analysis.

Table 4. Exporting Firms and R&D

Year	Non Exporters		Exporters	
	% Firms doing R&D	Total Number of non-exporters	% Firms doing R&D	Total Number of Exporters
1995	6.1	17907 (83.2%)	15.1	3623 (13.0%)
1996	5.5	18614 (81.0%)	14.6	4354 (19.0%)
1997	7.3	19298 (86.3%)	14.8	3057 (13.7%)
1999	3.9	17553 (86.2%)	13.6	2801 (13.8%)
2000	4.3	18187 (83.6%)	13.0	3575 (16.4%)
2006	8.5	24422 (82.3%)	10.4	5199 (17.7%)

Source: Calculated from the Annual Manufacturing Surveys.

The above analysis yields the likelihood of firms to commit R&D but not the propensity or intensity of doing so. To measure the propensity we use the ratio of R&D expenditures to the values of total inputs, in percentage terms. The results are shown in **Table 5**. All figures are quite small. None of them is higher than 1.5 percent. Interestingly for all variables supposedly represent globalization namely; export orientation and FDI, the results show that firms facing globalization do not necessarily posses higher propensity to engage in RD. Globalization may increase the likelihood or the incidence of R&D but it does not necessarily mean at high level.[4] Higher levels of R&D, regardless of denominator used may indicate sophistication so these small values suggest that, if any, R&D activities may involve only non-sophisticated activities. Another interesting observation is the observed turn around in 2006 where in the categories of export orientation and FDI versus non FDI, all respective firms have a higher propensity to engage in R&D compared to their non-exporter and/or non-FDI counterparts, though all are at lower percentage. The Asian crises have lowered propensity for R&D in all categories. The same pattern can also be observed for firms with new machinery investment versus those without it.

Table 5. Percentage of R&D Expenditures to the Value of Total Inputs

Category	Year		
	1995	2000	2006
Non Exporter	1.05	1.29	0..44
Exporters	0.88	0.87	0.70
No investment in new machinery	1.05	1.23	0.46
With investment in new machinery	0.90	0.92	0.65
No FDI firms	1.02	1.05	0.47
FDI firms	0.72	1.47	0.70
All firms	0.99	1.12	0.49

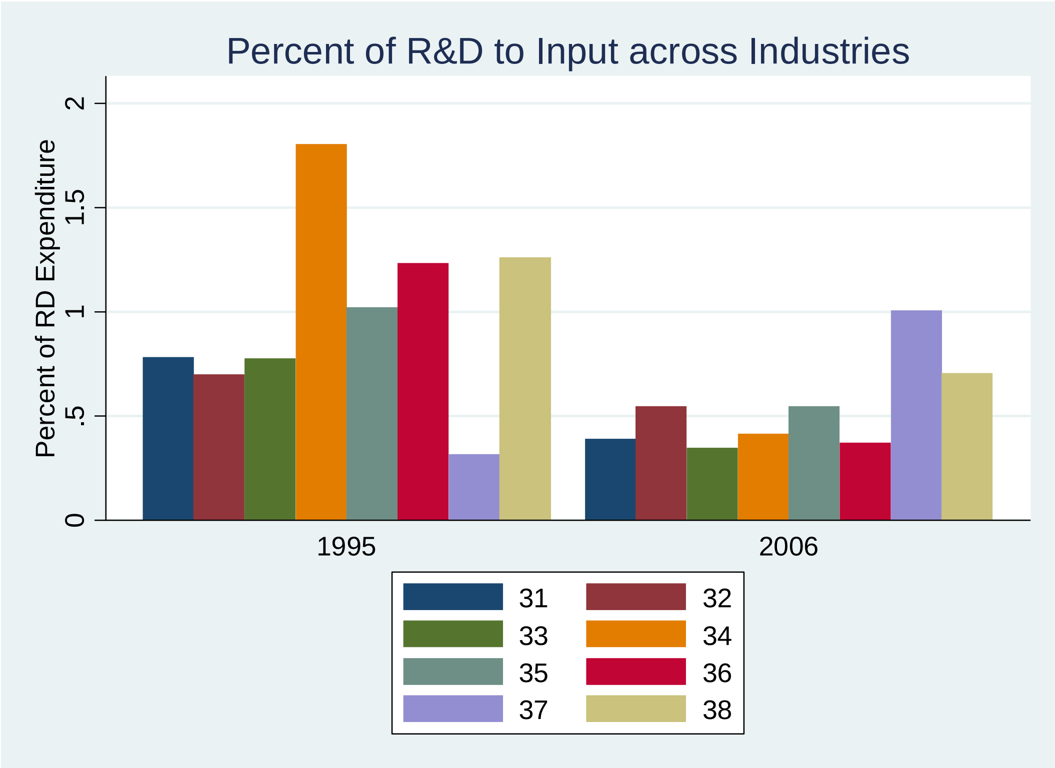
Source: Calculated from the Annual Manufacturing Surveys

R&D Intensity across Manufacturing Branches

The intensity to perform R&D certainly will differ from one industry to another. To provide more detailed pictures across manufacturing we replicate the above observation across two digits ISIC across manufacturing (**Figure 1**).

[4] In our terminology the likelihood to engage in R&D irrespective of how much firms spend on it, while their propensity is the percentage of R&D expenditure to the value if inputs which indicates 'level'.

Figure 1



Overall, the propensity to pursue R&D declined after the Asian crisis. Taking out the outlier from paper (ISIC 34), both basic metal (ISIC 37) and machinery (ISIC 38) have the highest R&D propensity. Still, the figures are low, for example in 2006 none of them exceeds 1 percent. One plausible explanation is that R&D is a risky adventure and the Asian crisis made firms more cautious. The other explanation links the R&D decision to that of new machinery investment since most R&D is done in preparation of installing new machinery/technology. With the same logic, since investing in new machinery in the face of a sluggish economy in the aftermath of the Asian crisis is a risky venture, R&D will also be affected.

Figure 2

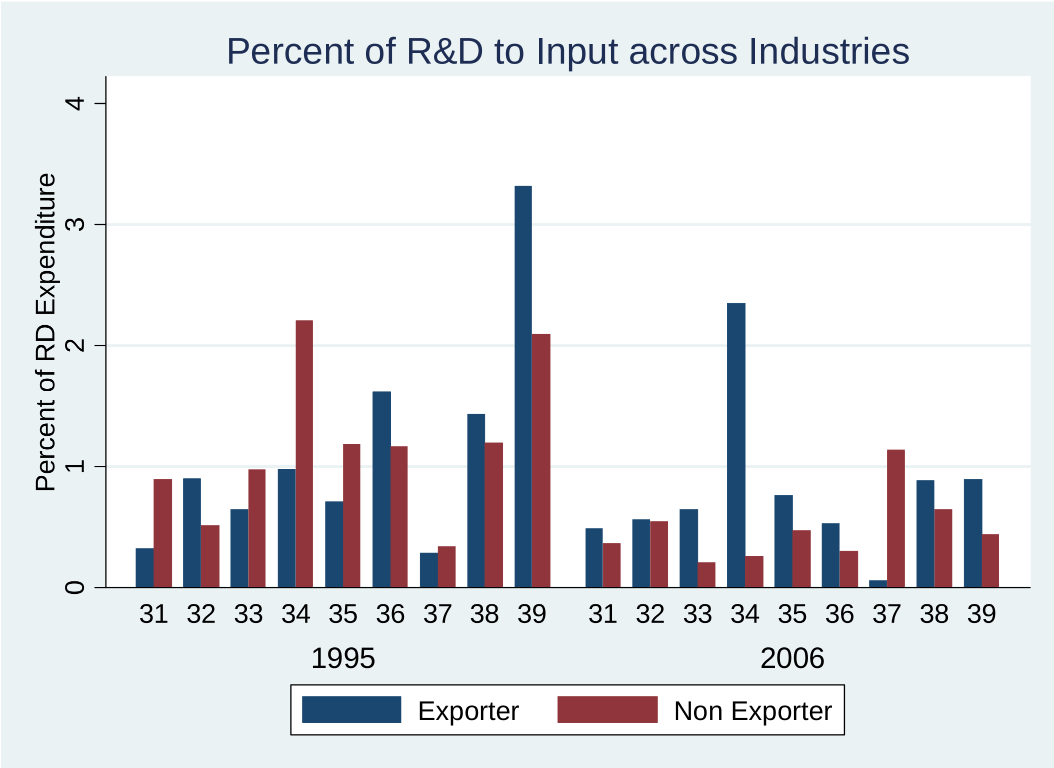
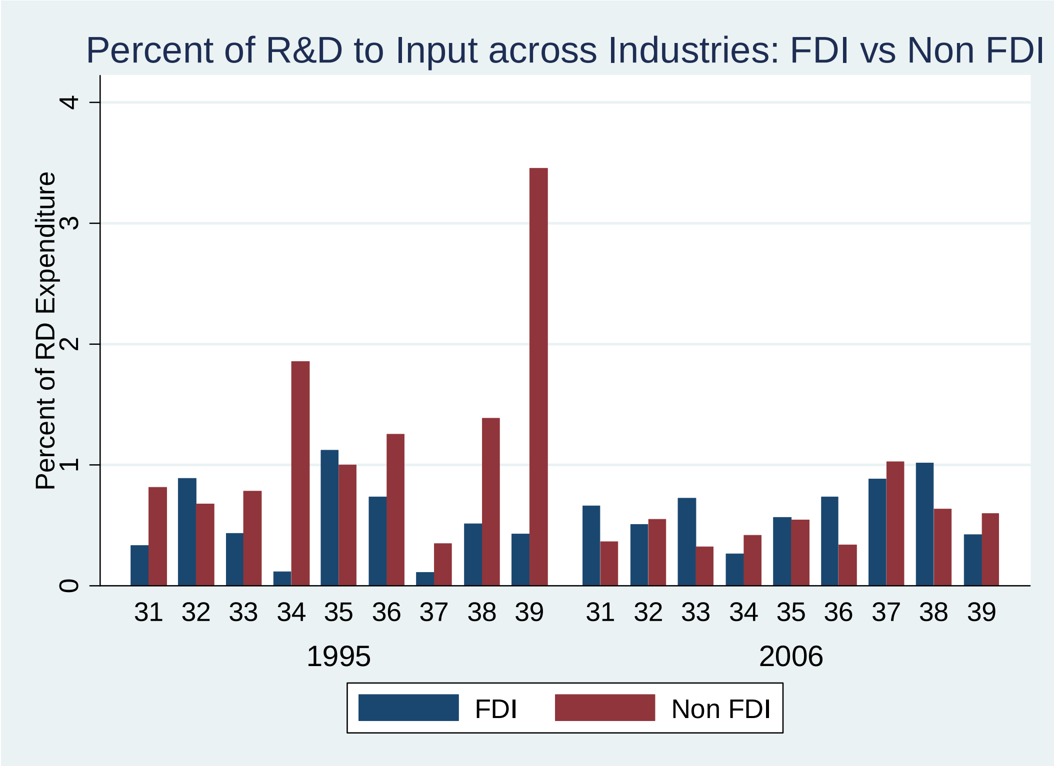


Figure 2 divides the sample into the exporter and non-exporter categories. The decrease of R&D propensity is also observed when comparing 1995 to 2006, but the decrease for exporters is less than non-exporters. In 1995 non-exporters in food (ISIC 31), woods (ISIC 33), paper (ISIC 34), chemicals (ISIC 35) and basic metal (ISIC 39) recorded higher R&D propensities. But the situation is reversed after the crisis. It appears that in the face of increasing uncertainty, exporters facing competition abroad have to maintain a minimum level or intensity of R&D expenditures which happens to be higher than non-exporting firms, otherwise they would lose businesses. One exception is heavily capital-intensive basic metal (ISIC 37) of which steel industry is included. Even when the overall figures are declining between 1995 and 2006, non-exporters have always higher R%D propensity.

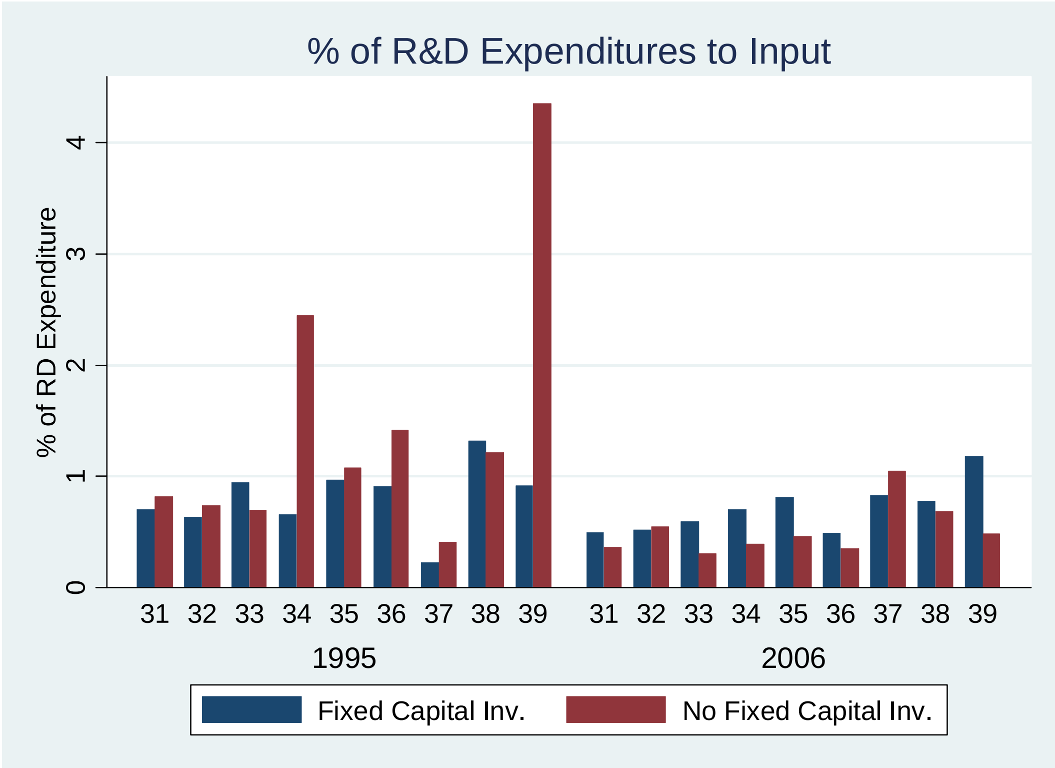
Figure 3



When comparing FDI versus non-FDI, there is no apparent consistent discernible pattern (**Figure 3**). For example in 1995 for food (ISIC 31), woods (ISIC 33), paper (ISIC 34), non-metallic (ISIC 36) and machinery (ISIC 38), the R&D propensity is higher for non-FDI firms. This completely reverses in 2006. For the rest the pattern is just the opposite. So the idea that being an FDI firm is a strong driver behind R&D is not as convincing as the case of being exporters. But for this the final conclusion may have to wait for a formal econometric test. In any case this pattern is useful in shaping our conceptual model.

Next we turn to investment in machinery as a prime driver for R&D activities (**Figure 4**). In 1995 the pattern is less clear, but in 2006 with basic metal (ISIC 37) as a clear exception, in almost all other industries, machinery-investing firms tend to have a higher R&D propensity. So in addition to a higher likelihood to engage in R&D (**Table 2**), the level of R&D expenditure is also relatively higher, which indicates a strong case for new machinery investment as a primary reason behind R&D.

Figure 4



<u>Effective Rate of Protection</u>

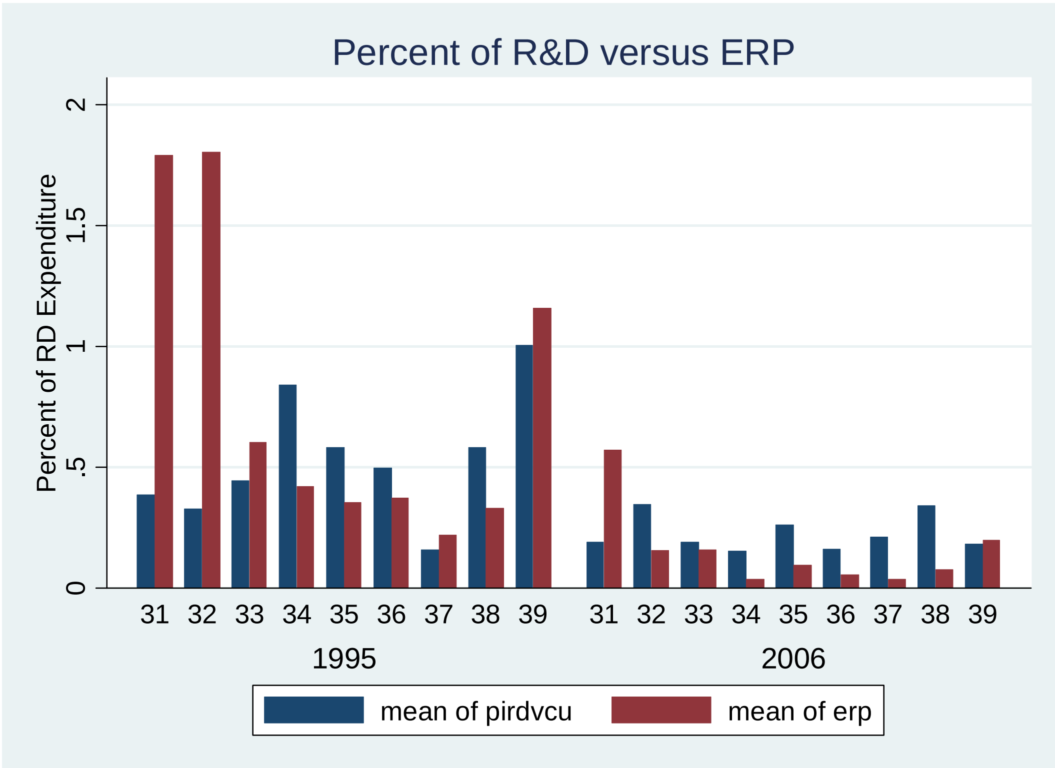
One way for a government to shield certain sectors from global competition is through tariff protection. This barrier will alter industry's relative profitability by creating an artificial price wedge. How the protection will affect R&D is at best ambiguous. If the market is contestable then the extra profit can reinvested in R&D to boost firms' competitiveness in anticipation of the day when the protection is eventually lifted. On the other hand, high artificial profits could also reduce pressure for firms to carry out R&D. Both forces are present in a protected environment but which one is stronger is a matter of empirical analysis.

To measure this we use the concept of the effective rate of protection (ERP) as in Amiti and Konings (2005).

(1) $$erp_{it}^{k} = \frac{(tariff_{t}^{k} - \alpha_{it}^{k} inputtariff_{t}^{k})}{(1-\alpha_{it}^{k})}$$

Where α_{it}^{k} is the ratio of inputs to outputs for firm i in industry k at time t. A lower output tariff would decrease the protection enjoyed by industry k, while a lower input tariff would increase the protection received by industry k. To examine the possible relationship between the R&D intensity and ERP, we compare the percent of R&D expenditures in total inputs to ERP in figure 5.

Figure 5



The overall pattern suggests that the percentage of R&D expenditure declined after the Asian crisis. But one thing is obvious that higher ERP is associated with a lower propensity conducting R&D. So dismantling of protection barrier has positive impact on firms to do R&D to stay competitive. If R&D is tied to new machinery investment then it is more likely directed to upgrade technology to boost competitiveness in the face of increasing competition from abroad.

Information Spillover

Spatial centralization of resources and spatial concentration of manufacturing in a few largest metropolitan areas has been a feature of the modern economy. Centralization of industrial location at least in the early stages, may bring benefits to firms (Hansen, 1990). One important benefit of such agglomeration is that firms conducting R&D can learn from each other, to create a synergy that collectively boosts their average productivity. In this regard there are two types of 'positive' externalities. First is localization; in this respect firms doing R&D learn from their own industry, which in the dynamic form, is often called Marshall-Arrow-Romer (MAR) externalities. Alternatively, firms learn from all firms in a city, where the diversity of local industries enhances the local information environment. This type of externalities is called urbanization or in the dynamic context is termed Jacobs' externalities (Jacobs, 1969).

In the Indonesian context, one important question is which type of externalities is actually stronger for R&D. If externalities are in the form of localization, smaller city are more likely to be the place of R&D activities specializing in just one industry or a closely connected industries. On the other hand if the externalities happen to be urbanization in nature, to thrive R&D activities need to find a location in a diverse and large urban environment. R&D activities are therefore more likely to be found in large urban areas. Another related question is whether externalities are mainly static or dynamic. If it turns out that externalities are dynamic – this would imply that R&D past activities affect the present productivity, because overtime a particular location would accumulate a large body of knowledge. The implication for R&D is that firms committing resources to do R&D would become more 'static' – tied to a particular industrial agglomeration – and less willing to move to cities where historically R&D has never existed, and thus have no built-up stock of knowledge.

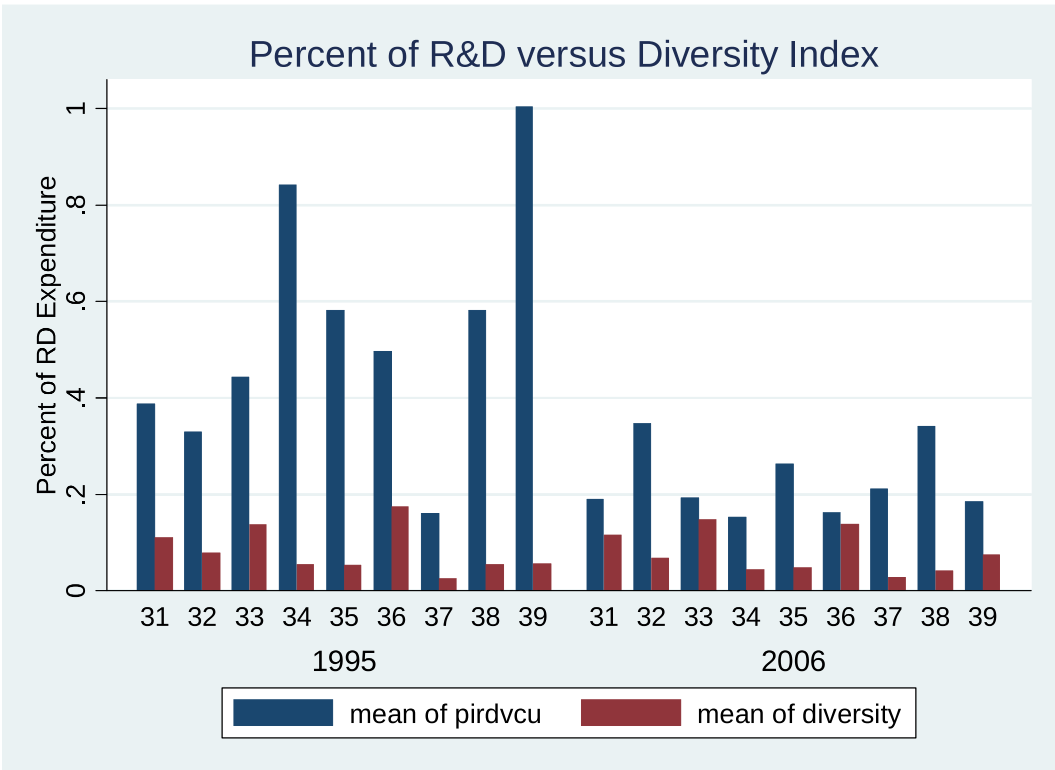
Localization/MAR externalities will be measured by total employment in the own industry in the respective districts. This measure is meant to capture interaction among firms within a district. Urbanization externalities are measured by a diversity index. For district i for example, the index of diversity is

$$(2) \qquad g_i^s = \sum_{j=1}^{J} \left[\frac{E_{ij}(t)}{E_i(t)} - \frac{E_j(t)}{E(t)} \right]^2$$

$E(t)$ is total national manufacturing employment and $E_j(t)$ is total national employment in industry j. Meanwhile, E_i and E_{ij} are the corresponding local magnitudes. The measure of urbanization economies $g^s{}_i(t)$ has a minimum value of zero, where in a district, each industry's share of local manufacturing employment is exactly the same as its national share, so the district is completely unspecialized because its industrial composition is merely a copy of the nation. At the other end, the maximum value of $g^s_i(t)$ will approach two for a district completely specialized in one industry, while at the same time national employment is concentrated in another industry. The higher is $g^s_i(t)$ the lower is the diversity, thus a district becomes more specialized.

To examine the location pattern of R&D activity we compare the percent of R&D expenditure to the index of diversity given in (2) across industry. For easy comparison we choose the year 1995 and 2006. The result is shown in **Figure 6**.

Figure 6



Although the pattern is somewhat less clear in 1995, the general relationship is that an industry with a higher R&D percentage tends to locate in a location with a lower diversity index or less specialized location, usually in bigger urban areas with bigger more diversified economies. Since previously it has been asserted that most R&D are directed toward preparation for new machinery investment (**Figure 4),** this type of R&D

may require only general information (capital goods markets, delivery times, general specifications, after sales service and so on) from its industrial surrounding.

3. The Model

The conceptual model is developed in accordance of what was observed in the background analysis that most R&D is presumably geared toward preparation for incoming new machinery and equipment. It is also tailored to accommodate the fact that the Indonesian manufacturing survey is at the establishment or plant level. A firm before pursuing a risky R&D project will examine its long-run profits or cost implications. From the economic theory we know that the existence of a duality between profit and cost optimization would allow us to derive demand for factors of production of which R&D is a crucial input.[5]

After an investment decision to improve machinery and equipment is made, the necessary R&D activities are determined. For this, we rely on the concept of the knowledge production function where R&D expenditure is related positively to innovations (Crepon and Duguet, 1997) and the learning by doing model (Romer, 1996) where innovations are learned from and are separable from the ongoing (constant return) production process.

First we assume that there is a relation ship between innovation (n) and R&D activities (R) in the following knowledge production function

(3) $n = n(R)$, where dn/dR>0 or a positive relationship exists between n and R.

Output, Y, is assumed to follow a general function

(4) $Y = Y(K, L, n)$

where K is capital stock, L is labor and n are the number innovation. Substituting (3) into (4) we have

(5) $Y = Y(K, L, R)$

[5] The conceptual model has undergone major revision in order to accommodate the suggestion that plant productivity should have an impact on R&D activities. Also the decision to carry out R&D has been restructured to account for concern that the choice model is not different from the location choice. Now the choice for R&D is treated more explicitly.

R&D is separable from the ongoing (constant return) production process. R&D is modeled as a shift factor in the production function. If a firm chooses to carry out R&D then it will add to its stock of knowledge *B*. By assuming a constant return to scale technology for *K* and *L* in the production function, the appropriate form of this setup is given by

(6) $Y = B^{\theta} K^{\alpha} L^{1-\alpha} R^{\theta D}$

With this specification the excess (super normal) profit function is defined by

(7) $\Pi = P.Y - \pi^{*}$

where π^{*} is reservation profit which is assumed to be affected by factors that are considered when choosing R&D projects such as the nature of the local agglomeration including its industrial diversity (g) and own industry employment (e) which capture technological information spillover as well as ERP) as a general measure of average profitability.[6] This also includes firm characteristics. R&D projects are risky undertakings, to account for different degree of risk aversion among different types of firm, firm characteristics such as being an exporter (ex) and/or an FDI are also included.[7]

In (7) an increase of π^{*} would reduce Π so $\Pi_{\pi^{*}} < 0$ which would lower the incentive to engage in R&D. Meanwhile the reservation profit is given by

(8) $\pi^{*} = \pi^{*}(g, e, ERP, ex, fdi)$

The relationship between π^{*} and ERP cannot be determined *a priori*, an artificial increase of profitability because of higher protection may make firms 'too lazy' to pursue R&D. In another case a foresighted firm may reinvest these profits in R&D in anticipation that tariff barrier will come down in the future, so $\Pi_{ERP} \gtreqless 0$. The relationship between the reservation profit and the nature of agglomeration (g and e) is also ambiguous. It is up to the empirical exercise to determine the direction of these relationships. Due to their outward orientation, exporters and FDI firms are presumably

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6 So essentially excess profit is before labor, capital and material costs.

7 This will allow us to incorporate firm characteristics in the choice carrying out R&D project or not to represent different degree of risk aversion.

less risk-averse and thus have lower reservation profits compared to non-FDI and non-exporters, so $\pi^*_{ex} < 0$ and $\pi^*_{fdi} < 0$.

In equation (6) D is a dichotomous variable with the value of one if the excess or super normal profit Π from undertaking an R&D project is greater or equal to zero or Π≥0 and having the value of zero otherwise or if Π<0.[8] If a firm chooses to undertake an R&D project then the production process will follow

(9) $Y = K^{\alpha} L^{1-\alpha} (BR)^{\theta}$.

In (9) the impact of B and R on Y is given by the parameter θ, which is not constrained so as to allow for decreasing, constant or increasing return of knowledge and R&D in the production. If a firm opts not to purse R&D because of profitability or cost concerns then the production will follow

(10) $Y = B^{\theta} K^{\alpha} L^{1-\alpha}$

which means a firm will use only the existing stock of knowledge. The per capita or intensive form of (9) is given by

(11) $y = \frac{Y}{L} = \left(\frac{K}{L}\right)^{\alpha} (BR)^{\theta} = k^{\alpha} (BR)^{\theta}$

where y is output per unit of labor Y/L and k=(K/L) is capital-labor ratio. .

A firm will choose a level of R&D, R, as to optimize the capital and labor costs plus R&D expenditure $C = rK + wL + R$, with the excess normal profit Π≥0 as a constraint, where r is price of capital and, w is wage rate. The conditional input demand function for R&D is then given by

(12) $R = R(r^*, \frac{Y}{L}, \pi^*(g, e, ERP, ex, fdi))$

If a firm chooses to realize (12) by committing resources to perform R&D this is because the excess normal profit requirement Π≥0 is met. Or alternatively it will not spend on R&D if it is unprofitable or too costly or if Π<0. In this case there will be no R&D activities or R = 0. In (12) r^* is price capital normalized by wages w. In this specification, y or Y/L can be interpreted as labor productivity so one can assess its

[8] Compared to the earlier version, the choices are much simplified. Rather than having to choose one among many alternatives we now have a yes or no decision.

impact on R&D activities R, that is to say, whether firms with higher labor productivity would have higher R&D intensity.

There is no specific 'price' for R to allow some flexibility of whether R&D is tied to capital or labor. The property of strict concavity of (5) is sufficient to establish that the negative relationship between r^*=r/w and R in equation (9) does exist. Empirically, this is a testable hypothesis which can be confronted with estimation results from the data sets.[9] Also the same property establishes positive relationship between R&D and output per labor.

In (12) the impacts of being exporters and being an FDI firm on performing R&D activities are given respectively by

(13) $$\frac{\partial R}{\partial ex} = \Pi_{\pi^*} \pi^*_{ex} > 0$$

and

(14) $$\frac{\partial R}{\partial fdi} = \Pi_{\pi^*} \pi^*_{fdi} > 0$$

So being less risk-averse, exporters and FDI firms are more likely to engage in R&D. The signs of other variables in (12) cannot be judged *a priori* – these will be determined by the empirical models.

Instead of innovations per se we now have R&D expenditure as the crucial input in the innovation process in the form of a conditional input-demand function.[10] The reservation profit π^* incorporates globalization variables and other firm-industry characteristics which will enable us to asses the impact of those variables on R&D and indirectly on innovations employing their presumed correspondence suggested above. The estimating version of equation (12) is therefore

(15) $$R_{it} = \delta_0 + \delta_1 (\frac{r}{w})_{it} + \delta_2 (\frac{Y}{L})_{it} + \delta_3 I_{it} + \Delta G_{it} + \Omega F_{it} + u_{it}$$

Where I is a dummy variable relating to whether a firm is investing in new machinery/equipment or not, G and F are vectors of globalization and location-industry level variables respectively. Variables representing G are being an exporter, being an

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[9] Interest rate r is calculated by dividing the amount of interest payment to total assets, while wages are constructed by dividing the total payroll for production workers with the total number of production workers.

[10] Instead of observing the count of innovations, we look at innovation-generating activity, namely R&D.

FDI versus non-FDI and ERP.[11] The vector F includes the diversity index g and own-industry employment. Equation (15) can be estimated directly, lumping together all variables affecting the decision to undertake R&D as well as the decision determining R&D intensity. But if one wants to mimic a dichotomous choice i.e. to undertake R&D or not depending on whether $\Pi \geq 0$ or $\Pi < 0$, the Heckman procedure can also be used.

4. Empirical Results

The estimation results of equation (15) are shown in **Table 6**. In the first two columns are the ordinary least squares method (OLS) applied to pooled data of the years 1995, 1997, 1999, 2000 and 2006. The difference between the first column and the second is that in the latter all variables supposedly affecting the reservation profit π^* are included and also the ratio of interest rate to wages is replaced with a dummy ind whether a firm committing new machinery investment or not as a direct test indicating whether R&D activities are tied to machinery investment. Finally the last two columns present the results of the two stage least squares – instrumental variables (2SLS-IV) estimation. All standard errors are clustered in a respective district. By construction output per labor in equation (11) is endogenous, thus output per labor in (12) and (15) is also exogenous. For the instrument we use the district average of firms' output.

Overall output per labor or labor productivity is positive and significant at least at the 10 percent level so labor productivity is an important determinant in R&D activities. In the model 1 of the OLS specification the coefficient of the ratio of interest rates to wages is negative and significant at the 5 percent level.[12] So there is an indication that R&D is tied to the acquisition of capital goods. If the relative price of capital goes up then it will have a negative impact not only on capital but also on R&D expenditures.

In model 1 the globalization variable is ERP is significant at the 5 percent level though the coefficient is small. The sign is negative which implies that lowering

[11] The exporter dummy is equal to one if a firm exports at least 2 percent its total output and zero otherwise. The FDI dummy is defined as equal to one if the share of foreign equity is at least 10 percent.

[12] We experiment with the Tobit procedure but it is very weak statistically because not many firms are carrying out R&D.

protection would induce firms to increase R&D expenditure. The coefficients of other globalization variables FDI and exporter dummies are positive, confirming the prediction given by (13) and (14), and also significant albeit at different levels of which the later is stronger statistically.

Turning to model 2 of the OLS specification, the most significant variable is the new investment dummy – signifying that the most important factor behind R&D in Indonesia is new investment in machinery and equipment. The exporter dummy retains its significant but the FDI dummy is now insignificant. So being exporters have stronger drive to carry out R&D compared to FDI firms.

Table 6. Determinants of R&D Expenditure: 1995-2006

Covariates	OLS		2SLS	
	Model I	Model II	Model I	Model II
Output per labor	0.027	0.018	0.384	0.174
	*[1.76]	**[2.25]	*[1.67]	*[1.70]
Ratio interest rate to wages	-1.11		-0.376	
	**[-2.38]		[-1.06]	
FDI Dummy	0.037	0.015	-0.032	-0.018
	*[1..63]	[1.10]	[-0.58]	[-0.57]
Exporter Dummy	0.036	0.025	0.018	0.020
	**[2.80]	**[2.93]	**[2.67]	**[3.31]
Effective Rate of Protection	-0.00001	-0.00003	-0.00001	-0.00004
	**[-2.99]	[-1.25]	[-0.83]	[-1.21]
New Investment in Machinery		0.043		0.036
		**[3.34]		**[3.71]
Local Manufacturing Diversity		-0.017		-0.012
(5 years Lag)		**[-2.47]		**[-1.99]
Manufacturing Employment		0.000		0.000
(5 years lag)		[-0.13]		[-0.95]
Industrial Dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
F-value	**3.29	**10.26		
Wald Chi-Square			**55.09	**73.14
Number of Observation	73706	73706	73706	73706

Notes: Figures in parentheses are-test.
* *:* Significant at the 10 percent level.
***:* Significant at the 5 percent level.

The ERP variable presents both in the model 1 and model 2 as to reflect the situation that it may not only represent long-run (reservation) profits but also affecting day to day operation especially when it comes to determine the level of R&D. It turns out that ERP is not significant in model 2. Its effect may be swept away by the presence of the new investment dummy of which most machinery is imported from abroad. This suggests that from all globalization variables in the model, the exporter dummy is the most robust. It survives different specifications as well as different estimation procedures.

The diversity index is negative and significant at the 5 percent level. R&D activities are higher in less specialized agglomerations usually in big urban areas – confirming the notion that most R&D activities require more general market information rather than industry-specific knowledge. The lag of own industry employment is not significant, suggesting that specialization of R&D activities in smaller cities is not a common phenomenon. Since the diversity index is also in the lagged form, these externalities are dynamic, so it is not easy to relocate the present R&D activities to non urban locations where historically they do not exist.

In the 2SLS-IV specification, output per labor is statistically weaker but still significant - reflecting the problem of finding good instruments with high predictive power but orthogonal to the error terms. One interesting finding is that the coefficient of labor productivity is now larger. The productivity effect on R&D is larger after the endogenous output per labor is taken care of.

The ratio of interest rates to wages is insignificant now although the sign remains negative as before. The exporter dummy is still significant (model 1 of 2SLS-IV) with a little smaller coefficient. ERP is not significant now, confirming that as a globalization variable ERP, like the FDI dummy is not as statistically robust as exporter dummy.

Selectivity of R&D Activities

In the Heckman procedure we estimate equation (11) explicitly acknowledging the decision that has to be made by a firm concerning R&D – whether to undertake R&D or not (incidence of R&D) and, if so, how much it is willing to spend on it (R&D intensity). The results are presented in **Table 7**.

Table 7. Selectivity of R&D Activity: 1995-2006 (Heckman Procedure)

Covariates	Model 1		Model 2	
	Continuous	Selection	Continuous	Selection
Output per labor	0.792	0.014	0.799	0.020
	**[2.05]	*[1.74]	**[1.97]	**[2.49]
Ratio interest rate to wages	-34.85		-25.81	
	[-1.28]		[-1.14]	
FDI Dummy	0.008	0.105	0.010	0.088
	[0.05]	*[1.74]	[0.07]	**[2.14]
Exporter Dummy	0.096	0.431	0.057	0.465
	[1.43]	**[11.97]	[1.35]	**[14.10]
Effective Rate of Protection		-0.0002	]	-0.0002
		**[-2.21]		*[-1.74]
New Investment in Machinery		0.650		0.633
		**[18.64]		**[19.86]
Local Manufacturing Diversity		-0.403		-0.337
(5 years Lag)		**[-2.40]		**[-2.27]
Manufacturing Employment		0.000		0.00001
(5 years lag)		[0.83]		**[3.00]
Industrial Dummies			Yes	Yes
Time Dummies			Yes	Yes
Mill-ratio	-0.073		-0.067	
	**[-5.86]		**[-6.33]	
Wald Chi-Square	**9.93		**57.68	
Number of Observation	107138		107138	

Notes: Figures in parentheses are-test.
* : Significant at the 10 percent level.
**: Significant at the 5 percent level.

In the selection (incidence of R&D) equation we include variables that affect reservation profits π^* such as a new machinery investment dummy, a diversity index, own industry employment, and EPR, along with the usual FDI and exporter dummies and output per labor. In the continuous equation the usual conditional input demand function is used where output per labor and the ratio of interest rate to wages are the main variables along with other control variables such as FDI and exporter dummies.

The inverse of Mill's ratio is strongly significant in both models, which implies that performing R&D is not a random event. There is self-selection for firms devoting resources to R&D. The difference between model 1 and model 2 is that in the former it does not have industry and time dummies. But so far the models are robust to the inclusion or exclusion of industry and time fixed effects.

Fulfilling the requirement for the conditional input-demand function set up, output per labor is significant in the continuous equation in both models. The ratio of interest rate to wages, however, is not significant though the sign conforms with the theory (negative). Neither of the exporter and the FDI dummies in the continuous equation is significant, suggesting that once an R&D decision is made R&D intensity in the day to day operation is not influenced by firm types. This is akin to short-run versus long run investment. Since R&D is tied to sunk-capital so once it is made it will bring the consequence of R&D spending before and presumably even after installation of the machinery.

In the selection equation, the ratio of interest rate to wages is replaced by a dummy of new machinery investment. The coefficient of output per labor is strongly significant in both models. So firms with higher labor productivity have higher probability to perform R&D.

Unlike in the continuous equation where they do not affect the level of R&D expenditures, the likelihood of firms undertaking R&D is now strongly influenced by whether or not they are FDI firms or exporters or not. The other globalization variable, ERP, is negatively related to the probability of carrying out R&D, though statistically is somewhat weaker than the exporter dummy.

The lag of the diversity index is statistically very strong and has a negative sign. This suggests that R&D activities are more likely to be found in less specialized agglomerations. The result for the lag of own industry employment is mixed. It is insignificant in model 1 where the dummy for new machinery investment does not appear. In model 2 it is significantly positive. Certainly there is some degree of co-linearity between these two but it still within a tolerable limit.

The most significant variable so far is the dummy for new machinery investment which signifies the most important motive behind commitment to R&D as asserted in the background analysis.

<u>Spillover of the FDI Presence on Domestic Firms' R&D</u>

It is asserted in the background analysis that the presence of FDI firms may have little impact on R&D. In this section we pursue this issue a little further by explicitly constructing a variable to capture FDI spillover. We experiment with two alternative indicators.[13] The first is the number of FDI firms in a particular location. In the second experiment, a diversity index is constructed exclusively for FDI firms, and added to the model in place of the number of FDI firms in a district. One after another, these variables are then put as a covariate in the regression of the conditional input demand function for R&D where the sample is exclusively restricted to non FDI firms. The results of the application of the Heckman procedure for this sample of domestic firms are shown in **Table 8**.

Table 8. Impact of the Presence of FDI Firms on Domestic Firms R&D (Heckman)

Covariates	Model 1		Model 2	
	Continuous	Selection	Continuous	Selection
Output	0.002 **[1.94]	0.0001 **[3.27]	0.002 **[1.94]	0.0001 **[3.05]
Ratio interest rate to wages	-19.18 [-1.00]		-17.22 [-0.95]	
Exporter Dummy	-0.021 [-0.37]	0.495 **[13.95]	-0.022 [-0.40]	0.490 **[13.83]
Effective Rate of Protection		-0.0002 **[-0.62]		-0.0002 [-0.37]
New Investment in Machinery		0.637 **[18.96]		0.634 **[19.15]
The number of FDI firms in a district	-0.001 [-1.03]	0.001 [1.40]		
Local diversity index of FDI firms				0.088 **[2.67]
Industrial Dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Mill-ratio	-0.063 **[-2.59]		-0.060 **[-2.41]	
Wald Chi-Square	**66.96		**69.16	
Number of Observation	104347		104347	

Notes: Figures in parentheses are-test.
* : significant at the 10 percent level.
**: significant at the 5 percent level.

Overall, the results are weaker than the full sample but they are still plausible statistically. The results for the crucial variables validating the equation as a conditional input-demand function, output per labor and the ratio of interest rates to wages are mixed. The coefficient of output per labor is positive and significant at the 5 percent

[13] We actually experiment with two other variables namely the share of value added of FDI firms and the share of FDI firms' workers in a particular district but both results are weak statistically.

level. The ratio of interest rates to wages has the right negative sign but it is insignificant. Obviously removing FDI firms from the sample weakens its statistical power.

None of the variables representing the presence of FDI firms matters in the continuous equation. In the selection equation only the diversity index of FDI firms is significant with a positive coefficient. The higher the FDI diversity index, the more specialized a location is with FDI firms from one particular industry. Only then will FDI firms have impact on R&D. However, this impact is limited to the incidence of R&D, but does not affect the intensity of the activities. The significance of this variable suggests that there is a critical mass of FDI firms in a location or in an agglomeration below which the impact of FDI firms, at least on the incidence of R&D at domestic firms is very small.

In this case the avenue through which FDI firms impact domestic firms' R&D could be through the force of competition or workers' movement in a locality or both. The limited impact of FDI firms on domestic firms' R&D can be explained by the circumstance that most of the FDI firms' R&D may have been performed in their home countries. Machinery and equipment may also have been standardized throughout their plants around the world, so not much specific information about capital goods technology can be exploited by domestic firms to produce a significant technological improvement.

Impact of R&D on Labor Productivity

The setting up of the model suggests that the causal relationship between R&D and labor productivity is bi-directional. R&D is modeled as a conditional input demand function from a constant-return production process which is estimated empirically. The results confirm that where output per labor affects R&D positively. So firms with higher labor productivity have higher R&D intensity. But by a construction, the intensive form of the production function in (9) also makes the direction of relationship to reverse. For this purpose we estimate (9) empirically. The results are presented in Table 9.

Table 9. Determinants of (log) Output per Labor Unit: 1995-2006

Covariates	OLS		2SLS	
	Model I	Model II	Model I	Model II
Log of Capital per Labor Unit	0.233	0.185	0.227	0.174
	**[18.09]	**[14.07]	**[17.54]	*[1.70]
Log of R & D Expenditure	1.971	1.401	6.211	4.375
	**[10.97]	**[10.42]	**[2.13]	*[1.95]
FDI Dummy		1.010		0.937
		**[14.91]		**[11.65]
Exporter Dummy		0.603		0.567
		**[13.53]		**[11.00]
Industrial Dummies	No	Yes	No	Yes
Time Dummies	No	Yes	No	Yes
Prob>F or Prob>Chi-Squared	**0.000	**0.000	**0.000	**0.000
R-Squared	0.227	0.349	0.177	0.325
Number of Observation	75109	75109	75109	75109

Notes: Figures in parentheses are-test.
* : Significant at the 10 percent level.
**: Significant at the 5 percent level.

In the first two columns the model is estimated with and without controlling for firm characteristics, industry and time dummies, ignoring the potential endogeneity of R&D. In the last two columns the 2SLS procedure is applied to account for this problem. For the instrument the district average of R&D expenditure is used. The coefficient of (log) R&D is always positive and significant. The coefficient of (log) R&D is positive, larger and always significant, though a little weak statistically when 2SLS specification is controlled for firm characteristics and industry-time dummies, which implies that R&D activities drive firms to become more productive. Therefore, the relationship between R&D and labor productivity is indeed bi-directional. The coefficient of (log) capital labor ratio suggests that the output elasticity with respect to capital is around 0.20.

5. Conclusion and Policy Relevance

In this paper we examine the impact of globalization on innovation in Indonesian manufacturing. One important contribution of this study is its method in dealing with the situation when the innovation data are very rudimentary. The lack of innovation data in the manufacturing survey has necessitated the use of R&D expenditure as an input in the innovation production function. Globalization is represented by being exporters, being FDI firms and the effective rate of protection (EPR). One caveat in this study is that globalization is treated as exogenous factor. The situation where firms can learns through R&D to become more productive so that they can enter the global export market is completely abstracted from and it is left for future research.

The model is set up such that within the concept of a conditional input demand function where it allows labor productivity to have impact on R&D. In this case we find that less productive firms are less likely to venture on R&D activities. The reverse causality is also true; namely firms with higher R&D intensity tend to be more productive.

In terms of globalization variables we find that being exporters is an important determinant of R&D. However, the impact of FDI firms on domestic R&D is only on the incidence but not on the intensity of R&D. It requires a critical mass of firms within a location or an agglomeration to have a meaningful impact. But the main motivation to engage in R&D is in preparation for the installation of new machinery and equipment. Through this avenue the impact of globalization may come indirectly from the desire of firms to remain competitive, by upgrading their machinery and equipment.

Also a lower ERP would induce firms to spend more on R&D. So lowering protection or trade barriers and maintaining openness will have positive impact on R&D. Despite the fact that trade barriers are trending downward many hurdles remains which continue to inhibit the flows of trade and investment. Two most important problems are the corruption and inefficiency of national customs and ports. The "national single window policy" and the establishment of Corruption Eradication Committee (KPK) would reduce corruption and bureaucratic inefficiency. But improving ports' efficiency would require substantial investment which cannot be done by the private sector alone.

With regard to information spillover R&D activities are more likely to be found in less specialized industrial or economic agglomerations presumably in larger and diverse urban areas but not in smaller cities. This is consistent with the earlier finding that the primary motivation for R&D in Indonesia is for adaptation, accommodation and perhaps some modification of new machinery and equipment to meet operational conditions in Indonesia, so the type of information needed is general and is not a specific to consumer needs. One policy implication from this is to maximize the gains from the current configuration of industrial agglomeration and minimizing the negative externalities by improving the connectivity between agglomerations.

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CHAPTER 7

Globalization, Innovation and Productivity in Manufacturing Firms: A Study of Four Sectors of China

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This paper investigates relationships between innovation input, innovation output and labor productivity in China for four major manufacturing sectors; textiles, wearing apparel, transport equipment and electronic equipment. It uses a large sample of firm level micro data and a structural model in the estimation. The data from 2005 to 2006 is estimated, and results of all the sectors show positive effects from innovation input to output, and then to firm performance. Globalization has various impacts on innovation, through exports. It has a positive effect on both the decision to carry out R&D, and intensity of R&D input in sectors with competitive advantage, such as textiles and transport equipment, but not in sectors with high levels of overseas capital control, such as electronic equipment and wearing apparel. Ownership reveals the same story in different sectors, namely that foreign firms tend to do less in innovation input and output, but they do have higher level of productivity. Moreover, market share, subsidy, firm size and other characters of firms are involved in the estimation, which explains significant difference in engaging in innovation and production. Thus, in all the sectors, market share improves R&D input, continuous R&D input and exports improve new products output. Subsidy sustains R&D input, but not innovation output.

Keywords: R&D, New Product, Productivity, Export, CDM Model

JEL Classification: D21 L67 O31

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1. Introduction

Innovation is a key concept in moving into the knowledge-based economy, not only for the further development of developed economies such as the United States and European countries, but also for the reform and development of China. During the past thirty years of reform, China has achieved rapid growth and becomes a "world factory". In the new century, China is seeking for a new development approach to improve productivity, save energy and resources, but maintaining the fast pace of development and aiming to be the world's manufacturing center at the same time. The most practicable strategy is to establish a knowledge-based economy and make innovation a main factor in research and development, production and management, especially in manufacturing sectors at the firm level. The macro data in Table 1 shows the fast growth of R&D input and productivity in China during the past decade. Nevertheless, the absolute amount, measured as R&D input in business, the rate of R&D input in GDP, or GDP per capita, is still far less than in developed countries. Industrial productivity in China is less than one sixth of the United States' level in 2008 even at purchasing power parity (PPP), which is much higher than current values in China.

Table 1. R&D Expenditure and Productivity across Countries

	China	India	Germany	Japan	Korea	USA
Total expenditure on R&D 1997 (% of GDP)	0.64	0.70	2.24	2.87	2.48	2.56
Total expenditure on R&D 2007 (% of GDP)	1.44	0.83	2.53	3.44	3.21	2.65
Business expenditure on R&D 1997 (% of GDP)	0.30	0.16	1.51	2.07	1.80	1.87
Business expenditure on R&D 2007 (% of GDP)	1.04	-	1.77	2.68	2.45	1.91
Business expenditure on R&D 1997 (USD Billion)	2.83	0.67	32.75	88.08	9.30	155.41
Business expenditure on R&D 2007 (USD Billion)	35.25	-	58.91	117.45	25.68	269.27
GDP per capita 1997 (USD)	771	437	26445	33776	11237	31038
GDP per capita 2007 (USD)	2560	965	40430	34262	21655	46680
Productivity in industry 2000 (PPP, USD)	8512	6349	57902	52086	35106	69507
Productivity in industry 2008 (PPP, USD)	18196	9656	84601	70709	64169	120118

Source: IMD, World Competitiveness Yearbook, online database.

Globalization has been regarded as a key to world development since the last century, no matter whether people have positive or negative attitudes towards it. China always shows an active attitude towards globalization by opening its market, especially the manufacturing sector, encouraging foreign direct investment (FDI) and exports. FDI has been encouraged, and has grown very quickly since the beginning of the reform process. It has higher levels of management and efficiency in production, brings a fresh atmosphere and new techniques, improves exports and helps the government gain foreign exchange. Nowadays, FDI is an important element in the Chinese economy, and it controls more than half of the firms in some key manufacturing sectors, especially in electronics-related high-tech sectors. At the same time, growth of exports supports the fast growth of the economy and helps the country obtain its reputation as "world factory". Table 2 shows the process of globalization. The Stock of incoming FDI has started from 0.15% of the world's total amount since the beginning of reform. It reached 2% in 1993, the highest to 3.46% in 1997, and nearly the same level with Canada in the first decade of this century. Export grew from less than 1% of the world to 5% in 2002, and nearly 10% in 2009. GDP grew from 2.58% of the world in 1980 to 8.21% in 2009, but the per capita value is still less than 10% of United States' level.

Table 2. Growth of FDI, Export and GDP in Mainland China

	1980	1990	2000	2005	2006	2009
Foreign direct investment stock-Inward (% of the world)	0.15	0.99	2.60	2.36	2.05	2.67
Total merchandise trade-Export (% of the world)	0.89	1.78	3.86	7.25	7.99	9.68
GDP (% of the world)	2.58	1.82	3.72	5.07	5.65	8.22
GDP per capita (% of USA)	2.66	1.61	2.84	4.40	5.02	8.21

Source: United Nations, UNCTAD database.

In the new century, China's development is focusing on sustainable development in a fast growing economy, and the improvement of residents' welfare. Innovation at the firm level is a key step in improving productivity, sustaining the reform of industrial structure and supporting manufacturing firms' competition in the global market. That is why the *Sustainable Development Strategy* and *Innovation-oriented Country Strategy* of China came into being in 2006.

Based on a large sample of firm level data, this paper will investigate why firms choose to carry out R&D, how R&D input supports new product output, how R&D activity affects productivity, and the effect of globalization, e.g. FDI and exports, on innovation during the process.

The paper focuses precisely on four major but distinctive manufacturing industries: Textiles (code 17), Wearing Apparel (code 18), Transport Equipment (code 37) and Electronic Equipment (code 40).[2] The first two industries are more labor intensive and low-tech, while the others are more capital intensive and high-tech. All four are not only important in the Chinese domestic market but also in the world market. The textile industry is the largest manufacturing sector in China, in terms of number of firms and size of labor force. The textiles and wearing apparel industries, are sectors with competitive advantages in the world market and but also are sectors in which trade conflicts can easily arise. Furthermore, these sectors have sufficient power to influence the employment market in China, and the textile products market worldwide. The transport equipment sector has been a developed industry for more than half a century in China, and it will grow fast with the high-speed railway plan in Mainland China in the coming decades. More than half of the electronic equipment firms are controlled by overseas capital, which makes it a sector with two foreign markets: materials and components imported from abroad and products exported abroad, especially to developed countries. All the four sectors have grown extremely quickly and have been quite innovative in recent years. Our analysis thus relies on four firm samples separately for the 2 years: 2005-2006.

The paper is organized as follows. Section 2 summarizes the literature strands. Section 3 introduces the equations of the structural model and the estimation method of this paper. Section 4 describes data and variables selection. The empirical results are presented in section 5 and section 6 draws the conclusion and policy suggestions.

[2] Electronic Equipment here means “Manufacture of Communication Equipment, Computers and Other Electronic Equipment”. It is comparable with code 32 in UN ISIC 3.1.

2. Literature Review

The productivity ratio between input and output in production has been a classical area of study since the Cobb-Douglas production function was proposed in 1928. Since then, thousands of discussions, ameliorations and empirical studies have been contributed to this academic area, together with the remarkable improvements by Tinbergen (1942), Solow (1957), and Jorgenson (1987). Griliches (1979) develops the knowledge production function and gives innovation criteria a new position in the equation. Crépon Duguet and Mairesse (1998) propose a new system, combining the innovation selection function, the knowledge production function and the production function together to analyze the innovation procedure and production performance. That is what we call the CDM model.

The CDM model is a systematic attempt to understand the relationships and linkages among innovation input, innovation output and production performance, especially using firm level data. Most of the existing studies using a CDM model incorporate survey data, especially Community Innovation Surveys (CIS) data from European countries.[3] Lööf and Heshmati (2002) study Swedish CIS II data to analyze knowledge capital and firm performance. They give a good comparison of key parameters in earlier CDM models. The parameters are various but all are positive using French and Swedish data. Janz *et al*. (2004) compare innovation and productivity in Germany and Sweden by using CIS III firm data and get "a common story across countries". Ferreira *et al*. (2007) give both separate and simultaneous estimation of a CDM equations system and get different results by using Portuguese CIS II firm data. Mohnen *et al*. (2006) work on CIS I firm data to compare 7 European countries and develop the measure of *innovativity*, which combines the micro measurement and aggregate macro comparison. Benavente (2002) estimates the CDM model by using Chilean survey data designed under the reference of CIS, but the sample size is much smaller.

[3] Up to 2010, Eurostat has launched five innovation surveys under the direction of the "Oslo Manual". These surveys are known as CIS I to CIS V, mainly organized in 1993, 1997-1998, 2000-2001, 2004, and around 2010.

A CDM related model has been estimated in a few papers using hard data, including data from China.[4] Jefferson *et al*. (2006) studies R&D and firm performance of Chinese large and medium-size manufacturing firms by using a rich set of census data from 1997 to 1999, with original observations of nearly 20,000 in all manufacturing sectors before being cleaned each year.[5] Hu and Jefferson (2004) discuss the same question using sample survey data of state-owned enterprises located in Beijing. These results suggest substantial and significant returns to R&D, and a difference across industries.

Export and FDI based globalization is another interesting topic discussed in academic papers. Empirical study of the linkage between exporting and innovation using micro data has increased in recent years. One direction emphasizes the contribution of innovation to entry into the global market. Most of the results suggest a positive effect of innovation on exports, e.g. among Canadian manufacturing firms by Baldwin and Gu (2004), German service firms by Ebling and Janz (1999), and Chinese firms by Guan and Ma (2003).[6] Another is the reverse direction; i.e. investigating the causality from exports to innovation, i.e. the learning-by-exporting effect in firms. A positive impact of exporting on innovation at the firm level is presented in Salomon and Shaver (2005) for Spain, Hahn (2010) for Korea, and Tsou *et al*. (2008) for Taiwan. Moreover, Amiti and Freund (2008) find that China's export growth is supported by growth of existing products, rather than new products, Wang and Wei (2008) find that foreign firms do not conduct R&D to introduce new products.

This paper will focus on firm behavior, from the innovation process to firm performance. Effects of exporting and foreign ownership on innovation are investigated during the stepwise estimation. The contribution of this study is the subdivided sector level study which tests the effectiveness of the CDM model by not

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4 Hard data means not survey data where standard answers are selected, but real amounts of value in accounting and production, such as the value of exports, sales of new products and so on.

5 The size is defined by the China National Bureau of Statistics. The standards are different among sectors using particular products, fixed assets and so on before 2002. The system was simplified in 2003 using three criteria i.e. labor force, sales of products and total assets, but most of them can be compared with the old standards. Here are the new standards for reference: medium-size manufacturing firms' must have at least 300 people, 30 million sales and 40 million assets; large-size must have 2000 people, 300 million sales and 400 million assets.

6 Other inconsistent results by Willmore (1992), Sterlacchini (2001) and other papers suggest the contrary, though the amount is much smaller than the positive results.

using survey, but firm level hard data, and distinguishes the globalization effect on innovation.

3. Econometric Model

The CDM model gives us a systematic understanding of the innovation path in production. It brings together the three main fields of investigation in the econometrics of research and innovation, i.e. why firms select innovation inputs, innovation output efficiency, and innovation's impact on productivity. It has three steps and four equations written as follows, with ***i*** index firms and ***t*** index year. Vector x series are explanatory variables, vector b series are parameters and vector u series are error terms.

Innovation input: $$brd_{(t-1)i} = x_{0(t-1)i}b_0 + u_{0i} \quad (1)$$

$$lrdpl_{(t-1)i} = x_{1(t-1)i}b_1 + u_{1i} \quad (2)$$

Innovation output: $$lnppl_{ti} = \alpha * \widehat{lrdpl}_{(t-1)i} + x_{2ti}b_2 + u_{2i} \quad (3)$$

Innovation performance: $$lp_{ti} = \gamma * \widehat{lnppl}_{ti} + x_{3ti}b_3 + u_{3i} \quad (4)$$

Step one, known as the innovation function, explains innovation input with two equations shown as equations (1) and (2). The first equation is a probit model as a selection equation to understand firms' decisions about whether or not to input innovation. The second equation is a Tobit model to explain why they would like to spend more or less on innovation. We use the Heckman procedure in the STATA software to estimate the first two equations, in which the data is one year earlier than the following two steps.[7] Explained variables in innovation input are measured by a binary variable (*brd*) in the probit model to identify whether firms have made an

[7] The result for electronic equipment is difficult to converge by using data of 2005. We use the pooled 2005-06 data in all the 3 steps after comparing the 2006-only result.

innovation input or not, and R&D intensity measured by R&D expenses per labor unit (*lrdpl*, in logarithm) in the Tobit model to explain why they would choose to spend different amounts on innovation. The regressors are market share, capital intensity, binaries of exporting and subsidy, as well as control variables such as firm size dummies and ownership dummies.[8]

Step two with equation (3) is a knowledge production function, proposed by Griliches (1979), which explains innovation input and its influence on innovation output. Innovation output is measured by new product output per labor unit (*lnppl*, in logarithm) to identify the extent to which firms have innovation output. Here we estimate its predicted value (*lnppl*) and input it as an explained variable in the third step, so that all the firms can be involved in the last equation. The predictor variables are predicted value of R&D expenses (*lrdpl*), capital intensity, a binary of export and subsidy, and dummy groups of firm size and ownership.

In the first two steps, we test an innovation related group of binary variables, export and subsidy, to explain the relative characters of globalization and government support for firms' innovation behavior.

Step 3 with equation (4) is an extended Cobb-Douglas production function to explain innovation output and its influence on productivity, measured by labor productivity (*lp*, in logarithm). The predicted value of innovation output (*lnppl*) is a regressor, except for the traditional variables of capital intensity and number of employees. Dummy variables for ownership, as well as region and sub-sector are also added in this step.

In order to include all the firms in the model, we follow the estimation method in Griffith *et al*. (2006) by using predicted values from earlier steps in later steps. Some groups of variables are added as binaries or dummies to specify characters of firms, such as ownership, region, size, sub-sector and so on. We also estimate the innovation input equation one year earlier than the innovation output and firm performance

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[8] "Subsidy" which is the income from government or international organizations, involves 3 main kinds. The first is innovation related income, e.g. subsidy for carrying out an R&D project or filing a patent, obtaining a development fund, or producing some special kinds of new products. The second is production related, e.g. return of added value tax for exports, subsidy for environment protection. The third is income of obtaining an award, e.g. bonus for pilot products, famous brand award and so on. Appendix Table A2 lists the average labor productivity of firms with or without subsidy. We will not discuss the table further due to the complex components of this variable.

equations, assuming that innovation input has a time lag in influencing innovation output, but the effect of innovation output on performance is mainly in the same year. Similarly, we estimate the pooled four sectors to test the robustness of our findings.

The estimation using estimated values assumes that all firms have the potential for innovation. This is a simplification of the original CDM model, which is much more convenient than the other two methods. One of these is the simultaneous estimation of four equations using the Inversed Mills Ratio, estimated in the earlier step, to correct the standard error. The other is to give zero observations, especially those in innovation variables, a very small value like 0.0001 to avoid selectivity bias (Jefferson *et al*., 2006).

4. Data and Description

4.1. Data and Selection

This paper will use the industrial census data in 2005 and 2006.[9] They are the most recent firm level data that it is possible to obtain from the China National Bureau of Statistics. It is a yearly census of all state-owned firms, and those non-state-owned middle and large firms above a designated size.[10] The criteria are all hard data and most of them are from yearly accounting reports by enterprises. The structure of the data is similar to but much richer than Jefferson *et al*. (2006) investigate, for the textile sector observations alone reach 20,000 before "cleaning" in 2006. The dataset gives us a wide field of research, but also poses challenges in terms of variances and other matters which require sector by sector investigation.

From the original data we delete those firms with fewer than 10 employees, or whose sales of products are less than RMB 5 million, or whose value added is less then zero.[11] Then we calculate the growth rates of sales, labor and capital for each firm.

[9] We do have a long panel before 2005, but there is a gap of observation changes and an unexpected absence of innovation criteria in 2004, which restricts the usage of the long run panel.

[10] The designated size means that Sales of Products is higher than RMB 5 million (about EUR550,000). Firms larger than this size are included in the census scheme and report their data every year by filling in a set of statistical forms. Firms smaller than this size are surveyed separately using sampling methods.

[11] The deletion of small sales firms can help us to get the same standard of state-owned and non-state-owned firms, since non-state-owned firms with sales less then 5 million are not included in the census scheme.

Firms with all the three growth rates between the 2.5 and 97.5 percentile are kept in the modeling. Thus we obtain two-year balanced data from 2005 to 2006.

Three groups of variables are selected to establish the CDM model. The first group are basic variables in innovation and the production function, including labor productivity calculated as value added divided by number of employees, number of employees, capital (shown as net value of fixed assets) per employee, all in logarithm.[12] The second group is innovation variables, with R&D expenses per labor unit (in logarithm), new products output per labor unit(in logarithm) and a binary to identify whether the firm has continuous R&D expenses or not in 2006, following its positive expenditure in 2005. The third group is extended variables including market size, measured by sales ratio in 3-digit sub-sectors, firm size by four dummies, categories of capital control by five ownership dummies to measure the ownership of each firm. All these variables are detailed in appendix A.[13]

4.2. Basic Description

Table 3 gives the basic description of variables in each sector and each corresponding year, with the pooled four sectors data in the last two columns for reference. For basic variables, average labor productivity increases more than 15% in textiles and transport equipment in 2006, about 10% in wearing apparel, but only 3.5% in electronic equipment, though this sector has the highest level of productivity. The average numbers of employees are around 300, 340 and 350 in the first three sectors respectively, and they do not change much across the two years. The number is much higher in electronic equipment firms, and it grows about 10% in 2006 to nearly 700 people. Capital intensity in wearing apparel is about 23,000 RMB, much lower than that of the other three sectors, whose intensity is about 70,000 to 80,000 RMB.

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[12] Capital per employee is also a predicted variable used in the innovation function to measure firm size, together with market size.

[13] It is the smallest sector category in China Industry Standard. The market size defined as sales ratio like: $lsts_{it} = \ln(S_{it} / \sum_{sub-sector} S_{it})$, with S_{it} index sales of products of firm i in year t, and $\sum_{sub-sector} S_{it}$ index of total sales of the 3-digit sub-sector that firm i involved in in year t. Each firm belongs to only one 3-digit sub-sector in the database. We do not have further information about different products in one firm.

Table 3. Means of Variables across Sectors and Years

	Textile		Wearing Apparel		Transport Equipment		Electronic Equipment		Pooled 4 Sectors	
	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005
Basic*										
Productivity	80.3	68.7	50.2	45.7	104.1	90.0	117.8	113.9	84.0	74.6
Labor	307	303	342	333	362	355	684	622	382	367
Capital per Employee	67.7	64.3	23.4	22.5	74.2	70.7	80.8	80.2	61.2	58.8
Innovation										
R&D *	2.5	1.5	1.7	1.9	10.1	8.5	18.3	16.9	11.0	9.7
R&D>0	0.062	0.057	0.048	0.047	0.215	0.192	0.281	0.251	0.121	0.110
Continuous R&D	0.035	-	0.025	-	0.148	-	0.202	-	0.080	-
New Product *	75.5	62.3	102.1	86.2	514.2	421.7	790.6	707.0	456.6	368.6
New Product>0	0.083	0.072	0.061	0.067	0.180	0.164	0.196	0.181	0.114	0.105
Dummy Variables										
Export=1	0.403	0.408	0.645	0.645	0.279	0.269	0.585	0.579	0.459	0.459
Subsidy=1	0.140	0.154	0.115	0.120	0.187	0.182	0.192	0.193	0.152	0.158
Firm Size										
Size:<50	0.128	0.130	0.033	0.032	0.110	0.116	0.082	0.085	0.097	0.099
Size:50-99	0.237	0.238	0.139	0.138	0.251	0.267	0.173	0.185	0.208	0.214
Size:100-249	0.350	0.349	0.401	0.407	0.345	0.341	0.287	0.283	0.350	0.350
Size:250-999	0.234	0.231	0.379	0.379	0.226	0.210	0.308	0.303	0.275	0.270
Size:>999	0.052	0.052	0.049	0.044	0.068	0.065	0.150	0.144	0.069	0.066
Ownership										
State-owned	0.009	0.010	0.006	0.006	0.049	0.052	0.018	0.018	0.018	0.018
Limited Liability	0.111	0.111	0.077	0.073	0.194	0.190	0.129	0.119	0.122	0.119
Share-holding	0.014	0.015	0.009	0.010	0.024	0.025	0.023	0.024	0.016	0.017
Private	0.586	0.575	0.422	0.414	0.426	0.415	0.252	0.251	0.469	0.460
HMT	0.135	0.134	0.239	0.238	0.081	0.078	0.261	0.259	0.166	0.165
Foreign	0.098	0.098	0.210	0.214	0.130	0.131	0.286	0.295	0.157	0.159
Number of Firms	13245		6645		5926		4534		30350	

Notes: (1) The table lists the balance panel data by year.
(2) Variables with "*" are original variables before logarithm, with the units of RMB000 in current prices, except labor which is headcount. Price is adjusted in the regression. The indices of the 4 sectors in 2006 are 102.1, 100.9, 99.5, and 96.6, respectively.
(3) R&D is the average R&D expense per employee of firms with R&D>0.
(4)New Product is the average new product output per employee of firms with New Product>0.
(5)HMT means Hong Kong, Macao and Taiwan.

For innovation variables, only about 5% to 6% of firms have R&D input in the first two low-tech sectors. This grows to about 20% in transport equipment, and nearly

30% in electronic equipment. In all these four sectors, for those firms with R&D input in 2005, more than half of them continue to input in innovation in the second year. This proportion is 77% in transport equipment and 80% in electronic equipment. Furthermore, R&D intensity is quite different among these sectors. Textile and wearing apparel firms have about 2,000 RMB R&D expenses per employee in those two years, while the number in transport equipment is about 10,000, and 18,000 in electronic equipment. The R&D expenses increase in three sectors and decrease in wearing apparel, but it is difficult to describe a long-term trend for the two-year data. For innovation output, the proportion of firms outputting new products firms is about 1% to 2% higher than the R&D input ratio in the two low-tech sectors, but is lower in the two high-tech sectors, especially about 7% to 8% lower in electronic equipment. The estimation result will explain why input is lower but output is higher in this sector. The intensity of new products output in all the sectors grows fast in 2006, though the average level is quite different among these sectors. High-tech sectors have much higher new product output than low-tech. This reaches 790,000 RMB in electronic equipment and 514,000 RMB in transport equipment. It is only around 100,000 RMB in wearing apparel, but this is higher than that in textiles.

The ratios of firms which export are about 40% in textiles, 64.5% in wearing apparel, and around 58% in electronic equipment. The export ratio is much lower in transport equipment, reaching only around 27% of all the firms in this sector. The ratio of firms receiving subsidy is higher in the high-tech sectors than in the low-tech sectors. Nearly 20% of high-tech firms have subsidy from the government, either for innovation or export. Only about 15% of textile firms and 12% of wearing apparel firms receive any subsidy from the government. The trend of this ratio goes slightly down in 2006 for all the sectors except transport equipment.

Firm size dummies show significant increases in the two smallest categories and decreases in the two largest categories in all these sectors. Ownership dummies show private firms are the largest ownership group in the first three sectors, comprising around 58% of textile firms, about 42% of wearing apparel firms and the same proportion in transport equipment firms. Overseas capital, including Hong Kong, Macao and Taiwan (HMT) and foreign capital, controls more than half of electronic equipment firms. Moreover, state-owned firms are a very small proportion in all these four sectors: 5% in transport equipment, and less than 2% in the other three sectors. Together with Limited Liability Corporations and Share-holding Corporations, firms controlled by state or public capital are less than 20% in all the sectors, except about 27% in transport equipment.

4.3. Innovation and Export in Firm Performance

Table 4 presents labor productivity in different innovation and/or export aggregations. In all these sectors, the productivity of R&D innovators is much higher than non-R&D innovators, and that of product innovators is much higher than non-product innovators in almost all cases, whether or not the firm is an exporter. For instance, the average productivity of innovators among electronic equipment firms is 46% larger than that of non-innovators in 2006, and 40% in 2005. The only exception is product innovators in wearing apparel, with 13% lower productivity than non-innovators in 2005. On the other hand, levels of productivity specifies by export are quite different among sectors. Non-exporters always have higher productivity than exporters in most cases in the low-tech sectors, but the productivity of exporters is higher than non-exporters in most cases in the high-tech sectors. The only two exceptions are textile product innovators in both years and non-product innovators in electronic equipment in 2006. Comparing these two methods of classifications, the difference between exporters and non-exporters is much smaller than that between innovators and non-innovators.

Table 4. Cross-table of Labor Productivity

	Textile		**Wearing Apparel**		**Transport Equipment**		**Electronic Equipment**	
	2006	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**
All firms	80.3	68.7	50.2	45.7	104.1	90.0	117.8	113.9
of which: Exporter	72.8	62.8	47.0	42.0	113.4	95.4	121.7	120.5
Non-Exporter	85.4	72.8	56.1	52.5	100.5	88.0	112.4	104.9
R&D Innovator	95.0	80.3	70.2	62.4	133.0	116.2	158.6	143.2
of which: Exporter	92.3	80.1	63.9	58.5	139.3	120.5	167.6	148.0
Non-Exporter	98.3	80.6	80.9	68.7	128.2	113.4	145.1	136.2
Non-R&D Innovator	79.4	68.0	49.2	44.9	96.2	83.8	102.0	104.1
of which: Exporter	71.0	61.4	46.1	41.3	100.7	85.5	103.2	111.0
Non-Exporter	84.8	72.4	54.8	51.6	94.8	83.3	100.3	94.7

Table 4 (continued). Cross-table of Labor Productivity

	Textile		Wearing Apparel		Transport Equipment		Electronic Equipment	
	2006	2005	2006	2005	2006	2005	2006	2005
Product Innovator	90.0	72.3	49.2	38.6	123.8	106.6	163.8	158.0
of which: Exporter	95.1	73.4	46.8	35.7	130.9	110.5	176.6	165.5
Non-Exporter	77.4	69.4	59.8	49.9	115.9	102.7	139.0	145.1
Non-Product Innovator	79.4	68.4	50.3	46.3	99.8	86.8	106.7	104.2
of which: Exporter	69.0	61.3	47.0	42.6	104.4	88.9	106.2	109.4
Non-Exporter	85.7	72.9	56.0	52.6	98.5	86.1	107.3	97.3

Notes: (1) The table lists the average value of balance panel data by year.
(2) The unit is RMB000 in current prices.
(3) Numbers of firms are omitted. The 3 smallest groups have 76, 89, and 118 firms.

5. Empirical Result

Empirical results of the CDM model help to answer the following questions, (i) why or why not the firms decided to engage in R&D input, and what is their reason for expending more or less in innovation if they decided to spend at all, (ii) whether innovation output is the result of R&D input or not, (iii) whether firms' innovation output improves their product output performance, and (iv) the effect of globalization variables, such as exporting and ownership, on innovation.

The results can be interpreted in two dimensions: the equation and variable level, and the sector level. The equation level tells us the main relationships of the innovation process, globalization and firm performance by the parameters of key variables. The sector level may tell a different story in different industries when they practice innovation. We will follow the equation level to organize the discussion.

5.1. Innovation Input

We start the interpretation by considering why and to what extent firms choose to innovate. The eight columns in Table 5 give estimates of the four selected sectors, and compare selection and intensity equations sector by sector. The innovation input equations show that firms' capital intensity and market share are significantly positive in improving R&D input for all the four sectors, in both selection and intensity equations, in 2005. They are extremely similar among sectors and between selection and intensity equations.

Table 5. Innovation Input: Selection and Intensity Equation

Dep. Var.= R&D	Textile		Wearing Apparel	
	Selection	Intensity	Selection	Intensity
	(1)	(2)	(3)	(4)
Market Share	0.109***	0.349***	0.130***	0.271**
	(0.017)	(0.071)	(0.021)	(0.119)
Capital per Employee	0.109***	0.510***	0.137***	0.251**
	(0.018)	(0.074)	(0.028)	(0.123)
Export	0.120***	0.327*	-0.059	-0.291
	(0.041)	(0.171)	(0.060)	(0.216)
Subsidy	0.223***	0.633***	0.318***	0.732**
	(0.046)	(0.186)	(0.073)	(0.329)
Size:50-99	0.181***	-	0.115	-
	(0.071)		(0.179)	
Size:100-249	0.211***	-	0.116	-
	(0.069)		(0.171)	
Size:250-999	0.448***	-	0.202	-
	(0.072)		(0.171)	
Size:>999	0.772***	-	0.376*	-
	(0.091)		(0.205)	
State-owned	0.146	-0.498	0.808***	-1.008
	(0.154)	(0.540)	(0.219)	(0.779)
Limited Liability	0.126**	-0.043	-0.039	-0.070
	(0.056)	(0.214)	(0.103)	(0.366)
Share-holding	0.234**	-0.097	0.018	1.089*
	(0.120)	(0.413)	(0.216)	(0.655)
HMT	-0.280***	-1.110***	-0.302***	-0.241
	(0.063)	(0.261)	(0.077)	(0.323)
Foreign	-0.115*	-0.509*	-0.254***	-0.253
	(0.066)	(0.262)	(0.078)	(0.306)
Constant	-1.394	-4.125	-0.904	-1.924
	(0.205)	(0.727)	(0.293)	(1.192)
Rho		0.825		0.660
		(0.040)		(0.229)
Wald		95.56		28.05
Log Likelihood		-4053.9		-1773.9
Observation		12982		6645

Note: Year=2005.

Table 5(continued). Innovation Input: Selection and Intensity Equation

Dep. Var.= R&D	Transport Equipment		Electronic Equipment	
	Selection	Intensity	Selection	Intensity
	(5)	(6)	(7)	(8)
Market Share	0.039***	0.194***	0.156***	0.196***
	(0.014)	(0.036)	(0.014)	(0.042)
Capital per Employee	0.236***	0.574***	0.070***	0.227***
	(0.021)	(0.067)	(0.013)	(0.038)
Export	0.060	0.110	0.010	-0.656***
	(0.050)	(0.126)	(0.037)	(0.098)
Subsidy	0.289***	0.129	0.663***	0.731***
	(0.050)	(0.129)	(0.036)	(0.151)
Size:50-99	0.265***	-	0.007	-
	(0.092)		(0.068)	
Size:100-249	0.519***	-	-0.002	-
	(0.088)		(0.070)	
Size:250-999	0.982***	-	0.060	-
	(0.093)		(0.084)	
Size:>999	1.493***	-	0.228**	-
	(0.120)		(0.104)	
State-owned	0.402***	-0.326	0.710***	-0.216
	(0.089)	(0.223)	(0.108)	(0.272)
Limited Liability	0.330***	0.195	0.478***	0.623***
	(0.055)	(0.165)	(0.049)	(0.154)
Share-holding	0.307**	0.562**	0.602***	0.686***
	(0.121)	(0.277)	(0.100)	(0.225)
HMT	-0.199**	-0.415*	-0.352***	-0.633***
	(0.086)	(0.251)	(0.047)	(0.149)
Foreign	0.102	0.287	-0.363***	0.074
	(0.067)	(0.178)	(0.046)	(0.146)
Constant	-2.222	-1.471	0.372	1.191
	(0.187)	(0.466)	(0.180)	(0.343)
Rho		0.370		0.322
		(0.086)		(0.119)
Wald		136.88		159.88
Log Likelihood		-4634.2		-9673.5
Observation		5926		9068

Note: Year=2005 for Transport Equipment, but pooled 2005 & 2006 for Electronic Equipment.

Export parameters are significantly positive in textiles and negative in electronic equipment, but are not significant in the other two sectors. Textiles is a traditional sector with a world competitive advantage that may encourage firms to decide to undertake R&D so as to keep their advantage, and the high profits from potential markets, by spending more on innovation. Transport equipment firms have the same ownership structure as textiles and some degree of advantage in the world market, which supports the positive but not significant coefficients in both equations. The opposite is true in electronic equipment; that is, a small positive but not significant coefficient is shown in choosing to innovate, but a large negative coefficient appears in the intensity equation, which means that the more firms export, the lower their level of R&D intensity. The result is partly because of the high proportion of overseas capital control in this sector. They pay more attention to exports, but do not necessarily do much research work since most of this kind of work has been done, or even the key component elements have been finished in foreign institutes and factories. A high level of globalization in this high-tech sector is a kind of product globalization, but not a globalization of research activity. Wearing apparel shows the same story, with large negative coefficients of export due to the similar ownership structure, and design work done abroad in exporting firms.

In all these four sectors, firms with subsidies choose to carry out R&D and the subsidy helps to improve R&D intensity. The parameters in all the equations show significantly positive effects, except only one positive but not significant coefficient in the intensity equation for transport equipment.

Firm size dummies suggest that larger firms tend to choose to carry out R&D, the same as suggested by market share. The parameters quickly go up in textiles and transport equipment, while the largest group of firms in the other two sectors have significantly positive effects.

Ownership dummies tell a common story in all the sectors, and we specially emphasize the effect in electronic equipment since the rule is especially clear in it. Compared with private domestic firms, firms controlled by overseas capital especially firms controlled from Hong Kong, Macao and Taiwan (HMT firms), tend not to undertake R&D, or to input less if they do. Firms controlled by state or public capital tend to carry out more R&D. This is a similar result to that derived from our earlier research, and we can get further explanation in the following steps. We can also obtain a successfully positive test in part of the Schumpeter hypothesis, by parameters of either market share or firm size. That is, large firms have a higher tendency towards innovation selection and innovation input.

5.2. Innovation Output

The knowledge production function in table 6 shows that predicted R&D expenses were significantly positive in improving innovation output in 2006. The marginal effects are similar (about 0.15 to 0.20) in the first three sectors, and up to 0.84 in electronic equipment. And if firms continue to do R&D in the second year, they will produce more new products.

Table 6. Innovation Output: Knowledge Production Function

Dep. Var.= New Product	Textile	Wearing Apparel	Transport Equipment	Electronic Equipment
	(1)	(2)	(3)	(4)
R&D_hat	0.152***	0.190**	0.156*	0.844***
	(0.049)	(0.081)	(0.082)	(0.097)
Continuous R&D	0.996***	1.110***	0.914***	0.528***
	(0.075)	(0.123)	(0.060)	(0.050)
Capital per Employee	0.059*	-0.040	0.036	-0.103***
	(0.035)	(0.037)	(0.055)	(0.032)
Export	0.641***	0.360***	0.611***	0.959***
	(0.047)	(0.071)	(0.056)	(0.075)
Subsidy	0.084	-0.062	0.106*	-0.306***
	(0.052)	(0.088)	(0.056)	(0.083)
Size:50-99	0.052	-0.067	0.018	-0.182**
	(0.073)	(0.174)	(0.098)	(0.073)
Size:100-249	0.005	-0.129	0.091	-0.166**
	(0.073)	(0.165)	(0.095)	(0.071)
Size:250-999	0.178**	0.020	0.414***	-0.236***
	(0.082)	(0.167)	(0.104)	(0.080)
Size:>999	0.506***	0.050	0.719***	-0.220**
	(0.112)	(0.205)	(0.139)	(0.104)
State-owned	0.476***	Dropped	0.159	0.427***
	(0.166)		(0.116)	(0.125)

Table 6 (continued). Innovation Output: Knowledge Production Function

Dep. Var.= New Product	Textile	Wearing Apparel	Transport Equipment	Electronic Equipment
	(1)	(2)	(3)	(4)
Limited Liability	0.148**	-0.150	0.065	-0.129
	(0.059)	(0.108)	(0.063)	(0.083)
Share-holding	0.363***	-0.210	0.096	-0.117
	(0.130)	(0.265)	(0.145)	(0.129)
HMT	-0.009	-0.197**	-0.095	0.147*
	(0.080)	(0.080)	(0.108)	(0.082)
Foreign	-0.064	0.027	-0.294***	-0.463***
	(0.073)	(0.078)	(0.088)	(0.057)
Constant	-0.980	-0.511	-1.081	-0.255
	(0.412)	(0.444)	(0.449)	(0.164)
Pseudo R^2	0.2899	0.1838	0.3065	0.2333
Log Likelihood	-2638.3	-1240.5	-1935.1	-3343.5
Observation	12962	6514	5892	9046

Notes: (1) Year=2006 for the first 3 sectors, but 2005 & 2006 pooled data for Electronic Equipment.
(2) R&D_hat is the estimated result in the innovation input equation, with 1 year lag to the innovation output equation, except the same year in the Electronic Equipment sector.

Export improves innovation output in all the sectors, which suggests that firms serving the global market tend to engage in producing new products, whether or not they themselves choose to undertake R&D.

Subsidy only significantly impacts innovation output in the two high-tech sectors, but in opposite directions. It is positive in transport equipment, but negative in electronic equipment since firms in the latter sector gain new products not by doing subsidy supported R&D, but more often by directly using technology transferred from abroad. Furthermore, domestic firms in the electronic equipment sector with low levels of output tend to obtain a variety of support from government in the name of innovation, since this sector has been defined as a core high-tech sector, and emphasized by the government as an area to be encouraged in innovation policy. Foreign firms get less in subsidy, but they hold their competitive advantage by using technology from abroad, which can sufficiently support the high efficiency of their product innovation. On the other hand, the insignificant coefficients in low sectors indicate two things. The first is that low-tech sectors like textiles and wearing apparel obtain subsidies for exporting to a greater extent than from innovation. The second is that the government pays more attention to the linkage of innovation and high-tech business, but ignores the importance of innovation in keeping a competitive advantage for those low-tech sectors that have already found global competitiveness.

Firms size dummies tell the same story of the importance of size in the first three sectors, supporting the opinion that large firms tend to have more new product output. On the other hand, large electronic equipment firms tend to have low new product intensity. Ownership in all the four sectors indicates that firms controlled by state or public capital have a high intensity of innovation output and firms controlled by overseas capital have less. Comparing with the R&D input equations in the first step, we get common results in ownership dummies, and similar results in at least three sectors except for electronic equipment in innovation output.

5.3. Innovation Performance

Finally, we interpret the firm performance estimation of the production equation as shown in Table 7. The parameters of estimated new product output in all four sectors give a positive effect. The elasticity of each sector is from 0.246 in transport equipment, to 1.112 in electronic equipment.

Table 7. Innovation Performance: Production Function

Dep. Var.= Productivity	Textile	Wearing Apparel	Transport Equipment	Electronic Equipment
	(1)	(2)	(3)	(4)
Capital per Employee	0.209***	0.188***	0.233***	0.125***
	(0.007)	(0.010)	(0.012)	(0.009)
Labor	-0.300)	-0.214***	-0.188***	-0.294***
	(0.008)	(0.013)	(0.015)	(0.010)
New Product_hat	0.354***	0.467***	0.246***	1.119***
	(0.017)	(0.040)	(0.026)	(0.029)
State-owned	-0.646***	Dropped	-0.427***	-0.683***
	(0.090)		(0.059)	(0.084)
Limited Liability	-0.118***	0.060	-0.068**	-0.386***
	(0.024)	(0.038)	(0.028)	(0.033)
Share-holding	-0.215***	0.242**	0.026	-0.439***
	(0.069)	(0.104)	(0.077)	(0.067)

Table 7 (continued). Innovation Performance: Production Function

Dep. Var.= Productivity	Textile	Wearing Apparel	Transport Equipment	Electronic Equipment
	(1)	(2)	(3)	(4)
HMT	0.037*	0.054**	0.029	0.258***
	(0.021)	(0.025)	(0.043)	(0.026)
Foreign	0.058**	-0.033	0.351***	0.453***
	(0.023)	(0.024)	(0.038)	(0.028)
Constant	4.964	4.607	4.289	5.535
	(0.071)	(0.108)	(0.163)	(0.091)
F	96.86	46.70	40.71	103.32
R^2	0.2913	0.1803	0.2927	0.3979
Observation	12962	6514	5892	9046

Notes: (1) Year=2006 for the first 3 sectors, but 2005 & 2006 pooled data for Electronic Equipment.
(2) Region dummies and sub-sector dummies are estimated, but omitted in the table.

In contrast with the results of the R&D input equations and new product output equations, the results for firm performance are quite different for the ownership dummies. Compared with private domestic firms, firms controlled by overseas capital tend to have higher productivity, though they input less in R&D terms, and produce fewer new products. On the other hand, firms controlled by state and public capital tend to have lower productivity, though they are apt to carry out R&D and have more new products. According to this point, one advantage of globalization is that the competition among firms in the global market leads to a positive effect on productivity growth in mainland China.

5.4. Globalization and Innovation

Comparing coefficients of the exports and foreign ownership dummies in the first two steps, the globalization of Chinese manufacturing sectors tells the following story. Exports and foreign markets are not necessarily the causation for R&D. It depends on whether the sector has a technological advantage controlled domestically or from abroad. The domestic control tends to improve performance and market growth by innovation, whilst the foreign control tends to finish the R&D and core technical work abroad and to perform only the manufacturing step in mainland China. Neither high-tech nor low-tech decides the high R&D effort. Sectors with local technology control, including patenting and design, prefer innovation input. Otherwise, high-tech sectors do not necessarily input in innovation in an environment of globalization, for they can obtain full technology support from the foreign market if the competitive advantage remains abroad.

Analysis of globalization by capital control gives the same summary, i.e. foreign firms do less in R&D input and new product intensity, but they do have higher productivity compared with other ownerships.

5.5. Pooled Four

In order to test robustness and compare the results at the aggregate level, we estimate the equations by using pooled data from the selected four sectors. Table 8 gives the results of three steps with four equations.

The estimated coefficients are robust when compared with the separate estimation of sector level equations in Tables 4 to 7. Coefficients in the first six rows indicate that market share positively effects the decision to make an R&D input, and R&D intensity, R&D input drives new product output, and new product output promotes growth of productivity, and persistent R&D input is an active cause in encouraging innovation output.

Table 8. Innovation Input, Output, and Performance: Pooled 4 Sectors

	(1) Selection	(2) Intensity	(3) Output	(4) Performance
Market Share	0.092***	0.250***	-	-
	(0.008)	(0.026)		
R&D-hat	-	-	0.114***	-
			(0.026)	
New Product-hat	-	-	-	0.344***
				(0.013)
Capital per Employee	0.137***	0.421***	0.066***	0.237***
	(0.010)	(0.035)	(0.016)	(0.005)
Labor	-	-	-	-0.219***
				(0.006)
Continuous R&D	-	-	0.939***	-
			(0.033)	
Export	0.037	-0.126	0.528***	-
	(0.025)	(0.078)	(0.026)	
Subsidy	0.394***	0.696***	0.115***	-
	(0.026)	(0.086)	(0.030)	

Table 8 (continued). Innovation Input, Output, and Performance: Pooled 4 Sectors

	(1) Selection	(2) Intensity	(3) Output	(4) Performance
Size:50-99	0.157***	-	-0.015	-
	(0.045)		(0.047)	
Size:100-249	0.247***	-	0.018	-
	(0.044)		(0.045)	
Size:250-999	0.475***	-	0.207***	-
	(0.046)		(0.048)	
Size:>999	0.736***	-	0.394***	-
	(0.056)		(0.060)	
State-owned	0.479***	-0.198	0.198***	-0.460***
	(0.062)	(0.174)	(0.073)	(0.043)
Collective	0.266***	0.256**	0.175***	-0.106***
	(0.031)	(0.104)	(0.034)	(0.016)
Corporate	0.389***	0.685***	0.306***	-0.029
	(0.066)	(0.180)	(0.075)	(0.043)
HMT	-0.303***	-0.798***	-0.136***	0.001
	(0.035)	(0.121)	(0.042)	(0.014)
Foreign	-0.178***	-0.123	-0.185***	0.136***
	(0.033)	(0.108)	(0.036)	(0.014)
Constant	-1.688	-3.017	-1.402	4.419
	(0.105)	(0.325)	(0.158)	(0.050)
Rho		0.626		
		(0.038)		
Wald		646.30		
F				270.21
R^2 / Pseudo R^2			0.2678	0.2777
Log Likelihood		-15335.7	-7831.9	
Observation		30087	30074	30074

Notes: Region dummies and sector dummies are estimated and significant, but omitted in the table.

In contrast to the various coefficients' direction of export in the separate four sectors, the aggregate estimation interprets that export to the global market does not significantly impact R&D input, but the overseas market demand does improve new product output.

Without the individual sector characteristics, subsidy retains positive significance in the first two steps using aggregate data, which suggests that subsidy is an important element in supporting the R&D input decision, innovation intensity and new product output. In addition, the effect might be varied in the different sectors that have been investigated in the former sections.

Size dummies indicate that large firms tend to make R&D input, and they also have a higher level of new product output intensity. Ownership dummies give the same result as before, namely that firms controlled by state and public capital have the contrary situation in innovation and productivity, compared with firms controlled by overseas capital. Firms controlled by state and public capital tend to undertake R&D, and they have a higher level of R&D intensity and new product output, but their productivity is lower than private domestic firms. However, firms controlled by overseas capital tend to do less in innovation, but they have a higher productivity, compared with private domestic firms.

6. Conclusion and Policy Remarks

By using a separately estimated CDM model, this paper investigates innovation behavior, and its ability to promote productivity in four Chinese manufacturing sectors. All “cleaned” firms are involved in the model by using predicted values of innovative variables in the estimation of the first two steps. Only four selected sectors are used in this paper due to the complex census data, but they do give sufficient results in different industries, as well as distinguishing the effects of exporting, subsidy, and ownership. Moreover, the results from pooled data sustain the robustness of the sector level estimations.

We conclude the paper by discussing four outcomes, which also indicate the directions for relative policy recommendation.

The main result is that the model proves the positive effect of innovation input on innovation output, and on innovation output on productivity. It sustains the national innovation strategy of improving innovation input in research and development, especially at the firm level. Firm level innovation input is the key element in improving labor productivity, and the foundation of welfare-based wealth accumulation.

The second outcome is that exporting improves innovation output, but does not always sustain innovation input. The innovation output efficiency depends on the demands of the global market through exports, and the innovation input depends not on exports, but on the competitive advantage of the sector in the world market. Therefore creating a competitive advantage in technology is as important as, or even more important than the advantage derived from exporting. The policy towards FDI should encourage not only foreign capital growth and foreign-owned manufacturing processes, but also technology transfer and the spillover of innovation. Besides exporting, customers' demand drives product innovation, which suggests that the exploration of the domestic market is another important means of promoting local R&D, especially for such a large market as mainland China. These are the key processes of the coming economic structure transformation in China.

The third outcome is the interesting opposite effect of different ownerships in innovation and productivity. Firms controlled by state and public capital innovate more due to their operation of the whole process of local production, though they tend to have low levels of productivity. Firms controlled by overseas capital innovate less but produce more, due to their lack of local R&D input, but transfer technology from abroad. In addition, native firms are sensitive to the influence of the government's innovation policies, but private firms controlled by overseas capital make their decision on innovation more simply, related to higher profits or lower taxes. The better way to encourage innovation is to open more and gives the decision to the firms, so that they can evaluate changes of the market through competition. The policy of encouragement of firms based on ownership criteria should be weakened, and the government should pay more attention to the construction of a fair market and competition environment.

For the above two conclusions, globalization is conducive to creating added value and to sustaining years of fast growth through exports and FDI. Moreover, the next step is to learn more from globalization, to establish a better environment of innovation by strengthening the protection of intellectual property rights, transferring policies from encouraging capital introduction to encouraging local innovation in an impartial market environment during the long term of sustainable development.

The last outcome is that innovation is effective not only in high-tech, but also low-tech sectors. Innovation has a positive effect in low-tech sectors such as textiles, which have already gained competitive advantage in long-term development through globalization. Innovation policy should pay more attention to encouraging R&D in this kind of sector, which is important for the maintenance of its competitiveness and for sustaining its employment.

Given the limitations of our work, and in particular to our using only 2 years' data from 4 selected sectors, these initial results should be merely taken as illustrative. We pay more attention to R&D and new product innovation rather than to exports in the systematic estimation, and leave a wide area for further investigation based on the large sample of firm level accounting data. One interesting field is the decomposition of productivity growth by R&D, exports, and FDI. Another is the specification of relationships between innovation and exports, the two key words in the Chinese economy. We will carry out further work in the rich mine of micro data.

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Appendix

Table A1. Variable Definition

Variable Name	Explanation
Basic	
Productivity	Value added per employee (in log.)
Labor	Number of employees (in log.)
Capital per Employee	Fixed assets per employee (in log.)
Market Share	Sales divided by total sales in 3-digit sub-sector (in log.)
Innovation	
R&D	R&D expenses per labor (in log.)
R&D_hat	Predicted value of R&D expenses per labor
New Product	New product output per labor (in log.)
tNew Product_hat	Predicted value of new product output per labor
Continuous R&D	Binary variable equals to 1 in year t if R&Dt>0 & R&Dt-1>0
Globalization	
Export	Binary variable equals to 1 if firm has export
Extended	
Subsidy	Binary variable equals to 1 if firm has subsidy income
Firm Size	
Size:<50	Dummy equals to 1 if employees<50 (for reference)
Size:50-99	Dummy equals to 1 if employees>=50 & <100
Size:100-249	Dummy equals to 1 if employees >=100 & <250
Size:250-999	Dummy equals to 1 if employees>=250 & <1000
Size:>999	Dummy equals to 1 if employees>=1000
Ownership	
State-owned	Dummy equals to 1 if it is a stat-owned firm
Limited Liability	Dummy equals to 1 if it is a limited liability Corporation
Share-holding	Dummy equals to 1 if it is a Share-holding Corporation
Private	Dummy equals to 1 if it is a private firm (for reference)
HMT	Dummy equals to 1 if it is a firm of Hong Kong, Macao and Taiwan funds
Foreign	Dummy equals to 1 if it is a foreign funded firm
Other Dummies	
Region Dummies	Dummies represent different provinces of China (Zhejiang for reference)
Sub-sector Dummies	Dummies represent 4-digit sub-sectors in each sectors (The first sub-sector for reference)
Sector Dummies	Dummies represent 2-digit sectors (Textile for reference)

Table A2. Average Labor Productivity of Firms With or Without Subsidy

	Textile		Wearing Apparel		Transport Equipment		Electronic Equipment	
	2006	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**
All firms	80.3	68.7	50.2	45.7	104.1	90.0	117.8	113.9
of which: Subsidy>0	76.1	67.4	62.8	56.3	112.9	103.0	134.5	126.1
R&D Innovator	95.0	80.3	70.2	62.4	133.0	116.2	158.6	143.2
of which: Subsidy>0	86.3	87.0	85.3	67.2	143.1	117.5	147.9	149.0
Non-R&D Innovator	79.4	68.0	49.2	44.9	96.2	83.8	102.0	104.1
of which: Subsidy>0	74.4	65.0	60.4	55.2	92.8	95.7	120.3	105.2
Product Innovator	90.0	72.3	49.2	38.6	123.8	106.6	163.8	158.0
of which: Subsidy>0	77.8	70.3	50.0	40.9	140.1	114.9	150.6	159.4
Non-Product Innovator	79.4	68.4	50.3	46.3	99.8	86.8	106.7	104.2
of which: Subsidy>0	75.8	67.0	64.1	58.5	100.3	99.2	125.6	110.9
Exporter	72.8	62.8	47.0	42.0	113.4	95.4	121.7	120.5
of which: Subsidy>0	72.7	66.6	63.1	55.7	115.4	97.8	122.7	118.2
Non-Exporter	85.4	72.8	56.1	52.5	100.5	88.0	112.4	104.9
of which: Subsidy>0	80.5	68.7	61.8	58.4	111.0	106.5	154.7	138.0

Notes: (1) The table lists the average labor productivity of balance panel by year.
(2) The unit is RMB000 in current price.

CHAPTER 8

Trade Reforms, Competition, and Innovation in the Philippines

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What is the impact on firms' innovative activities of the removal of barriers to trade? Does the increase in competition arising from trade reforms lead to increases in innovation? This paper attempts to examine the link between trade liberalization and innovation, using firm panel data on the Philippine manufacturing industry. With the framework of Impulliti and Licandro (2009, 2010) as guide, a two-stage approach is tested, where trade and innovation are linked via competition. A reduction in tariffs leads to an increase in competition as price cost margins fall due to the increase in the number of players in the domestic market. With the reduction in price cost margins, profits fall and the productivity threshold above which firms can operate profitably increases. This forces inefficient firms out of the market and resources are reallocated from exiting firms to the higher productivity surviving firms, which innovate at a faster pace. The results show that trade liberalization, has significant positive impact, through competition, on innovation.

Given the crucial role of competition in the relationship between trade liberalization and innovation, it is important for the government to maintain the contestability of markets. The presence of trade barriers or government regulations that limit market entry can create inefficiencies leading to reduced long-term growth. These weaken competition and prevent structural changes from taking place, resulting in resources being tied to low-productivity industries. Weak competition reduces the pressure on firms to adopt new technology or innovate, resulting in low growth of productivity and a loss of competitiveness. Despite two decades of implementing liberalization policy, competition and productivity growth remained weak in the Philippines, not only due to the presence of structural and behavioral barriers to entry, but also to the country's inadequate physical and institutional infrastructure. Due to the fundamental weakness of competition in many major economic sectors, the gains from liberalization remained limited and this slowed down the country's economic growth.

Key Words: Trade, Competition, Innovation, Philippine manufacturing

JEL Classification: L1, O, F1

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1. Introduction

Innovation is defined as the implementation of a new or significantly improved product or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations (OECD, 2007). In general, there is broad consensus among economists that research and development/innovation is a major source of economic growth (Gilbert, 2006). As Aghion and Howitt (1999) argue, innovation is a crucial ingredient to long-run economic growth. Moreover, research shows that the social return to investment in R&D is higher than the private return (Griliches, 1992).

Trade and government policy, along with other factors like institutions, market structure, and market imperfections, can have profound effects on an economic agent's incentives to engage in innovative activities. In the last two decades, we have witnessed rising globalization as countries opened up their economies, creating a new economic environment particularly for developing countries. With the removal of barriers to trade, competition has intensified and has presented both opportunities and challenges to domestic firms to innovate and improve their competitive position.

The number of studies on the impact of trade liberalization on innovation through competition is just starting to grow. The recent literature on trade liberalization looks at its impact on productivity and has increased largely due to the availability of micro data. This body of literature has found that industries facing the greatest tariff reduction and import competition have faster productivity growth than relatively protected industries. This is due to resource allocation arising from the exit of inefficient plants and productivity improvements within existing plants (Pavcnik, 2002 for Chile; Amite and Konings 2007 for Indonesia; Fernandes 2007 for Columbia; among others).

Meanwhile, the theoretical literature on competition and innovation[2] has shown two contradictory views. On the one hand, the Schumpeterian (1942) view argues that increased competition will reduce profits and the company's incentive to innovate. This view sees monopolies as natural breeding grounds for R&D. On the other hand, the opposite view points out that greater competition increases the incentive for firms to

[2] In general, competition and knowledge transfers represent the mechanisms affecting the level of innovation.

innovate in order to survive. Aghion *et al.* (2006) proposed an inverted U-shaped relationship between competition and innovation. The empirical literature has shown mixed evidence on the relationship between competition and innovation.

Since the 1980s, the Philippines has implemented market-opening reforms such as trade and investment liberalization, deregulation, and privatization in order to encourage competition in the economy, increase productivity and stimulate economic growth. The Philippines has made considerable progress in opening-up the economy to competition not only by removing tariff and non-tariff barriers in the manufacturing and agriculture sectors but also in deregulating and liberalizing infrastructure utilities. At the same time, foreign investment rules were relaxed in almost all sectors particularly in areas reserved only for Filipinos. As a result, the current regime is substantially more open, particularly in manufacturing industry.

Using newly created manufacturing firm-level panel data from the Philippines, the paper will examine the impact of trade reforms through increased competition on domestic firms' innovative activities. The study is relevant given not only the substantial reforms implemented in the last two decades but also in the light of the country's low R&D expenditures and the urgent need for technology upgrading. The study will address the following question: What is the impact of the removal of barriers to trade on firms' innovative activities? Did the increase in competition arising from trade reforms lead to increases in innovation?

Clearly, there is a need to understand the impact of trade reforms on innovation along with its other determinants, to help the government in properly identifying the necessary policy measures to encourage R&D investments and technological upgrading in the Philippines. Trade liberalization was one of the major economic reforms carried out in the last two decades. With intense competitive pressures arising from this series of policy changes, understanding their impact on innovation is crucial, particularly since innovation is closely intertwined with growth.

The paper is divided into six parts. After the introduction, section two focuses on the trade and industrial policies and economic performance of the Philippine manufacturing industry. Section three reviews selected literature on competition and innovation. Section four presents the methodology of the paper while section five analyzes the results. Section six concludes and discusses the implications of the paper.

2. Philippine Manufacturing Industry: Trade Policy Reforms, Performance, and Structure

2.1. Government Trade Liberalization Policy

Like most developing countries, the Philippines adopted an import substitution strategy from the 1950s up to the late 1970s. The manufacturing sector is the country's most favored industry given the high level of protection and substantial investment incentives that it enjoyed from the fifties till the eighties. To promote manufacturing growth and development, the government also created regulatory institutions to control prices, domestic supply, and market entry in sectors like cement, passenger cars, trucks, motorcycles, iron and steel, electrical appliances, sugar milling and refining, flour milling, textiles, and paper[3]. This complex maze of protectionist, investment incentive and regulatory policies left a legacy characterized not only by high levels of industrial concentration, and the concentration of economic wealth among a small number of families and groups[4] but also by the lack of a culture of competition and a weak competition policy framework.

After more than three decades of protectionism and import substitution, the government started to liberalize the trade regime by removing tariff and non-tariff barriers. At the same time, privatization and deregulation policies were implemented. The first tariff reform program (TRP 1) initiated in 1981 substantially reduced the average nominal tariff and the high rate of effective protection that characterized the Philippine industrial structure. TRP I also reduced the number of regulated products with the removal of import restrictions on 1,332 lines between 1986 and 1989.

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[3] The government deliberately limited the number of industry participants in the motor vehicle, motorcycle, and electrical appliance industries. The government also created a state-controlled monopoly in the iron and steel industry. Textiles was one of the most highly protected sectors which developed under a complex system of import restrictions, foreign exchange controls, tariffs, subsidies, and investment incentives such as easy access to dollar allocations for the industry's raw material and machinery imports, tax concessions, and easy access loans. Collusive agreements in cement and flour were tolerated by the government.

[4] The Foundation for Economic Freedom reported that the richest 15% of all families account for 53% of total national income. Claessens *et al*. (1999) noted that the Ayala family controlled 17% of total market capitalization while the top ten families in the Philippines controlled 53% of market capitalization.

The second phase of the tariff reform program (TRP II) was launched in 1991. TRP II introduced a new tariff code that further narrowed down the tariff range with the majority of tariff lines falling within the three to 30% tariff range. It also allowed the "tariffication" of quantitative restrictions for 153 agricultural products, and tariff realignment for 48 commodities. With the country's ratification of its membership of the World Trade Organization (WTO) in 1994, the government committed to removal of import restrictions on sensitive agricultural products, except rice, and their replacement with high tariffs. The number of regulated products declined to about 3% in 1996 and by 1998, most quantitative restrictions were removed, except those for rice.

In 1995, the government initiated another round of tariff reform (TRP III) as a first major step in its plan to adopt a uniform 5% tariff by 2005. This further narrowed down the tariff range for industrial products to the 3 to 10% range. In 1996, the government legislated the tariffication of quantitative restrictions imposed on agricultural products, and the creation of tariff quotas imposing a relatively lower duty up to a minimum access level (or in-quota rate), and a higher duty beyond this minimum level (or out-quota rate).

In 2001, more legislation (TRP IV) was passed to adjust the tariff structure towards a uniform tariff rate of 5% by the year 2004, except for a few sensitive agricultural and manufactured items. In October and December 2003, the Arroyo government issued Executive Orders 241 and 264, respectively, to modify the tariff structure such that the tariff rates on products that were not locally produced were made as low as possible while the tariff rates on products that were locally produced were adjusted upward. This resulted in tariff increases on a group of agricultural and manufactured products. As will be shown below, the legislation of EOs 241 and 264 did not lead to any substantial increases in either average nominal or effective protection. However, since many of the tariff increases were made selectively to favor particular industry sectors, the twin EOs hardly made a significant contribution to reducing our highly dispersed tariffs.

Table 1 presents the statutory tariff rates from 1998 to 2004 for the country's major economic sectors. Note that since 2004, no major "Most Favored Nation" (MFN) tariff changes have been implemented. The tariff changes pursued were mainly those arising from regional trading agreements such as the ASEAN Free Trade Agreement. It is evident from the data that our overall level of tariff rates is already low. The average tariff rate for all industries is 6.82%. Agriculture has the highest average tariff rate of 11.3%. Manufacturing rates are the same as the total industry average with an average tariff rate of 6.76%. Fishing and forestry has an average rate of 6% while mining and quarrying is the lowest at 2.5%. Unlike the rest of the sectors where "ad valorem" tariffs are used, tariff quotas are used in agriculture primarily because of the increased protection that they can provide against large reductions in import prices.

Table 1. Average Tariff Rates by Major Economic Sector: 1998-2004

	Implementation of Major Tariff Policy Changes						
Major Sectors	1998	1999	2000	2001	2002	2003	2004
All Industries	11.32	10.25	8.47	8.28	6.45	6.6	6.82
Coefficient of variation	0.96	0.91	0.99	1.04	1.17	1.06	1.07
% of tariff peaks	2.24	2.24	2.48	2.5	2.69	2.53	2.71
Agriculture	15.9	13.2	11.5	12.3	10.4	10.4	11.3
Coefficient of variation	1.07	1.14	1.3	1.23	1.31	1.22	1.17
Fishing & forestry	9.4	8.9	6.7	6.7	5.8	5.7	6
Coefficient of variation	0.63	0.7	0.66	0.62	0.45	0.48	0.57
Mining & quarrying	3.3	3.3	3.1	3.2	2.8	2.7	2.5
Coefficient of variation	0.42	0.41	0.24	0.23	0.38	0.4	0.48
Manufacturing	11.38	10.35	8.5	8.28	6.39	6.57	6.76
Coefficient of variation	0.93	0.88	0.95	1	1.13	1.03	1.03

Source: Aldaba (2005).

Note, however, that a lower level of tariff protection does not always imply that the tariff schedule is less distorting. The economic and trade distortions associated with our tariff structure depend not only on the size of tariffs but also on the dispersion of these tariffs across all products. Two measures are estimated: the percentage of tariff peaks and the coefficient of variation. Tariff peaks are represented by the proportion of products with tariffs exceeding three times the mean tariff, while the coefficient of variation is the ratio of the standard deviation to the mean. In general, the more dispersion in a country's tariff schedule, the greater the distortions caused by tariffs on production and consumption patterns.

As Table 1 shows, while the average tariff rate for all industries dropped from 11.32% in 1998 to 6.82% in 2004, tariff dispersion widened as the coefficient of variation went up from 0.96 to 1.07. The ad valorem tariffs for mining and quarrying as well as those for fishing and forestry show the most uniformity while those for agriculture and manufacturing exhibit the most dispersion.

Table 1 also indicates that the percentage of tariff peaks (tariffs that are greater than thee times the mean tariff) went up from 2.24% in 1998 to 2.71% in 2004. An increase in the number of tariff peaks occurs when high tariffs are reduced by less than the average reduction over all tariffs. The greater the percentage of tariff peaks in a country's tariff schedule, the greater the potential economic distortions, particularly when highly substitutable products are present in both domestic and world markets. The sectors with tariff peaks consisted mostly of agricultural products with in- and out-quota rates. The sectors with tariff peaks consisted of sugarcane, sugar milling and refining, *palay*, corn, rice and corn milling, vegetables like onions, garlic, and cabbage, roots and tubers, hog, cattle and other livestock, chicken, other poultry and poultry products, slaughtering and meat packing, coffee roasting and processing, meat and meat processing, canning and preserving fruits and vegetables, manufacture of starch and starch products, manufacture of bakery products excluding noodles, manufacture of animal feeds, miscellaneous food products, manufacture of drugs and medicines, manufacture of chemical products, and manufacture and assembly of motor vehicles.

Within the manufacturing sector, the average nominal tariff rates vary, with food manufacturing receiving the highest level of 13.8% in 2004 while machinery only receives 3% tariff (see Table 2). The other manufacturing sectors enjoying relatively high average tariff rates include textiles and garments with 11.7% and furniture and fixtures with 11.2%. The rubber and plastic products sector has an average tariff rate of 9% while the beverages sector has an average rate of 8.6%. Based on the coefficient of variation, machinery, transportation, food processing, and chemicals and chemical products exhibit the largest dispersion of tariffs while tobacco, textiles and garments, and furniture and fixtures have relatively low dispersion. Note that manufacturing sectors with relatively high coefficients of variation such as machinery and chemical and chemical products are the same sectors with the lowest average tariff rates of three and 3.6%, respectively.

Table 2. Structure of Average Tariff Rates in the Manufacturing Sector

	1998	1999	2000	2001	2002	2003	2004
Manufacturing	11.4	10.3	8.5	8.3	6.4	6.6	6.8
CV	0.93	0.88	0.95	1	1.13	1.03	1.03
Food manufacturing	20.8	18.2	16.1	16.5	14.4	12.9	13.8
CV	0.98	0.92	1.06	1.08	1.2	1.08	1.01
Beverages	15.3	13.6	9.7	9.7	7	7	8.6
CV	0.41	0.5	0.52	0.52	0.44	0.44	0.53
Tobacco	18.6	13.9	9.1	9.1	6.5	6.5	7.6
CV	0.21	0.22	0.27	0.27	0.22	0.22	0.31
Textile & garments	18.8	17.6	14.3	14.1	10.6	10.9	11.7
CV	0.38	0.31	0.43	0.46	0.45	0.48	0.42
Leather	13	10.6	8.5	8.1	6.1	7.9	7.7
CV	0.76	0.74	0.72	0.7	0.53	0.7	0.77
Wood	13.8	12.3	9.9	9.9	7.1	7.5	7.5
CV	0.59	0.56	0.64	0.64	0.66	0.66	0.66
Furniture & fixtures	19.6	16.3	15	14.4	10.8	11.1	11.2
CV	0.39	0.36	0.45	0.48	0.49	0.45	0.44
Paper	14.2	12.1	9.4	8.9	6	6.6	5.7
CV	0.64	0.6	0.56	0.59	0.64	0.67	0.72
Chemicals & chemical	4.7	4.5	3.9	3.9	3.2	3.3	3.6
CV	0.86	0.84	0.64	0.65	0.73	0.79	1.09
Rubber & plastic prods	13.4	12.1	9.1	9.3	7.9	8.7	9
CV	0.58	0.52	0.56	0.54	0.57	0.56	0.57
Non-metallic mineral	9.8	9	6.7	6.4	4.8	5.7	5.7
CV	0.8	0.77	0.69	0.7	0.6	0.76	0.77
Basic metals	10.2	9	7.8	6.9	4.9	5.4	5.3
CV	0.74	0.73	0.73	0.78	0.74	0.82	0.83
Machinery	6.2	5.9	4.8	4.5	3	3.1	3
CV	0.99	0.96	1.03	1.01	1.16	1.23	1.27
Transportation	11.5	11.2	8.9	8.6	8.1	8.1	7.9
CV	1.09	1.12	1.03	1.06	1.15	1.16	1.2
Miscellaneous prods	8.5	7.5	6	5.8	4.4	4.9	5
CV	0.89	0.81	0.8	0.82	0.76	0.83	0.9

2.1. Economic Performance of Manufacturing Industry: 1980s-2000s

The overall performance of manufacturing industry generally, in terms of output and employment generation has been weak. Table 3 shows that from the 1980s up to the 1990s, manufacturing growth was very slow; averaging 1% in the 1980s and 2% in the 1990s. Growth picked up in the 2000s with manufacturing expanding by 3.4% on the average. However, there seems to have been very little movement of resources in the manufacturing industry, as its share to total industrial output declined from 26% in the 1980s to 25% in the 1990s and to about 24% in the 2000s. As in manufacturing, growth in the agriculture sector remained sluggish up to the 1990s and averaging a rate of 4% during the most recent period. The services sector has been the best performer in all three decades. On average, its growth rate went up from 2.3% in the 1980s to 5% in the 2000s. Broad growth took place as its sub-sectors consistently experienced rising growth rates. Services also accounted for the bulk of the economy's output with the sector's average share rising substantially from 49% in the 1980s to 55% in the current period.

Table 3. Average Value Added Growth Rates and Structure

	Average Growth Rate			Average Value Added Share		
Year	81-89	90-99	00-09	81-89	90-99	00-09
Agric, Fishery, &Forestry	1.3	1.5	3.5	**23.5**	**21.6**	**19.2**
Industry Sector	0.9	2.1	3.9	**27.6**	**26.4**	**25.4**
Mining & Quarrying	3	-1.4	12.7	1.7	1.3	1.5
Manufacturing	0.9	2.3	3.4	**25.9**	**25.1**	**23.8**
Service Sector	2.3	3.7	5.2	**48.9**	**52**	**55.4**
Construction	-1.4	2.9	4	7.5	5.6	4.6
Electricity, Gas and Water	5.3	5.3	3.7	2.6	3.1	3.2
Transport, Communication & Storage	3.7	4.4	7.6	5.3	6	8.3
Trade	3	3.5	5.3	13.9	15.3	16.6
Finance	2.3	5.6	6.9	3.5	4.4	5.3
Real Estate	2.5	2.2	3.2	5.4	5.5	4.7
Private Services	5.5	3.6	3.8	6.3	7	8.1
Government Services	3.2	3.6	2.8	4.6	5.2	4.5
TOTAL GDP	**1.7**	**2.8**	**4.6**	**100**	**100**	**100**

Source: National Income Accounts, NSCB.

In terms of employment generation, manufacturing industry failed in creating enough jobs to absorb new entrants to the labor force. Table 4 indicates that its share of total employment remained stagnant at 10% in the 1980s till the 1990s and dropped to

9.2% in the 2000-2008 period. The services sector is the most important provider of employment in the recent period with its average share increasing from 40% in the 1980s to 47% in the 1990s. Currently it accounts for an average share of almost 54%. Agriculture's share in total employment dropped continuously from 50% in the 1980s to 43% in the 1990s and to 37% in the current period.

Table 4. Employment Growth Rate and Structure

Economic Sector	Average Growth Rate			Average Share		
	81-89	90-99	00-09	81-89	90-99	00-09
Agriculture, Fish'y, Forestry	**1.2**	**0.7**	**1.4**	**49.6**	**42.8**	**36.6**
Industry	2.5	1.7	0.8	10.6	10.6	9.6
Mining and Quarrying	5.3	-4.6	7.9	0.7	0.5	0.4
Manufacturing	**2.5**	**2.1**	**0.6**	**9.9**	**10.2**	**9.2**
Services	**4.8**	**4.2**	**3.6**	**39.8**	**46.6**	**53.8**
Electricity, Gas and Water	**5.7**	**5.7**	**3.6**	**0.4**	**0.4**	**0.4**
Construction	**4.9**	**5.3**	**2.6**	**3.5**	**5**	**5.2**
Wholesale & Retail Trade	6.2	3.8	4.6	12.5	14.6	18.4
Transport, Storage &Com	4.9	6.1	3.4	4.4	5.9	7.5
Finance, Ins, Real Estate & Business	3.2	6.2	8	1.8	2.2	3.3
Community, Social & Personal Services	4.1	3.6	2.5	17.1	18.5	19
TOTAL EMPLOYED	2.7	2.5	2.5	100	100	100

Source: National Income Accounts, NSCB.

Table 5 shows the distribution of value added in manufacturing industry. Consumer goods comprised the bulk of manufacturing value added, although their share declined from 57% to 50% between the eighties and the 1990s. In the current period, the sector's share remained at 50%. Food manufacturing represented the most important sub-sector accounting for an average share of 39% of the total in the current period. Intermediate goods followed with a share of 27% in the 2000s, a decline from 35% in the 1990s and 31% in the 1980s. Petroleum and coal had the highest average share of 14% in the 2000s. With the growing importance of electrical machinery, the share of capital goods increased steadily from 10% in the 1980s to 13% in the 1990s and 19% in the 2000s. Electrical machinery posted an average growth rate of 3% in the 1980s, 6% in the 1990s, and 12% in the 2000s.

Table 5. Average Value Added Structure and Growth

Industry Group	Average Growth Rate			Average Value Added Share		
	1980-89	1990-99	2000-08	1981-89	1990-99	2000-08
Consumer Goods	**0**	**2**	**5**	**57**	**50**	**50**
Food manufactures	-1	2	6	44	36	39
Beverage industries	7	2	4	4	4	4
Tobacco manufactures	1	1	-6	3	3	1
Footwear wearing apparel	6	2	2	5	6	5
Furniture and fixtures	2	2	7	1	1	1
Intermediate Goods	**2**	**2**	**2**	**31**	**35**	**27**
Textile manufactures	0	-5	0	4	3	2
Wood and cork products	-5	-4	-4	2	2	1
Paper and paper products	4	-1	2	1	1	1
Publishing and printing	3	1	0	1	2	1
Leather and leather prod.	-3	5	0	0	0	0
Rubber products	1	-2	0	2	1	1
Chemical & chemical	-1	2	3	7	6	6
Petroleum & coal	6	4	3	12	17	14
Non-metallic mineral	2	2	3	2	3	2
Capital Goods	**2**	**6**	**6**	**10**	**13**	**19**
Basic metal industries	10	-2	13	3	2	2
Metal industries	4	0	7	2	2	2
Machinery ex. electrical	0	6	2	1	1	2
Electrical machinery	7	13	6	3	6	12
Transport equipment	-5	2	5	1	1	1
Miscellaneous manufactures	8	5	7	2	2	3
Total Manufacturing	1	2	4	100	100	100

2.2. Concentration Ratios and Price Cost Margins

Table 6 presents the domestic concentration ratios covering the years 1988, 1994, and 1998. The year 1988 represents the years prior to the liberalization carried out during the mid-1990s while 1998 represents industrial concentration afterwards. As the figures show, in most sectors, four-firm concentration ratios increased during the entire period under review. On average, the four firm concentration ratio for the manufacturing industry went up from 71% in 1988 to 81% in 1998. Petroleum refineries remained almost unchanged. Increases in concentration are observed in tobacco from 97% to 99.5%, non-electrical machinery from 64% to 95%, petroleum and coal from 81 to 100%, other non-metallic from 69% to 90% and miscellaneous manufactures from 71% to 93%. Although decreases are seen in nonferrous metal, industrial chemicals, transport and iron and steel, the sectors remained highly concentrated.

Table 6. CR4 1988, 1994, 1995, and 1998

Sector	1988	1994	1995	1998
High (above 70 percent)				
Petroleum Refineries	100	100	100	99.93
Professional and Scientific	100	100	99.97	97.41
Tobacco	96.64	99.56	99.41	99.5
Nonferrous Metal Products	99.67	99.28	98.57	97.76
Glass and Glass Products	96.33	90.58	92.05	95.43
Industrial Chemicals	90.14	87.52	84.65	86.49
Transport Equipment	80.98	86.2	84.4	77.67
Pottery, China and Earthen	92.82	86.05	93.74	d
Food Processing	79.51	81.37	81.74	a
Iron and Steel	84.18	80.64	70.55	79.43
Machinery except Electrical	63.59	77.47	79.43	94.9
Petroleum and Coal Products	81.1	77	87.4	100
Fabricated Metal Products	73.45	74.48	74.32	78.24
Other Chemicals	66.37	75.64	69.09	80.92
Rubber Products	79.15	73.5	73.66	90.33
Other Nonmetallic Mineral	68.92	71.31	74.54	90.03 [d]
Paper and Paper Products	78.97	71.23	70.4	78.14
Miscellaneous Manufacture	70.87	70.62	76.76	92.77
Textiles	64.12	64.14	72.37	72.84
Food Manufacturing	63.48	69.74	77.92	86.94[a]
Beverages	48.19	70.08	63.43	73.51
Electrical Machinery	64.8	69.36	63.73	72.42
Leather and Leather Products	57.7	63.89	64.02	73.47 [c]
Wood and Cork Products	40.5	55.47	65.35	76.32

Table 6. CR4 1988, 1994, 1995, and 1998

Sector	1988	1994	1995	1998
Printing and Publishing	42.13	47.26	51.08	82.08
Plastic Products	49.41	40.75	50.87	70.09
Moderate (40 percent to 69 percent)				
Metal Furniture	80.88	79.49	62.67	b
Cement	45.3	48.3	45.37	68.22
Leather Footwear	30.33	41.7	55	c
Furniture	19.51	40.91	41.64	62.54 [b]
Low (below 39 percent)				
Wearing Apparel except Footwear	34.7	31.69	26.52	23.57
Total Manufacturing	70.88	73.63	73.64	80.55

Source of basic data: National Statistics Office, 1988 and 1994 Census of Establishments and 1995 and 1998 Annual Survey of Establishments. The concentration ratios refer to the ratio of census value added by four largest firms to total in each five-digit PSIC sector. The concentration ratios given above are weighted averages for three-digit PSIC.

[a]combined food manufacturing and food processing;
[b]combined metal furniture and furniture;
[c]combined leather footwear and leather products ;
[d]combined pottery,china and other nonmetallic products

As discussed earlier, the average tariffs rates have been substantially reduced to low levels. Table 7 presents four-firm concentration ratio (CR4) calculations for manufacturing industry adjusted for the presence of imports. In general, given the relatively low tariff rates affecting manufacturing industry the calculated ratios seem to indicate that the industry is already contestable. In most sectors, the concentration ratios are below 35% such as in paper & paper products, rubber & plastic, medical & precision instruments, basic metals, and machinery and equipment not elsewhere specified (nec), while fabricated metal products and publishing & printing are about 36%. For chemicals & chemical products, 41%; other transport equipment, about 45%; and for motor vehicles, non-metallic and food products, the concentration ratios range from 54 to 57%. However, high ratios ranging from 60-82% are still prevalent in sectors such as refined petroleum, tobacco, beverages, and flat glass (non-metallic products).

Table 7. Four Firm Concentration Ratios (2003)

PSIC	Description	CR4
23	Coke, Refined Petroleum and other Fuel Products	79.8
16	Tobacco Products	72
15	Beverages	62.4
26	Other non-metallic: flat glass	82.4
34	Motor Vehicles, Trailers, and Semi-trailers	57.2
15	Food	55.7
26	Other Non-Metallic Mineral products	54.3
26	Other non-metallic: cement	52.7
19	Tanning and Dressing of Leather; Luggage, Handbags and Footwear	45.1
35	Manufacture of Other Transport Equipment	44.8
24	Chemicals and Chemical Products	40.6
22	Publishing, Printing and Reproduction of Recorded Media	36.3
28	Fabricated Metal Products, Except Machinery and Equipment	35.8
29	Machinery and Equipment, n.e.c.	34.5
27	Basic Metals	30.5
33	Medical, Precision and Optical Instruments, Watches and Clocks	29.4
21	Paper and Paper Products	29
25	Rubber and Plastic Products	28.3
36	Manufacture and Repair of Furniture	22.7
20	Wood, Wood Products and Cork, Except Furniture; Articles of Bamboo, Cane, Rattan and the Like; Plaiting Materials	20.4
17	Textile	4.4

CR4 = 4-firm concentration ratio calculated as the value of output by the four largest firms to the total for each 5-digit industry level. The CR4 calculations are adjusted for import penetration (MPR), i.e., (1-MPR)*CR4. Import penetration shares are estimated as the ratio of imports to output plus imports less exports.

Table 8 presents price cost margin (PCM) estimates with an average of 29% for manufacturing industry. In a number of sectors, PCMs are already low in 2003, ranging from 8 to 19% covering leather, fabricated metal, transport equipment, garments, machinery (excluding electrical), and printing and publishing. Moderate PCMs that range from 22 to 38% are found in food, plastic, wood, rubber, and furniture products. Finally, PCMs are high in beverages, tobacco, non-metallic products (including cement), and glass and glass products. In these sectors, PCMs range from 45 to 62%. These sectors are also the most highly concentrated within manufacturing industry.

Table 8. Price Cost Margins

Code	Description	PCM based on Roeger method	Standard Errors	PCM based on simple method
313	Beverages	0.62***	0.06	0.53
314	Tobacco	0.59***	0.04	0.47
361,363&369	Pottery, cement & other nonmetallic	0.60***	0.1	0.57
362	Glass and Glass Products	0.50***	0.04	0.52
352	Other chemicals	0.45***	0.04	0.37
341	Paper and Paper Products	0.38***	0.03	0.36
351	Industrial chemicals	0.38***	0.03	0.35
355	Rubber products	0.34***	0.05	0.28
332&386	Furniture including Metal Furniture	0.32***	0.03	0.22
385	Professional and Scientific equipment	0.31***	0.29	-0.06
331	Wood and Cork	0.31***	0.02	0.26
372	Nonferrous metal	0.31***	0.05	0.21
390	Miscellaneous manufactures	0.30***	0.04	0.2
356	Plastic products	0.30***	0.02	0.25
353	Petroleum refineries	0.29***	0.11	0.21
383	Electrical machinery	0.28***	0.01	0.25
354	Petroleum and Coal	0.27***	0.12	0.21
321	Textiles	0.26***	0.02	0.27
311&312	Food processing & manufacturing	0.24***	0.03	0.28
371	Iron and Steel	0.22***	0.01	0.26
342	Printing and Publishing	0.19**	0.11	0.16
382	Machinery except Electrical	0.18***	0.04	0.11
322	Wearing Apparel except Footwear	0.16**	0.12	-0.01
384	Transport equipment	0.12***	0.04	0.14
381	Fabricated metal	0.10**	0.04	0.17
323&324	Leather & leather footwear	0.08***	0.04	0.16
	All manufacturing	*0.29****	*0.02*	*0.3*

Note: PCMs in column 3 are estimated using Roeger regression while those in column 4 are based on accounting data using average variable costs as proxy for marginal costs. *** indicates significance at the 1% level.

Source: Aldaba (2008).

2.3. Total Factor Productivity Growth

Table 9 presents estimates of Total Factor Productivity (TFP) growth. The growth figures are normalized and interpreted as growth relative to 1996. From 1996 to 2006, aggregate productivity gains are evident in the leather, textiles, furniture, other manufacturing, and basic and fabricated metal sectors. Leather grew by 9.5%, textiles by 2.4%, other manufacturing by 2.9%, furniture by 1.9% and basic metals by 1.3%. Meanwhile, six sectors covering food, beverages, and tobacco; garments; wood, paper, and publishing; coke, petroleum, chemicals and rubber; non-metallic products; basic and fabricated metal products as well as machinery and equipment, motor vehicle and other transport registered negative productivity growth rates from 1996 to 2006. On the whole, the manufacturing sector's aggregate productivity declined by 3.4% from 1996 to 2006.

Table 9. Total Factor Productivity Growth

Sector	Year	TFP Growth relative to base year 1996	Sector	Year	TFP Growth relative to base year 1996
Food, beverages, & tobacco	1996	0	**Non-metallic products**	1996	0
	1997	0.45		1997	0.11
	1998	3.01		1998	1.47
	2000	-0.82		2000	-1.12
	2002	-1.83		2002	-7.38
	2003	-2.25		2003	-2.2
	2005	-1.36		2005	0.39
	2006	-1.44		2006	-0.65
Textile	1996	0	**Basic metal & fabricated metal products**	1996	0
	1997	1.8		1997	-0.2
	1998	1.01		1998	-4.39
	2000	0.95		2000	-1.77
	2002	-0.46		2002	-3.18
	2003	1.2		2003	-2.7
	2005	6		2005	-4.47
	2006	2.35		2006	1.32
Garments	1996	0	**Machinery & equipment, motor vehicles & other**	1996	0
	1997	1.12		1997	0.37
	1998	2.46		1998	-4.92
	2000	0.51		2000	0.9
	2002	0.49		2002	-2
	2003	0.62		2003	-2.75
	2005	-0.75		2005	-1.7
	2006	-0.99		2006	-0.86

Table 9 (continued). Total Factor Productivity Growth

Sector	Year	TFP Growth relative to base year 1996	Sector	Year	TFP Growth relative to base year 1996
Leather	1996	0	**Furniture**	1996	0
	1997	-1.35		1997	1.16
	1998	0.81		1998	1.64
	2000	0.63		2000	3.12
	2002	7.2		2002	3.46
	2003	12.1		2003	2.03
	2005	8.09		2005	2.59
	2006	9.54		2006	1.86
Wood, paper, & publishing	1996	0	**Other manufacturing**	1996	0
	1997	0.61		1997	-0.18
	1998	0.29		1998	3.01
	2000	-2.46		2000	0.27
	2002	-1.06		2002	1.49
	2003	-3.85		2003	0.63
	2005	-3.64		2005	1.18
	2006	-5.39		2006	2.87
Coke, petroleum, chemicals & rubber	1996	0	**All manufacturing**	1996	0
	1997	-0.61		1997	-0.23
	1998	-2.68		1998	-1.59
	2000	2.94		2000	-0.44
	2002	-6.65		2002	-4.86
	2003	4.19		2003	-1
	2005	-1.11		2005	-2.53
	2006	-4.76		2006	-3.37

Source: Aldaba (2010).

Note: These growth figures are normalized and interpreted as growth relative to base year 1996.

2.4. R&D/Innovation

The indicators most commonly used to monitor the resources devoted to Research and Development (R&D) are given by the gross domestic expenditure on R&D and R&D intensity measured by the percentage of GDP devoted to R&D. Table 10 presents these two indicators for the Philippines, along with its neighbors in Southeast Asia. Research intensity is low in the Philippines with investment in R&D declining from 0.15% in 2002 to 0.12% in 2005. Singapore is the most research intensive as its ratio almost doubled between 1996 and 2007 from 1.37 to 2.61, respectively. In terms of R&D expenditures per capita, the Philippines and Indonesia registered the lowest figures with the Philippines declining from purchasing power parity $ (PPP$)4 in 2002 to PPP$3 in 2005.

Table 10. R&D as Percentage of GDP and R&D per Capita

Data: Gross Domestic Expenditure on R&D as a percentage of GDP

Year	PHIL	SING	THAI	MAL	INDO
1996	...	1.37	0.12	0.22	...
1997	...	1.48	0.1	...	...
1998	...	1.81	...	0.4	...
1999	...	1.9	0.26	...	...
2000	...	1.88	0.25	0.49	0.07
2001	...	2.11	0.26	...	0.05
2002	0.15	2.15	0.24	0.69	...
2003	0.14	2.11	0.26	...	...
2004	...	2.2	0.26	0.6	...
2005	0.12	2.3	0.23	...	0.05
2006	...	2.31	0.25	0.64	...
2007	...	2.61	...	...	...

Table 10 (continued). R&D as Percentage of GDP and R&D per Capita

Data: Gross Domestic Expenditure on R&D per capita (in PPP$)

Year	PHIL	SING	THAI	MAL	INDO
1996	...	384	6	18	...
1997	...	440	5	...	...
1998	...	520	...	32	...
1999	...	578	12	...	...
2000	...	632	12	45	2
2001	...	696	13	...	1
2002	4	747	13	67	...
2003	4	764	15	...	...
2004	...	882	16	66	...
2005	3	996	16	...	2
2006	...	1104	18	80	...
2007	...	1342	...	...	...

Source: UNESCO Institute for Statistics.

Table 11 presents the number of researchers (measured in full-time equivalent). In the Philippines, this increased to 6896 in 2005 from 5860 in 2003. Expressed in terms of researchers per million inhabitants, this went up from 71 in 2003 to 81 in 2005 for the Philippines. In Singapore, this went up significantly from 2,535 in 1996 to 5,575 in 2005 and to 6,088 in 1007. In Thailand, the ratio increased from 100 in 1996 to 311 in 2005. In Malaysia, this was 503 in 2004 and 205 in Indonesia in 2001.

Table 11. Number of Researchers

Data: Researchers (Full Time Equivalent) - Total

YEAR	PHILS	SING	THAI	MAL	INDO
1996	...	9108	6038	1894	...
1997	...	9704	4409	...	...
1998	...	11396	...	3416	...
1999	...	12598	10418	...	...
2000	...	16633	...	6423	44984
2001	...	16740	17710	...	42722
2002	...	18120	...	7157	...
2003	5860	20024	18114	...	...
2004	...	21359	...	12670	...
2005	6896	23789	20506	...	...
2006	...	25033	...	9694	...
2007	...	27301	...	...	...

Data: Researchers per million inhabitants (Full Time Equivalent)

YEAR	PHILS	SING	THAI	MAL	INDO
1996	...	2535	100	90	...
1997	...	2615	72	...	...
1998	...	2977	...	154	...
1999	...	3203	169	...	...
2000	...	4139	...	276	219
2001	...	4103	281	...	205
2002	...	4398	...	295	...
2003	71	4820	281	...	...
2004	...	5087	...	503	...
2005	81	5575	311	...	...
2006	...	5736	...	372	...
2007	...	6088	...	...	...

Source: UNESCO Institute for Statistics.

These figures tend to indicate that the Philippines have been under-investing in R&D. In a study on R&D gaps in the Philippines, Cororaton (1999) estimated a gap of 0.6% of GDP based on the average ratio in the 1980s. In terms of R&D manpower, the results showed the need for an additional 197 scientists and engineers per million populations based on the average level in the 1980s. Cororaton also pointed out the large gap in the country's institutional structure characterized by a weak national science and technology system including incentives and protection of intellectual property rights.

3. Brief Review Of Selected Literature

There are three strands of literature on international trade and growth that are important in assessing the effects of trade liberalization on innovation: trade and competition, competition and innovation, and trade and innovation.

Competition and Innovation

The existing theoretical models on competition and innovation point to two opposing views. Early endogenous growth and Industrial Organization models suggested that competition appears to be detrimental to innovation and technical progress. Rents are seen as the major source of innovation for companies wishing to engage in R&D. Increased competition leads to a decline in innovative activity as more competition reduces the monopoly rents that reward successful innovators. Hence, large firms provide a more stable platform for investment in R&D. In contrast, the opposite view contends that competition may foster innovation as firms need to escape increased competition from rival firms. Competition will force firms to innovate in order to survive.

In an effort to reconcile the two views, Aghion *et al.* (2001) extended the basic Shumpeterian model by allowing incumbent firms to innovate. Traditional models were based on the assumption that innovation was done by outsiders or new entrants competing against incumbents with conventional technology and that the payoff of innovation was equal to the post-innovation rent (pre-innovation rent was zero). The Aghion *et al.* model assumes that innovation incentives depend on the difference between post-innovation and pre-innovation rents. Firms innovate to reduce production costs and this is done in a step-by-step manner where a laggard firm must first catch up with the technological leader before becoming a leader. Greater competition may foster innovation and growth as it may reduce a firm's pre-innovation rents by more than it reduces post-innovation rents. Competition may increase the incremental profits from innovation and encourage R&D investments aimed at escaping competition. Competition is particularly intense in "neck-and-neck" industries, where competition is so close that it is hardly possible to determine which firm is leader, and the "escape competition" effect is strongest in these industries. On the other hand, in less neck-and-neck or unleveled industries, more competition may reduce innovation as the reward for laggard firms catching up with the technological leader may fall; this is the Schumpeterian effect.

The model predicts an inverted-U shaped relationship between competition and innovation. At low levels of competition, the "escape competition" effect dominates while at higher levels of competition, the "Schumpeterian effect" dominates. To test the model, Aghion *et al.* (2002) used a panel dataset of UK firms. The results confirmed the presence of a strong inverted U relationship and the gradient of the curve tends to be steeper for firms that are in more neck-and-neck industries. Looking at entry and innovation, Aghion and Burgess (2003) showed that competition can affect innovation depending on the firm's level of efficiency. In particular, firms close to the efficiency frontier are expected to survive and deter entry by innovating. An increased entry threat leads to greater innovation aimed at escaping that threat. In contrast, firms that are far below the frontier are in a weaker position to fight external entry. An increased entry threat reduces the payoff from innovating, since the innovation's expected life horizon has become shorter. Competition thus provides incentives for more efficient firms to innovate and a disincentive for less efficient ones. In a related model, Aghion *et al.* (2005) predict that firms located in more pro-business environments are more likely to respond to competition by innovating.

Empirical studies that investigated the relationship between competition and innovation showed mixed results. The Schumpeterian argument predicts a negative relationship. Earlier studies that used market concentration as proxy for competition showed a positive relationship between industry concentration and R&D intensity (implying a negative relationship). However, more recent studies showed that this disappears when inter-industry differences such as industry characteristics and technological opportunities are taken into account (Gilbert, 2006). Geroski (1990) did not find support for the Schumpeterian assertion that monopoly power stimulates innovation. More recent empirical studies on the relationship between competition and innovation pointed to a positive relationship. Empirical work by Geroski (1995), Nickell (1996), and Blundell *et al.* (1999) found a positive correlation between competition and innovation. Creusen *et al.* (2006) also found a positive relationship between competition and innovation but no evidence for the existence of an inverted – U.

Hopman and Rojas-Romagosa (2010) analyzed the relationship between changes in competition levels and innovation efforts. Using OECD panel data, the authors found a monotonic relationship between the variables, but did not find an inverted-U relationship as in the influential Aghion *et al.* (2001) paper. Gorodnichenko *et al.* (2009) tested predictions about the impact of competition and linkages with foreign firms on domestic firms' innovative efforts, using data on firms in 27 transition economies. Their findings showed that competition has a negative effect on innovation, especially for firms that are far from the efficiency frontier. Firms that have market power tend to innovate more, but greater pressure from foreign competition also stimulates innovation. The paper did not find support for an inverted U effect of competition on innovation. Carlin, Schaeffer and Seabright (2004) also tested the inverted U hypothesis using data on transition economies. The results showed that innovation is higher in monopolistic industries.

In the Philippines, similar studies linking competition and innovation have not yet been done. Research work on innovation focused on the estimation of the R&D gap (Cororaton, 1999) as well as analysis of the state of science and technology and R&D in the country along with recommendations on how to improve the innovation system and how to catch up (Cororaton, 2002; Patalinghug, 1999 and 2003; and Macapanpan, 1999). These studies show that the government's science and technology (S&T) policy lacks focus and does not provide clear direction for technology innovation. As such, it has failed to encourage private sector participation despite the R&D incentives granted. Institutional mechanisms are weak with lack of coordination of planning and budgeting activities. Major recommendations include improvements in R&D investment, manpower, the incentive system, institutional arrangements and S&T coordination mechanisms.

Trade and Competition

Since the early 1980s, the new trade theory has shown that aside from the gains from trade due to specialization based on comparative advantage, trade liberalization can lead to additional gains by reducing the "deadweight losses" created by the ability of domestic firms to exercise market power. An open trade regime is a powerful instrument for disciplining the firms that have market power. Competition from imports constrains the ability of domestic producers to engage in anti-competitive activities which would otherwise reduce welfare (Cadot, Grether, & de Melo, 2000). This is known in the Industrial Organization literature as the "imports-as-competitive discipline" hypothesis. When confronted with intensified competition, domestic industries which may have accumulated oligopoly profits in heavily protected markets, are forced to behave more competitively.

Most of the empirical work on the imports-as-competitive discipline hypothesis focus on profitability regressions, which regress a measure of profitability such as price cost margin on import penetration (the ratio of imports to domestic consumption), as a proxy for trade policy and intensity of import competition and other factors affecting industry profitability. Since marginal costs are not observable, mark-ups are only inferred indirectly from price cost margins. Other proxies used for trade policy include effective protection rates, tariff rates, or import license coverage ratios.

In general, the empirical evidence provides strong support for the imports-as-competitive discipline hypothesis. Based on industry-level cross-section data, Schmalensee (1989) indicated that the ratio of imports to domestic consumption tends to be negatively correlated with the profitability of domestic sellers, especially when domestic concentration is high. Pugel (1980) also found that import penetration has a stronger negative relationship with domestic profitability when conventional measures of entry barriers are high.

Reviewing the literature on the impact of trade liberalization on price cost margins, Erdem and Tybout (2003) and Tybout (2001) concluded that based on numerous empirical studies of firm- and plant-level liberalization episodes, mark-ups decline with import competition and this empirical evidence provide robust confirmation for the import discipline hypothesis. Among import-competing firms, trade liberalization squeezes price cost margins, inducing some intra-plant efficiency gains as well as additional efficiency gains due to the closure of weak plants. The authors added that the effect was particularly marked among large plants. As Roberts and Tybout (1996) wrote in an earlier paper, in every country studied, relatively high industry-wide exposure to foreign competition is associated with lower margins and the effect is concentrated in larger plants.

Using panel data sets on firms, Harrison (1994) examined the results for Cote d'Ivoire and Krishna and Mitra (1998) for India. Harrison found that mark-ups were negatively related to import competition in Cote d'Ivoire. In India, Krishna and Mitra also showed that mark ups fell during the trade reform period. Earlier studies by De Melo and Urata (1986) and Tybout (1996) for Chile and Grether (1996) for Mexico showed the same finding. Erdem and Tybout (2003) cautioned that care must be exercised in interpreting the results. The authors noted that the studies only describe the short-run effects of trade liberalization. Reforms in trade regimes trigger a dynamic adjustment process that may take a long time to play out (plausibly lasting more than a decade).

Other studies showing further evidence that trade liberalization has a pro-competitive effect include those carried out by Levinsohn (1993) for Turkey; Warzynski (2002) and J. Konings, Vanseele, and Warzynski (2002) for Romania and Bulgaria; as well as Goldar and Agarwal (2004), Kambhampati and Parikh (2003), and Srivastava *et al.* (2001) for India. These country studies provide support to the import discipline hypothesis that trade liberalization can lead to substantial reductions in price cost margins at least in those industries that are imperfectly competitive. For the Philippines, Aldaba (2007) confirmed the same finding that price cost margins fall with import competition, and that trade liberalization has a disciplining effect on firms' pricing behavior.

With the availability of micro data, the recent literature on trade liberalization and productivity has increased substantially. This body of literature shows that industries facing the greatest tariff reduction and import competition have faster productivity growth than relatively protected industries. This is due to resource allocation arising from the exit of inefficient plants and productivity improvements within existing plants. Empirical studies showing these results were pioneered by Pavcnik (2002) for Chile; Topalova (2003) for India; Muendler (2002) and Amite and Konings (2007) for Indonesia, Schor (2003) for Brazil and Fernandes (2007) for Columbia. For the Philippines, Aldaba (2010) also provided some evidence that trade liberalization leads to productivity increases. Trade liberalization drives the process of restructuring and reshuffling of resources within and across sectors of the economy such that unprofitable activities contract while profitable ones expand. Trade liberalization allows more productive firms to expand while less efficient firms either exit or shrink. With the exit of inefficient firms, resources (labor and capital) will be freed and will move to other industries where they can be used more productively.

Trade and Innovation

Recent literature on trade and growth shows that international trade affects firms' innovative activities through increased competition. As Licandro (2010) noted, increasing evidence supports the claim that international trade enhances innovation and productivity growth through an increase in competition.

In an earlier work based on Schumpeterian growth theory and using firm panel datasets for India and the UK, Aghion and Burgess (2003) found that reducing barriers to entry to foreign products and firms has a more positive effect on economic performance for firms and industries that are initially closer to the technological frontier. Incumbent firms that are sufficiently close to the technological frontier can survive and deter entry by innovating. On the other hand, firms that are far below the frontier are in a weaker position to fight external entry since this will reduce their expected payoff from innovating. Thus liberalization encourages innovation in industries that are close to the frontier and discourages innovation in industries that are far from it. Productivity, outputs, and profits should be higher in the industries and firms that are initially more advanced. The authors suggested that for countries to benefit from liberalization, policies that allow firms to upgrade their technological capabilities or which allow workers to move from low to high productivity sectors are important.

Griffith, Harrison and Simpson (2006) assessed the impact of product market reforms under the European Union's (EU)'s Single Market Programme (SMP) on innovation activity using an unbalanced panel of nine countries and 12 2-digit manufacturing industries covering the period 1987-2000. Their results suggest that the SMP's product market reforms led to an increase in product market competition which was measured by a reduction in average profitability. Moreover, increased competition led to an increase in R&D intensity in manufacturing industries. Increased R&D intensity translated into faster total factor productivity (TFP) growth. The authors indicated that reforms that put pressure on profitability are likely to lead to increased innovation.

Fernandes (2009) examined the effects of increased import competition to product quality upgrading using Chilean manufacturing plant data. The results showed a positive and significant effect from import competition on product level product quality upgrading. The author suggested that increased exposure to import competition, including from China and India, may be beneficial because it encourages producers to focus on offering upgraded and differentiated products, rather than "mundane" labor intensive, ones.

Bloom, Draca, and Van Reenen (2010) examined the impact of Chinese import competition on patenting, IT, R&D and TFP in 12 EU countries using a panel dataset for the period 1996-2007. The key results are: first, Chinese import competition increases innovation and TFP within surviving firms. Firms facing higher levels of import competition from China create more patents, spend more on R&D, raise their IT intensity and TFP. Secondly, Chinese import competition reduces employment and survival probabilities in low-tech firms, and these firms' TFP declines and they exit much more rapidly than high-tech firms in response to Chinese competition. The authors noted that the results suggest that increased import competition from China has caused a significant technological upgrading in European firms through faster diffusion and innovation. The policy implication is that reducing import barriers against low wage countries like China can bring about welfare gains through technical change.

4. Description Of Methodology And Data

4.1. Overall Framework

The foregoing review highlights three important effects of trade liberalization: trade reforms increase competition, trade reforms have positive effects on innovation, and trade reforms lead to the selection of the most productive firms. Trade liberalization thus has *pro-competitive effects* and as Bhagwati (1968) wrote, it is seen as a powerful and administratively simple way to enhance competition Krugman and Helpman (1989) further noted that international trade increases competition. With trade liberalization, imports can discipline the market by forcing domestic firms to lower their prices and behave competitively. Based on a comprehensive review of empirical studies of firm- and plant-level liberalization episodes in various countries, Erdem and Tybout (2003) concluded that mark-ups decline with import competition.

Through the competition channel, trade liberalization also has *innovation effects*. Newer studies by Fernandes and Bloom, Draca and Van Reenenhave shown some evidence of the positive impact of trade liberalization on innovation. Economic profits or rents can serve as rewards for entrepreneurship and encourage innovation. An increase in competition may increase incentives for incumbent firms to adopt more or to innovate in order to prevent an erosion of their market position. Note, however, that increased competition may also reduce the incentive or reward for innovation or entry and may discourage these activities.

Through the competition channel, trade liberalization also leads to *selection effects*. As trade liberalization squeezes price cost margins, some intra-plant efficiency gains are made, and additional efficiency gains are induced due to the closure of weak plants. In the presence of within-industry firm heterogeneity, trade liberalization may lead to improved productivity through the exit of inefficient firms and the reshuffling of resources and outputs from less to more efficient firms. Melitz (2002) points out that trade opening may induce a market share reallocation towards more efficient firms and generate an aggregate productivity gain, without any change at the firm level[5]. As

[5] In Melitz (2003), the channel through which selection happens is the labor market; trade liberalization increases labor demand, these bids up wages and the cost of production forcing least productive firms to exit the market.

Pavcnik, Topalova, and Tybout showed; trade liberalization induces the least productive firms to exit the market and the most productive non-exporters to become exporters.

Impulliti and Licandro (2009, 2010)[6] introduced a framework that attempts to link together these three effects of trade liberalization. Basically, trade affects both firm selection and innovation through the competition channel. Trade liberalization leads to an increase in the number of firms in the domestic market raising product market competition and lowering the markup rate. The selection effect of trade operates through endogenous markups resulting from oligopolistic competition[7] among firms. The reduction in the markup rate (or increase in competition) due to trade liberalization reduces profits, raises the productivity threshold above which firms can profitably produce and forces the less productive firms out of the market. Resources are reallocated from exiting firms to the higher productivity surviving firms which innovate at a faster pace.

Given the relationship between trade liberalization and innovation operating through the competition channel, the impact of trade liberalization on innovation is examined through a two-stage approach where competition is endogenous. The same framework was used by Griffith, Harrison, and Simpson (2006) to address the endogeneity of competition in analyzing the relationship between product market reform and innovation in the EU. The following basic econometric model is tested:

Competition function

$$\text{Competition}_{ijt=}\ \text{f}(\text{Trade}_{jt}\ , \text{Z}_{ijt}) \qquad \text{equation (1)}$$

Innovation function

$$\text{Innovation}_{ijt=}\ g(\text{Competition}_{ijt}\ , \text{Z}_{ijt}) \qquad \text{equation (2)}$$

Where *i* indexes firms, *j* industries and *t* years. Equation (1) describes the relationship between trade reforms and competition while equation (2) characterizes the relationship between innovation and competition and links trade reforms with innovation through

6 Both are preliminary and incomplete draft versions.
7 In Melitz (2003), the model assumes monopolistic competition.

competition. Z is a vector of control variables that may affect the firm's innovation efforts.

Following Aghion *et al.* (2002), the price cost margin is used as an indicator of product market competition, while research and development expenditures are used as a proxy for innovation. The authors noted that the price cost margin has several advantages over other indicators such as market shares, the Herfindahl index, or the concentration index. These measures require a definition of both the geographic and product boundaries of the market in which the firm operates. This becomes important particularly for firms that operate in international markets, so that traditional market concentration measures could be extremely misleading.

The specific competition and innovation functions are described by equations (3) and (4) below:

$$PCM_{ijt} = \beta_0 Tariff_{jt} + \beta_1 TGap_{ijt} + \beta_2 Age_{ijt} + \beta_3 Size_{ijt} + \beta_4 Time + \beta_5 Ind + \varepsilon_{ijt}$$

equation (3)

$$RD_{ijt} = \alpha_0 PCM_{ijt} + \alpha_1 TGap_{ijt} + \alpha_2 Age_{ijt} + \alpha_3 Size_{ijt} + \alpha_4 Time + \alpha_5 Ind + \omega_{ijt}$$

equation (4)

where PCM is price cost margin, Tariff is a trade reform indicator, TGap or technology gap is the distance to the technological frontier and is a measure of efficiency, RD is research and development expenditures, Age and Size are firm characteristics measured by firm age and total number of workers, respectively; Time and Ind are time and industry dummies, and ε and ω are error terms. Apart from output tariff, effective protection rate (EPR) will also be used as a trade reform indicator. EPRs represent rates of protection of value added and measure the net protection received by domestic producers from the protection of their outputs and the penalty from the protection of their inputs.

To control for the effects of the selection process on competition and innovation, net entry is also incorporated in the model:

$$PCM_{ijt} = \lambda_0 Tariff_{jt} + \lambda_1 TGap_{ijt} + \lambda_2 Age_{ijt} + \lambda_3 Size_{ijt} + \lambda_4 NetEntry_{jt} + \lambda_5 Time + \lambda_6 Ind + \rho_{ijt}$$

equation (3a)

$$RD_{ijt} = \delta_0 PCM_{ijt} + \delta_1 TGap_{ijt} + \delta_2 Age_{ijt} + \delta_3 Size_{ijt} + \delta_4 NetEntry_{ijt} + \delta_5 Time + \delta_6 Ind + \gamma_{ijt}$$

equation (4a)

A positive relationship is expected between competition (as measured by PCM) and trade liberalization (with Tariff and EPR as indicators). As tariffs or EPRs are lowered, price cost margin or profitability is reduced, which indicates increased competition. This is the main channel through which trade liberalization affects innovation. Hence, the trade indicators (Tariff and EPR) do not directly enter equation (4).

A negative relationship is expected between PCM (measure of competition) and RD (measure of innovation). As price cost margin or profitability is reduced due to trade reforms, competition increases raising the productivity threshold above which firms can profitably produce. This forces less productive firms out of the market. Resources are reallocated from exiting firms to the higher productivity surviving firms which innovate at a faster pace.

The price cost margin (PCM) or Lerner index is an indicator of the level of competition or degree of monopoly power of firms in industries. It is often used as an indicator of the strength of competition in the market. In theory, it is defined as price minus marginal cost over price and reflects the degree of monopoly power measured by the mark-up pricing above marginal costs (see Appendix 1). It should be noted that high PCMs are not necessarily an indication of bad market performance or that a firm is less competitive. While a high PCM implies market power, it could also indicate high firm efficiency. If these high mark-ups or margins are the result of internal efficiency improving measures or represent gains from product innovation or techniques that a firm employs, then the firm is still considered competitive.

The empirical measurement of PCM is difficult since marginal costs are not directly observable and are quite hard to estimate. Indirect measures have been developed based on accounting data, with average variable costs acting as proxy for marginal costs. Critiques noted that measured in this manner, PCM omits capital costs and becomes a poor indicator of excess profits.

Aghion *et al.* (ibid) used operating profits net of depreciation and provisions less the financial cost of capital. This is given by the following:

$$B = \frac{\text{Operating profits} - \text{Financial cost of capital}}{\text{Sales}} \qquad \text{equation (5)}$$

where Financial cost of capital is defined as $[capital\ cost * capital\ stock]$. They assumed the cost of capital to be 0.085 for all firms and time periods while capital stock is measured using the perpetual inventory method. Measured this way, it is more like the ratio of price less average cost to price. Note that in 1988, Hall developed an alternative way to measure mark-ups from the production function of firms. Using the properties of the Solow residual under perfect competition, Hall derived an empirical specification that allows the retrieval of industry wide mark-ups (measured by price/marginal costs). Comparing the econometrically estimated PCMs with calculated accounting margins, Siotis (2003) found that overall, the accounting margins approach yields reasonable and precise estimates indicating that accounting based PCM measures may not be as flawed as previously thought, at least when the sample size is large both within the sample and over time.

In this paper, the PCM is defined as:

$$B = \frac{\text{Total revenue} - \text{Compensation} - \text{Total cost} - \text{Financial cost of capital}}{\text{Total revenue}} \qquad \text{equation (6)}$$

$$\text{Total costs} = \text{Raw materials} + \text{Fuel} + \text{Electricity} + \text{Depreciation} + \text{Other costs}$$

$$\text{Financial cost of capital} = [\text{Index of investment goods} * \text{Real interest rate}] * \text{Book value of assets}$$

where the implicit price index for gross domestic capital formation is used as a price index of investment goods while the 180-day Treasury Bill interest rate less inflation is used as measure of real interest rate.

Aghion *et al. (ibid)* measure the technology gap between firms within an industry as the proportional distance a firm is from the technological frontier. In this paper, this is given by the difference between the log total factor productivity (TFP) of the most productive firm in a given industry and log TFP of each firm in the industry.

Domestic firms are differentiated depending on the trade orientation of their industry sector. Firms in a traded sector are more exposed to foreign competition than firms in a non-traded sector. Based on the sector's import penetration ratio, and export intensity ratio calculated from the year 2000 Input-Output Table, each industry sector is classified into traded or non-traded. A sector is classified as non-traded if export and import ratios are zero or less than 1%. This includes manufacturing sub-sectors such as slaughtering and meat packing, ice cream, mineral water, and custom tailoring and dressmaking.

A traded sector is categorized into three: purely importable, purely exportable, or mixed. A purely exportable sector is characterized by zero or minimal imports and substantial exports or an export ratio of at least 10%. Examples are tobacco leaf flue-curing, articles made of native materials, wood carvings, fish drying, knitted hosiery, crude coconut oil, rattan furniture, and jewelry. A purely importable sector is characterized by minimal exports and significant imports or an import ratio of at least 10%. Examples are meat and meat products, coffee roasting and processing, butter and cheese, animal feeds, starch and starch products and manufacture and assembly of motor vehicles. A mixed sector has substantial imports and exports such as motor vehicle parts and components, semi-conductor, parts and supplies for radio, TV, communication, appliances and house wares, garments, carpets and rugs, furniture, along with sugar, glass, chemicals, cigarette, soap and detergents, iron and steel and drugs and medicines. Notice that a lot of the products under both the mixed and purely importable sectors are also among the products with tariff peaks[8]. Moreover, aside from tariff protection, certain products under these sectors also received additional protection through safeguard measures that are imposed on importations of cement, glass, chemicals, and ceramic tiles.

[8] Tariff peaks refer to tariffs that are greater than three times the mean tariff. The sectors with tariff peaks were sugarcane, sugar milling and refining, *palay*, corn, rice and corn milling, vegetables such as onions, garlic, and cabbage, roots and tubers, hogs, cattle and other livestock, chicken, other poultry and poultry products, slaughtering and meat packing, coffee roasting and processing, meat and meat processing, canning and preserving fruits and vegetables, manufacture of starch and starch products, manufacture of bakery products excluding noodles, manufacture of animal feeds, miscellaneous food products, manufacture of drugs and medicines, manufacture of chemical products, and manufacture and assembly of motor vehicles.

4.2. Data

The paper uses the firm level panel data created in the first Micro Data Project of the Economic Research Institute for ASEAN and East Asia (ERIA).[9] The dataset consists of firm level information on revenues, employment, compensation, physical capital, R&D expenditures, and production costs from the Annual Survey and Census of Establishments of the National Statistics Office (NSO). The firm-level panel dataset built covered the period 1996 to 2006, with three missing years (1999, 2001, and 2004). The years 2000 and 2006 are both census years while the remaining six years are surveys.

The panel dataset is unbalanced and covers all firms with two or more overlapping years during the period 1996-2006. Firms with missing zero or negative values for the variables listed above as well as firms with duplicates were dropped. Firms with missing research and development expenditures and those with less than 10 workers were also excluded. Firm exit is indicated by firms that are no longer included in the 2006 census as well as those whose 2-digit PSIC codes have changed. Firm entry is defined based on the firm's year of establishment or year when it started operating. Net entry by PSIC code is calculated as firm entry less exit. Firm age is calculated based on the firm's year of establishment or year when it started operating. The panel dataset is unbalanced with a total of 8,296 observations. Table 12 presents a summary of the data along with the calculated price cost margins and financial cost of capital.

[9] The National Statistics Office provided excellent assistance in building the panel dataset.

Table 12. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Total revenue (in million pesos)	8296	736	5200	0.065	233000
Compensation (in million pesos)	8296	43	141	0	2640
Total costs (in million pesos)	8296	594	4510	0.026	203000
Book value of fixed assets (in million pesos)	8296	180	1000	0	47600
Capital cost	8296	0.07	0.059	0.03	0.219
Financial cost of capital (in million pesos)	8296	15	102	0	5750
Price cost margin	8296	0.053	0.259	-6.086	0.96
R&D expenditure share (as % of value added)	8296	0.005	0.068	0	5.373
Age of firm (in years)	8263	17	14	0	100
Total number of workers	8296	264	703	10	14647
TFP Gap	8296	0.371	0.146	0	1.054
Tariff (in percent)	8296	9.087	6.309	1.073	60
Net entry	8296	-3	6.9	-52	6

Tariff rates by manufacturing sub-sector were obtained from the Philippine Tariff Commission. The tariff rates are originally coded based on Harmonized System (HS) codes. These were converted into the Philippine System of Industry Classification (PSIC) code to be consistent with the firm level data. Effective protection rates (EPRs were sourced from studies by Manasan and Pineda (1999) for the 1990s and Aldaba (2005) for EPRs in the more recent period.

The TFP Gap indicator was calculated based on the total factor productivity (TFP) estimates obtained from an earlier ERIA study by Aldaba (2010). TFP is defined as the residual of a Cobb-Douglas production function and is estimated using the methodology of Levinsohn and Petrin (2001). In estimating the production function, data on value added (output less cost of materials and energy) and two factors of production, labor and capital, were used. Fuel and electricity data were employed as proxy for productivity shocks.[10] A production function was estimated for 11 industry-sectors. The estimates of firm *i*'s TFP is obtained by subtracting firm *i*'s predicted *y* (or log of output) from its actual *y* at time t. To make the estimated TFP comparable across

[10] To address the simultaneity problem in input choice when estimating the production function by ordinary least squares (OLS), a semi-parametric estimator with an instrument to control for unobserved productivity shocks is applied. For this instrument, Olley and Pakes (1996) use investment while Levinsohn and Petrin (2002) suggest the use of intermediate inputs.

industry-sectors, a productivity index is created. The TFP Gap is given by the difference between the TFP index of the most productive firm in a given industry *j* at year *t* and TFP index of each firm *i* in the industry *j* at year *t*.

Table 13 presents a descriptive summary of the variables by industry orientation: non-traded (e.g. slaughtering, mineral water, dressmaking), purely importable (e.g meat processing, coffee roasting), purely exportable (e.g. tobacco leaf flue-curing, products made of native materials, fish drying), and mixed sector (e.g. motor vehicles, semi-conductors, garments). In terms of R&D spending (as a percentage of value added), the mixed sector registered the highest ratio at 0.6%, closely followed by the purely importable sector at 0.5%. The purely exportable sector has an average ratio of 0.3% while the lowest ratio is posted by the non-traded sector at around 0.2%. The purely importable sector has the highest price cost margin at 9.2% followed by the purely exportable sector at 5.5% and the mixed sector at 5%. The lowest price cost margin is observed in the non-traded sector with an average PCM at 3.7%. The mixed sector has the largest average number of workers at 291 followed by the purely importable sector at 209 workers. Average firm age is about 16.3 years in the mixed sector and 18.7 years in the purely importable sector. Average output tariffs are highest in the purely importable sector at 13.4% followed by the non-traded sector at 9.3%. The lowest output tariff is in the mixed sector at 8.6%. Average EPRs for all sectors range from 10 to 13.7%.

Table 13. Summary Statistics by Trade Orientation

Variable	Non-traded		Purely Importable		Purely exportable		Mixed sector	
	Obs	Mean	Obs	Mean	Obs	Mean	Obs	Mean
R&D expenditure share (as % of value added)	377	0.0018	775	0.0045	628	0.0026	6516	0.0055
PCM	377	0.0372	775	0.092	628	0.0548	6516	0.0495
Total workers	377	174.082	775	209.703	628	108.804	6516	291.127
Age	373	15.3995	771	18.6887	624	18.5016	6495	16.315
TFP gap	377	0.3859	775	0.3551	628	0.3508	6516	0.374
Tariff	377	9.2912	775	13.3604	628	8.9374	6516	8.5812
EPR	377	12.0489	775	10.0601	628	13.6641	6516	13.7386

Table 14 presents the yearly exit and entry rates. Exit rates increased from 6% in 1998 to about 22% in 2000 and 32% in 2001 but dropped to 26% in 2003 and further to 13% in 2005. Entry rates are low and declined continuously from 5% in 1998 to 1% in 2003 and to less than 1% in 2005 and 2009.

Table 14. Entry and Exit Rates, 1996-2006

Year	Exit Rate	Entry Rate	Total Number of Firms
1996			
1997			
1998	6.14	5.05	277
2000	21.96	1.63	551
2001	31.71		1009
2003	26.14	1	903
2005	13.05	0.24	1226
2006		0.09	4330

5. Analysis Of Results

To examine the impact on innovation of the increased competitive pressure arising from trade reforms, a two-stage approach is applied as specified in equations (3) and (4). The profitability level measured by PCM is the main channel through which trade liberalization affects innovation. PCM and RD are simultaneously determined.

The model is estimated using two methods. First, a two-stage instrumental variables (IV) technique is applied. Equation (3) is the first stage in the IV estimation of the second stage given by equation (4). PCM and RD are estimated by instrumental variables where Tariff is the excluded instrument. Two estimators, fixed effects (FE) and random effects (RE) are used. The Hausman test is used to decide between FE and RE.

Second, a Tobit estimation method is also applied where observations on RD are censored at 0. Note that RD observations contain either zeroes for firms that do not engage in innovation or a positive value for those that decided to innovate.

5.1. All Manufacturing: No Entry and Exit Indicators

Table 15.1 presents the results of the first stage of the IV estimation which evaluates the degree of correlation between trade reforms, as measured by Tariff, and the endogenous regressor, PCM, which is our measure of profitability. The first stage regression results suggest that the excluded instrument Tariff is highly correlated with PCM based on both the FE and RE methods. The coefficient on Tariff is positive and highly significant indicating that trade reforms have a strong positive impact on the level of profitability. The results also show a negative association between TFP Gap and profitability. The coefficient on TFP Gap is negative and highly significant in both FE and RE methods. This indicates that firms that are farther from a technological frontier (less productive firms) have lower profitability than efficient firms which tend to have higher profitability.

Table 15.1. First Stage IV Results: FE and RE

ALL MANUFACTURING

PCM	Tariff		EPR	
	(1) FE	(2) RE	(1) FE	(2) RE
Age	0.00031	-0.000458*	-0.0039674	-0.0008581*
	0.0026855	0.0002743	0.0022206	0.000539
Total workers	-0.00001	-0.000028***	-8.15E-06*	-0.0000241***
	0.0000128	0.0000054	0.0000128	6.94E-06
TFP Gap	-2.54176***	-1.483633***	-2.557112	-2.08648***
	0.1052527	0.04587	0.1052544	0.0568845
Trade	0.0069049***	0.002489***	0.0006741	0.0004895
	0.0022272	0.0007028	0.0004289	0.0002319
Constant	1.096718***	0.5535773***	1.254195	
	0.1022577	0.0254748	0.0889347	
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
F-Statistic	1.65		1.65	
Prob>F	0		0	
Observations	8263	8263	8263	8263
R-squared	0.0672			
Hausman Test				
Chi2	45.22			8.27
Prob>chi2	0.0001			0.9605

Note: * 10% level of significance, **5% level of significance, ***1% level of significance.

Using EPR as a trade indicator, the random effects method shows that the coefficient on EPR is positive but not significant. The coefficient on total workers is negative and highly significant. The coefficient on TFP Gap is also negative and highly significant while the coefficient on age is negative and significantly different from zero.

Table 15.2 presents the results of the second stage IV estimation, which looks at the relationship between profitability and innovation where RD is the dependent variable. The FE results based on Tariff as trade indicator show a significant negative relationship between PCM and RD which indicates that reduced profitability (suggesting high competition) due to trade reform is associated with increased RD. The RE results show the same negative relationship between PCM and RD, but not at a significant level. The coefficient on TFP Gap is negative in both FE and RE methods but is insignificant.

Table 15.2. Second Stage IV Results: FE and RE

RD	Tariff		EPR	
	(1) FE	(2) RE	(1) FE	(2) RE
PCM	-0.114983*	-0.095598	-0.074743	-0.111575
	-0.0704618	-0.0776039	-0.129896	-0.111468
Age	-0.00044	0.0001051	-0.000256	0.0000963
	-0.0005744	-0.000084	-0.000737	-0.000158
Total workers	-0.00000538*	-2.25E-06	-5.06E-06*	-4.56E-06
	-0.00000285	-0.00000265	-2.81E-06	-3.16E-06
TFP Gap	-0.11871	-0.0520831	-0.015795	-0.096095
	-0.1816651	-0.1146816	-0.332906	-0.232484
Constant	0.09242	0.027075	0.0419677	0.0494711
	-0.0904484	-0.0444074	-0.163868	-0.095103
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
F-Statistic	3.13		3.57	
Prob>F	0		0	
Observations	8263	8263	8263	8263
R-squared	0.0044			
Hausman Test				
Chi2	45.22			8.27
Prob>chi2	0.0001			0.9605

Note: * 10% level of significance, **5% level of significance, ***1% level of significance.

Using EPR as trade indicator, the random effects method shows that none of the explanatory variables is significant. The coefficient on PCM is negative but is insignificant.

To test the appropriateness of RE, a Hausman test was implemented. Using Tariff as trade indicator, the result shows a rejection of the null hypothesis that the RE estimator is consistent. Using EPR as trade indicator, the result indicates an acceptance of the null hypothesis.

The model is refitted as a Tobit with lnRD being left censored at zero. The first stage results presented in Table 16.1 show that Tariff has a highly significant positive effect on profitability. TFP Gap has a highly significant negative impact on profitability. Similarly, Total workers also has a highly significant negative impact while Agehas a significant negative effect on profitability. We expect trade reforms to increase the probability that a firm will face more competition and lower profitability. The lower TFP Gap will increase the probability that profitability will be higher. The smaller the firm in terms of numbers of workers and the younger the firm, the higher the probability that profitability will be higher.

Table 16.1. First Stage IV Results: Tobit

ALL MANUFACTURING

PCM	Tariff	EPR
Trade	0.0012992***	0.0000996
	-0.000547	-0.0001304
Total workers	-0.0000211***	-0.000021***
	-0.00000405	-4.05E-06
Age	-0.0003406*	-0.0003545*
	-0.0002017	-0.0002018
TFP Gap	-1.242917***	-1.234866***
	-0.0393622	-0.039239
Constant	0.4478913***	0.4647943
	-0.0196814	-0.0182534
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	8263	8263
R-squared	0.1207	0.12

Note: * 10% level of significance, **5% level of significance, ***1% level of significance.

With EPR as trade indicator, the first stage results show that the coefficient on EPR is positive but not significant. The coefficient on TFP is negative and highly significant. The coefficient on total workers is also negative and highly significant. For age, the coefficient is negative and significant.

The second stage Tobit results are presented in Table 16.2. The results show that with Tariff as trade indicator, PCM has a significant negative effect on lnRD. The lower profitability (suggesting higher competition) will increase the probability that a firm will engage in R&D activities and will increase its R&D intensity. The Tobit results also show a highly significant negative effect for Total workers and negative effect for Age. With EPR as trade indicator, none of the explanatory variables is significant. The coefficient on PCM is negative but insignificant.

Table 16.2. Second Stage IV Results: Tobit

LnRD	Tariff	EPR
PCM	-10.44935*	-10.05107
	-5.906214	-17.95807
Total workers	-0.0005009***	-0.0004926
	-0.0001365	-0.0003815
Age	-0.0064991*	-0.0063593
	-0.0035068	-0.0068841
TFP Gap	-5.04204	-4.551069
	-7.30149	-22.14417
Constant	-0.5995352	-0.7849602
	-2.761603	-8.364468
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	8263	8263
R-squared	0.1207	0.12

Note: * 10% level of significance, **5% level of significance, ***1% level of significance.

On the whole, using tariffs as trade indicator, the results tend to confirm that trade liberalization may stimulate firms to innovate through competition. For EPR, however, this is not the case. While the correct signs on the coefficient of EPR and PCM are obtained, these are not significant. Regarding the TFP gap, the expected negative relationship is found, however, the result is also not statistically significant.

5.2. All Manufacturing: With Entry and Exit Indicators

Tables 17.1-18.2 show the results with an additional control variable for exit and entry measured by net entry. Using IV, the first stage results indicate a strong positive impact of trade liberalization on competition based on both tariff and EPR as trade indicators. As tariffs (and EPRs) decline, price cost margin or profitability is reduced which indicates increased competition. The coefficient on TFP Gap is negative and highly significant. The coefficient on Net Entry is also negative but insignificant.

Table 17.1. First Stage IV Results: FE and RE

ALL MANUFACTURING

PCM	EPR		TARIFF	
	(1) FE	**(2) RE**	**(1) FE**	**(2) RE**
Age	-0.0039215*	-0.0007018*	0.0003441	-0.0004529*
standard error	0.0022208	0.0004111	0.0026855	0.0002718
Total workers	-0.00000818	-0.0000282***	-5.38E-06	-0.0000279***
standard error	0.0000128	0.00000648	0.0000128	5.37E-06
TFP Gap	-2.557469***	-1.864594***	-2.54216***	-1.475161***
standard error	0.1052466	0.0532788	0.1052451	0.0456886
Net Entry	-0.0007582	-0.000508	-0.0007556	-0.0001445
standard error	0.0006247	0.0004102	0.0006239	0.0004494
Trade Indicator	0.0006674	0.000427**	0.006884***	0.0024462***
standard error	0.0004289	0.0002165	0.0022271	0.0006985
Constant	1.255121		1.098123***	
standard error	0.088931		0.1022564	
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
Observations	8263	8263	8263	8263
R-squared (overall)	0.0694		0.0669	
Hausman Test				
Chi2		13.32	52.66	
Prob>chi2		0.7145	0.0000	

Note: * 10% level of significance, **5% level of significance, ***1% level of significance.

Table 17.2. Second Stage IV Results: FE and RE

RD	EPR		TARIFF	
	(1) FE	(2) RE	(1) FE	(2) RE
PCM	-0.0739931	-0.1189551	-0.1148789*	-0.0916575
standard error	0.1310972	0.1272509	0.0706754	0.0784155
Age	-0.0002561	0.0000955	-0.0004381	0.0001054
standard error	0.0007356	0.000136	0.000573	0.0000833
Total workers	-0.00000505*	-0.00000422	-0.00000538*	-2.09E-06
standard error	0.00000282	0.00000396	0.00000285	2.65E-06
TFP Gap	-0.0138511	-0.1017999	-0.1184321	-0.0459054
standard error	0.3360179	0.2370014	0.1822321	0.1152147
Net Entry	0.0000574	0.0000826	0.0000259	0.0001785
standard error	0.0171815	0.0001225	0.0001468	0.0001243
Constant	0.0409574	0.0471517	0.0922571	0.0306018
standard error	0.1654865	0.092097	0.0907753	0.0469146
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
Observations	82633	8263	8263	8263
R-squared (overall)	0.0047	0.0102	0.0044	0.0118

Note: * 10% level of significance, **5% level of significance, ***1% level of significance.

In the second stage, the results based on the fixed effects (FE) method with Tariff as trade indicator, show some evidence of a positive effect of competition on innovation brought about by trade liberalization. The coefficient on PCM is negative and significant at the 10% level. The coefficient on Total workers is negative and significant. The coefficient on TFP gap is negative but not statistically significant. In the case of EPR as trade indicator, the random effects (RE) results show that although the coefficient on PCM is negative, it is not significant. It is important to note that the EPRs used are based only on output and input tariff rates and do not take into account the presence of non-tariff barriers, such as import controls and restrictions, which are more binding than tariffs. Although tariff rates are reduced, importation is still limited due to the presence of these restrictions. This may be one possible explanation of why in most cases, though EPR has the correct sign, it is not significant.[11]

Tables 18.1-18.2 present the results of the first and second stages, respectively, using a Tobit regression. Based on Tariff as trade indicator, trade liberalization has a positive effect on innovation through competition. The results show a positive relationship between tariff and PCM and a negative relationship between PCM (measure of competition) and RD (measure of innovation).

Table 18.1. First Stage TOBIT

ALL MANUFACTURING

PCM	EPR	TARIFF
Trade Indicator	0.0000993	0.0012991***
standard error	0.0001304	0.0005476
Total workers	-0.000021***	-0.0000211***
standard error	0.00000405	0.00000405
Age	-0.0003541*	-0.0003405*
standard error	0.0002018	0.0002018
TFP Gap	-1.234975***	-1.242921***
standard error	0.0392628	0.0393829
Net Entry	-0.0000404	-0.00000138
standard error	0.0004832	0.0004833
Constant	0.4647379***	0.4478903***
standard error	0.0182669	0.0196862
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	8263	8263
Adj R-squared	0.118	0.1186

[11] Import ratios were also calculated as an alternative trade indicator. However, the inconsistencies in using matched aggregated import data at the industry level with the survey and census data prevented us from using them.

Table 18.2. Second Stage TOBIT

LnRD	EPR	TARIFF
PCM	-11.70061	-11.17755*
standard error	19.68247	6.144492
Total workers	-0.0005295	-0.0005185***
standard error	0.0004182	0.000142
Age	-0.0067569	-0.0065736*
standard error	0.0075315	0.0036446
TFP Gap	-6.638679	-5.993806
standard error	24.27343	7.596961
Net Entry	-0.0188524***	-0.0188251***
standard error	0.0073079	0.0070451
Constant	-0.0445921	-0.2880717
standard error	9.166121	2.872541
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	8263	8263
R-squared		

Note: * 10% level of significance, **5% level of significance, ***1% level of significance.

In the first stage, the coefficient on TFP gap is negative and highly significant. Similarly, the coefficient on Total Workers is negative and highly significant. The coefficient on Net Entry is negative but is insignificant. In the second stage, the coefficient on Net Entry is negative and highly significant indicating that higher net exit will increase the probability that surviving firms will engage in R&D activities. Note that as tariffs decline, price cost margin or profitability is reduced, competition increases and less efficient firms are forced out of the market. The coefficient on Age is negative and significant and similarly, the coefficient on Total Workers is negative and highly significant. Based on EPR as trade indicator, the evidence that trade liberalization leads to innovation is relatively weaker. The coefficient on PCM is negative, but not significant.

5.3. Manufacturing by Trade Orientation: No Entry and Exit Indicators

The model is next tested using the different manufacturing sectors classified based on their trade orientation: non-traded, purely importable, purely exportable, and mixed sector. Two regressions methods are applied, IV and Tobit. For IV, two estimation techniques are applied: FE and RE.Two trade indicators are used, output tariffs and effective protection rates.

Tables 19.1-20.2 summarize the key results for the mixed sectors. Using IV regression and Tariff as trade indicator, some evidence of a positive effect of trade liberalization on innovation is found. The coefficient on Tariff is positive and highly significant while the coefficient on PCM is negative and significant. Using EPR as trade indicator, the coefficient is positive and highly significant, but for PCM, while the coefficient is negative it is not significant.

Table 19.1. First Stage IV Results: FE and RE

MIXED SECTOR

PCM	EPR		TARIFF	
	(1) FE	(2) RE	(1) FE	(2) RE
Age	-0.002196	-0.0007068	0.000307	-0.0006029
	-0.0025562	-0.0004806	-0.0032214	-0.0004183
Total workers	-9.02E-06	-.0000277***	-9.32E-06	-.0000288***
	-0.0000131	-6.69E-06	-0.0000131	-6.37E-06
TFP Gap	-2.663347***	-1.983007***	-2.664046***	-1.855282***
	-0.1171964	-0.061406	-0.1172395	-0.0592093
Trade Indicator	.0024892***	.0017411***	.0075801**	.006108***
	-0.0009776	-0.000455	-0.0034387	-0.0014744
Constant	.9566725***		.8702728***	
	-0.1404109		-0.1532073	
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
Observations	6495	6495	6495	6495
R-squared (overall)	0.0723		0.0736	
Hausman Test				
Chi2		9.67		9.23
Prob>chi2		0.9169		0.9329

Table 19.2. Second Stage IV Results: FE and RE

MIXED SECTOR

RD	EPR		TARIFF	
	(1) FE	(2) RE	(1) FE	(2) RE
PCM	-0.0552967	-0.0906546	-0.1351851	-.1295984*
	-0.0833932	-0.0678799	-0.107184	-0.0682428
Age	-0.0000902	0.0001219	-0.0004435	0.0001018
	-0.0006294	-0.0001337	-0.0007396	-0.0001255
Total workers	-4.91e-06*	-3.09E-06	-5.67e-06*	-3.80E-06
	-2.89E-06	-2.58E-06	-3.26E-06	-2.70E-06
TFP Gap	0.0258156	-0.0453125	-0.1875423	-0.1114657
	-0.2241031	-0.1348436	-0.2875925	-0.126285
Constant	0.0048743	0.0256419	0.0858808	0.0527683
	-0.0895349	-0.0546182	-0.1135132	-0.0512104
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
Observations	6495	6495	6495	6495
R-squared (overall)	0.0043	0.0124	0.0045	0.0112

The same results are obtained in the Tobit regression; both EPR and tariff have the correct positive signs which are highly significant; however, while the coefficient on PCM is negative as expected, it is not significant. The results also show a highly significant negative relationship between PCM and TFP gap and a highly significant negative relationship between number of workers and R&D.

Table 20.1. First Stage IV Results: Tobit

MIXED SECTOR

PCM	(1) TARIFF	(2) EPR
Age	-.0003994 *	-.0003936*
	-0.0002435	-0.0002436
Total workers	-.0000216***	-.0000219***
	-4.33E-06	-4.34E-06
TFP Gap	-1.332122***	-1.322314***
	-0.0474155	-0.0472372
Trade Indicator	.0030229***	.0005372*
	-0.001026	-0.0002858
Constant	.4655379***	.5039854***
	-0.0301794	-0.0258772
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	6495	6495
Adj R-squared	0.1189	0.1182

Table 20.2. Second Stage IV Results: Tobit

LnRD	(1) TARIFF	(2) EPR
PCM	-5.733137	-8.414397
	-3.639965	-6.594807
Total workers	-.0003721***	-.000431***
	-0.0000925	(.0001546)*
Age	-.0060584**	-0.0070863
	-0.0029606	-0.003938
TFP Gap	0.9419193	-2.583998
	-4.813166	-8.691929
Constant	-5.503807***	-4.12588
	-1.890225	-3.403656
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	6495	6495

For the other remaining sectors- non-traded, purely importable, and purely exportable- the evidence that trade liberalization affects innovation through competition seems to be weak. The general results show that although the coefficient on the trade indicator (EPR or Tariff) is correct, it is not significant. Similarly, the coefficient on PCM has the correct sign but is also not significantly different from zero.

5.4. Manufacturing by Trade Orientation: With Entry and Exit Indicators

The next set of results use the same basic model with a control variable for the selection process measured by Net Entry. Tables 21.1 to 22.2 present the results for the mixed sector. With Net Entry as an additional control variable, the results based on Tariff as trade indicator show some evidence of a positive effect of competition on innovation brought about by trade liberalization.

Using IV regression with Tariff as trade indicator, the REfirst stage results show that Tariff and PCM have a positive relationship that is highly significant. TFP and PCM have a highly significant negative relationship indicating that less efficient firms have lower profitability. The coefficient on Total Workers is negative and highly significant. The second stage results show that PCM and R&D have a significant negative relationship.

Table 21.1. First Stage IV Results: FE and RE

MIXED SECTOR

PCM	EPR		TARIFF	
	(1) FE	(2) RE	(1) FE	(2) RE
Age	-0.0022093	-0.0006576	0.000412	-0.0005626
	0.0025548	0.00045	0.0032198	0.0014297
Total workers	-0.00000916	-0.0000285***	-0.00000945	-0.0000292***
	0.0000131	0.00000654	0.0000131	0.0003939
TFP Gap	-2.663204***	-1.919879***	-2.663662***	-1.793328***
	0.1171321	0.0603512	0.1171664	0.00000622
Net Entry	-0.0012348*	-0.000747*	-0.0012958**	-0.0005875
	0.0006493	0.000448	0.0006495	0.0581184
Trade Indicator	0.0024525***	0.0016159***	0.0077154**	0.0057119***
	0.0009773	0.0004418	0.0034372	0.0004647
Constant	0.9578304***	0.734464***	0.8680335***	
	0.1403352	0.0323591	0.1531157	
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
Observations	6495		6495	6495
R-squared (overall)	0.0723		0.073	
Hausman Test				
Chi2		11.99		11.65
Prob>chi2		0.848		0.821

Table 21.2. Second Stage IV Results: FE and RE

RD	EPR		TARIFF	
	(1) FE	(2) RE	(1) FE	(2) RE
PCM	-0.0543989	-0.0956812	-0.1348164	-0.1336937*
	0.0846258	0.0727616	0.1052708	0.0724602
Age	-0.0000874	0.0001196	-0.0004415	0.0001007
	0.0006315	0.0001289	0.0007327	0.0001213
Total workers	-0.00000489*	-0.00000302	-0.00000567*	-0.00000371
	0.0000029	0.00000274	0.00000326	0.00000281
TFP Gap	0.0281981	-0.0523605	-0.186552	-0.1139012
	0.2273521	0.139814	0.2824784	0.1294799
Net Entry	0.0000751	0.0001017	-0.0000268	0.0001094
	0.0001747	0.0001321	0.0002033	0.0001416

Table 21.2 (continued). Second Stage IV Results: FE and RE

RD	EPR		TARIFF	
	(1) FE	(2) RE	(1) FE	(2) RE
Constant	0.0039449	0.0286122	0.0855136	0.0519422
	0.0907382	0.05666	0.1116845	0.0506673
Year Dummies	Y	Y	Y	Y
Industry Dummies	Y	Y	Y	Y
Observations	624	624	6495	6495
R-squared (overall)	0.0043	0.0124	0.0045	0.0114

The Tobit results show that based on Tariff as trade indicator, there is some evidence linking trade liberalization to innovation through competition. In the first stage, a highly significant positive relationship between PCM and Tariff is found. With respect to the control variables, the coefficient on Age is negative and significant while the coefficient on TFP gap is negative and highly significant. The coefficient on Total Workers is negative and highly significant.

Table 22.1. First Stage IV Results: Tobit

MIXED SECTOR

PCM	(1) TARIFF	(2) EPR
Age	-0.0004035*	-0.000397*
	0.0002437	0.0002438
Total workers	-0.0000216***	-0.0000218***
	0.00000434	0.00000434
TFP Gap	-1.331775***	-1.321962***
	0.0474237	0.047248
Trade Indicator	0.0030443***	0.0005407*
	0.001027	0.000286
Net Entry	0.0002632	0.0002235
	0.0005458	0.0005457
Constant	0.4598655***	0.4916265***
	0.0267683	0.0235211
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	6495	6495
Adj R-squared	0.1188	0.1181

Table 22.2. Second Stage IV Results: Tobit

LnRD	(1) TARIFF	(2) EPR
PCM	-6.083573*	-8.772339
	3.682705	6.686467
Age	-0.0059966**	-0.0070351*
	0.0030161	0.0040205
Total workers	-0.0003815***	-0.0004406***
	0.0000937	0.0001567
TFP Gap	0.4578945	-3.076967
	4.868762	8.810686
Net entry	-0.013027**	-0.0125073*
	0.0059947	0.0070161
Constant	-2.754255	-1.409861
	1.85854	3.355992
Year Dummies	Y	Y
Industry Dummies	Y	Y
Observations	6495	6495

In the second stage (R&D equation), the coefficient on PCM is negative and significant. The Net Entry indicator and PCM also have a negative correlation that is significant at the 5% level which suggests that as more firms exit (presumably the inefficient ones), the remaining or surviving firms tend to engage in R&D activities. These results tend to show that with a tariff reduction, firm profitability declines which indicates an increase in competition. As competition increases, less productive firms are forced out of the market while the productivity and innovation activities of surviving firms increase. The second stage IV results also show a significant relationship between Age and LnRDand a highly significant negative correlation between total workers and LnRD.

For the non-traded, purely importable and purely exportable sectors, the same results obtained earlier were found, indicating the lack of strong evidence that would link trade liberalization with innovation. While the correct signs on the coefficients are obtained in most cases, these are not statistically significant.

6. Conclusions and Policy Implications

6.1. Summary of Major Findings

The most recent literature on trade and growth shows that international trade affects firms' innovative activities through increased competition. As Licandro (2010) noted, increasing evidence supports the claim that international trade enhances innovation and productivity growth through an increase in competition. In the Philippines, trade liberalization has been at the core of economic reforms. The increase in competition arising from the removal of barriers to trade has presented both opportunities and challenges to domestic firms to innovate and improve their productivity. This paper has attempted to examine the link between trade liberalization and innovation. What is the impact of the removal of barriers to trade on the firms' innovative activities? Did the increase in competition arising from trade reforms lead to increases in innovation?

Impulliti and Licandro (2009, 2010) introduced a framework where trade affects both firm selection and innovation through the competition channel. Given an oligopolistic environment, trade liberalization leads to an increase in the number of firms in the domestic market which raises product market competition and lowers the markup rate. The selection effect of trade operates through endogenous markups resulting from oligopolistic competition among firms. The reduction in the markup rate (or increase in competition) due to trade liberalization reduces profits, increases the productivity threshold above which firms can profitably produce and forces the less productive firms out of the market. Resources are reallocated from exiting firms to the higher productivity surviving firms which innovate at a faster pace.

Without Net Entry indicator, both the IV and Tobit results show that for overall manufacturing industry, trade liberalization affects innovation through competition. In the first stage, Tariff is highly correlated with PCM while in the second stage, a significant relationship between PCM and R&D is obtained. This suggests that reduced profit (which implies high competition) is associated with increased R&D.

Controlling for firm entry and exit, the IV and Tobit results show generally the same findings. With Tariff as trade indicator, trade liberalization has a strong positive impact on competition while competition has a significant effect on R&D.

Firms have also been grouped based on their trade orientation intensity: nontraded, purely importable, purely exportable, and mixed sector. It is in the latter sector where trade is most intense. In general, the major results again confirm the importance of market competition as the channel through which trade liberalization affects innovation. Selection arising from competition also plays a role. These results are highlighted in the mixed sector which is characterized by substantial imports and exports of products in industries like motor vehicle parts and components, semi-conductors, parts and supplies for radio, TV, communication, appliances and house wares, garments, carpets and rugs, furniture, along with sugar, glass, chemicals, cigarette, soap and detergents, iron and steel and drugs and medicines.

Based on IV regression, the key results in the mixed sector show a significant positive effect of trade liberalization on innovation through competition. The same results are obtained in both models with and without the Net Entry indicator. The results tend to show that with a tariff reduction, firm profitability declines which indicates an increase in competition. As competition increases, the productivity threshold in which firms could operate profitably increases, hence less productive firms are forced out of the market while more productive firms are allowed to continue their operations. With competition, the productivity and innovation activities of the surviving firms increase.

The Tobit results show a highly significant positive relationship between PCM and Tariff as well as a significant positive relationship between PCM and EPR. In the first stage, a highly significant positive relationship between PCM and Tariff is found. In the second stage, a significant negative correlation between PCM and LnRD is found. The Net Entry indicator and PCM also have a negative correlation that is significant at the 5% level. This suggests that as more firms exit (presumably the inefficient ones), the remaining or surviving firms tend to engage in R&D activities. The results tend to imply that with a tariff reduction firm profitability declines which indicates an increase in competition. As competition increases, less productive firms are forced out of the market while the productivity and innovation activities of surviving firms increase.

6.2. Some Policy Recommendations

Given the crucial role of competition in the relationship between trade liberalization and innovation, it is important for the government to maintain the contestability of markets. Contestability is the essence of effective competition; for as long as markets remain contestable (when entry into a market is easy), we would expect large firms in an oligopolistic environment to act independently, and monopolies to behave in a competitive manner. If entry is easy and costless, the potential threat from imports or from domestic competitors will make incumbent firms behave competitively.

It is important to note that the presence of market imperfections, such as abuse of dominant position and other anti-competitive business practices, along with trade barriers or government regulations, limit market entry and create inefficiencies leading to reduced long-term growth. These weaken competition and prevent structural changes from taking place, resulting in resources being tied to low-productivity industries. Weak competition reduces the pressure on firms to adopt new technology or innovate, resulting in low growth of productivity and a loss of competitiveness.

Philippine experience has shown that after two decades of implementing liberalization and other market-opening policies, competition and productivity growth remained weak not only due to the presence of structural and behavioral barriers to entry, but also to the country's inadequate physical and institutional infrastructure. Due to the fundamental weakness of competition in many major economic sectors, the gains from liberalization remained limited which slowed down the country's economic growth.

The results have a bearing on the possible impact of the government's selective protection policy on competition and innovation. This policy, which was adopted in 2003, increased the tariff rates on selected agriculture and manufacturing products which has led to a sizeable proportion of products with tariff peaks. The paper's findings tend to suggest that an increase in tariffs will increase profitability and reduce competition which would likely result in reduced innovation, holding all else equal. The selective protection policy must thus be reviewed, given its likely negative impact on competition and innovation and taking into account the current low level of R&D spending and overall innovation activity in the country.

It is necessary to address the remaining barriers to market entry (and exit) such as selective tariff protection and non-tariff measures in rice, sugar, automotive parts and components and other manufacturing products. The government needs to veer away from protectionist policies and mechanisms that intervene in the market and try to decide and select which firms should survive and which ones would die. In the light of the findings of this paper and the increasing globalization and economic integration that make industries more mobile through production networks and supply chains, the government should focus on designing an overall policy and strategy that would ensure competition, innovation and the productivity growth of firms. Beginning in January 2010, the ASEAN Trade in Goods Agreement (ATIGA) where tariffs were reduced to zero in a substantial number of products has been implemented. Whether this will lead to more competitive markets in the Philippines depends not only on the overall trade creation and trade diversion effects of the ASEAN Economic Community (AEC) but also on the government strategy that will be put in place to help our industries face increased competition from imports, and take advantage of opportunities such as bigger export markets and increased foreign direct investment flows. Note also that there are other important determinants of innovation including human capital, infrastructure, and institutional factors that must be closely examined along with their interaction with trade policy reform indicators.

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Appendix

Appendix I: Price Cost Margin

A.P Lerner (1933-34) defined PCM or Lerner index of monopoly power as:

$$B = \frac{P - MC}{P} \qquad \text{equation (1a)}$$

Where B is price cost margin, P is price, and MC is marginal cost. For a competitive firm, $P = MC$ and the Lerner index is equal to zero. For a monopolist, $P>MC$ and the Lerner index becomes positive and varies between 0 and 1.

The mark up ratio, a simple way of measuring the level of competition, is given by the ratio of price to marginal cost of production by firms in an industry. This can be written as:

$$\mu = \frac{P}{MC} \qquad \text{equation (1b)}$$

Where μ is the mark up ratio. This variable indicates the level of competition or market power of firms in industries. When firms have market power, P>MC and mark ups are greater than 1 in equilibrium. In perfect competition, P=MC. The price cost margin can be easily mapped into the mark up ratio μ. Equation (6) can be rewritten as:

$$\mu = \frac{1}{1 - B} \qquad \text{equation (1c)}$$

CHAPTER 9

Trade Liberalization and Innovation Linkages Micro-evidence from Vietnam SME Surveys

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Vietnam has long been pursuing its far-reaching trade liberalization program which has led to rapid economic growth and poverty reduction. Innovation has long been considered an important factor for creating and maintaining the competitiveness of nations and firms. This paper investigates the impacts of trade liberalization on innovation activities by SMEs, the most dynamic and important sector for Vietnam's future economic development. Using the recently released Vietnam Small and Medium Enterprise Survey, we find that innovation, as measured directly by 'new products', 'new production process' and 'improvement of existing products' are strongly influenced by trade liberalization.

***Keywords*:** Innovation, Export, Vietnam, SME, Trade liberalization

JEL Classification: D21, L23, O31, O32

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1. **Introduction**

After 20 years of reform, Vietnam has put in place the fundamentals of a market economy and actively participated in the globalization process by opening up the economy to international flows of capital and trade in goods and services.[2] The emergence of the market-based economy with appropriate institutions, stable macroeconomic environment and the support of the government for business development have allowed Vietnam to (i) unlock the potential of the agriculture sector, turning Vietnam from a food-hungry country to the world's third largest rice exporter[3]; (ii) encourage the development of a vibrant domestic private sector; (iii) attract a large amount of foreign investment; (iv) realize its comparative advantages and gain more benefits from international trade. These factors underlie the economic success that Vietnam has been achieving since the early 1990s. The country is now recognized as being among the most successful developing countries in terms of economic growth and poverty reduction.

As can be seen in Figure 1, during the period 1990–2008, the annual GDP growth rate averaged more than 7 percent, and Vietnam's growth rates today remain among the highest the region. The average annual GDP growth was about 5-6 percent during the period1990–91, climbing to and then staying at about 8 percent from 1992 to 1997. GDP growth, however, declined between 1998 and1999, partly because of the Asian crisis and the dissipation of the effects of reform. Since 2000, the economy has regained its momentum. Its annual growth rate exceeded 7 percent—reaching 8.5 percent in 2007—then dropped back to an estimated 6.2 percent in 2008, owing to the effects of the global recession. High and continuous GDP growth rates and successful economic development from 2000 to 2008 have resulted in significant improvements in the population's welfare and in substantial poverty reduction. According to the

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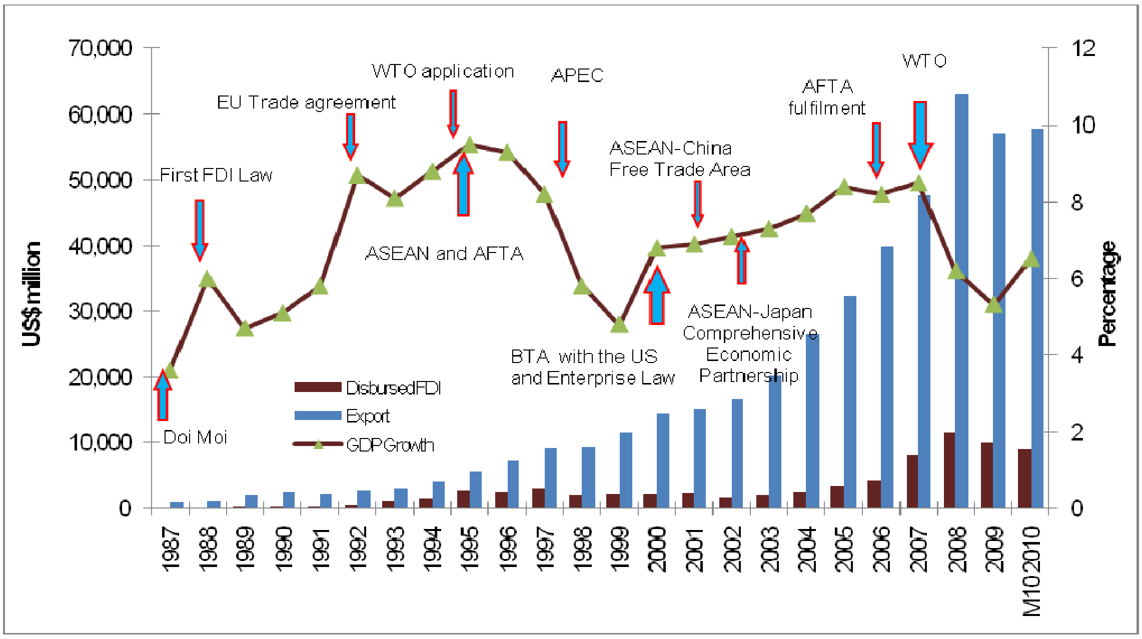
[2] "Globalization" is a loaded concept and may mean different things to different people, in different contexts. From an economic perspective, it usually refers to the removal of barriers to the cross-border movements of goods, funds, personnel and information. The more easily such movements take place, the higher the degree of globalization.

[3] Che *et al.* (2003) report that market reform leads to an increase in rice productivity, pointing to the importance of market competition, secured property rights and efficient use of resources. See http://www.crawford.anu.edu.au/degrees/idec/working_papers/IDEC03-7.pdf

Vietnam Household Living Standard Survey, the total poverty incidence declined from 58 percent in 1993 to 37 percent in 1998, 29 percent in 2002, 19.5 percent in 2004, and 16 percent in 2006 (SRV 2003; Nguyen 2009). In addition, improvements have been made in other aspects of human welfare, such as the sharp rise in the percentage of literate adults (to over 90 percent), longer life expectancy (over 70 years), and a lower mortality rate for children less than five years old (40 per 1,000 live births in 2003).

Figure 1. Vietnam Trade Liberalization and Economic Development



Note: In 1992, Vietnam signed a trade agreement with the European Union (EU). In 1995, it joined ASEAN and committed to fulfill the agreements under AFTA by 2006. Vietnam applied for WTO membership in 1995 and became a member in 2007. In 1998, it became a member of the Asia-Pacific Economic Cooperation (APEC) and, in the year 2000, signed the Bilateral Trade Agreement with the United States (VN-U.S.BTA). This agreement came into force in December 2001. Recently, Vietnam has also joined regional integration clubs such as ASEAN-China Free Trade Area (2002) and ASEAN-Japan Comprehensive Economic Partnership (2003).

As a result of its effort to integrate into the global economy, Vietnam has substantially liberalized its trade and investment regimes which have enabled Vietnam to attract a large inflow of foreign direct investment (FDI) and witness trade expansion. The process has created a growing and dynamic private sector consisting of mainly small and medium enterprises. In the face of Vietnam's increased integration into the world market, and particularly following the country's entry into the WTO at the end of 2006, the SMEs are having a great opportunity to expand by exporting to other markets. But at the same time they are also facing tough competition on their door step.

According to endogenous growth theory, technological innovation is important to the “sustained” growth of an economy (Romer, 1986; Lucas, 1988).[4] Like many other emerging market economies/countries, globalization brings about opportunities and also pressures for Vietnamese domestic firms to innovate and improve their competitive position. Many of these pressures and opportunities operate through increased competition from, and linkages with, foreign firms and exposure to the international market. The major problem is that the Vietnamese private sector, and small and medium enterprises in particular, is not yet sufficiently competitive. As a result, most companies cannot yet withstand the competitive pressure resulting from liberalization and the opening to the world market, not to mention exporting to the world market. The key question facing policy makers is how to improve the competitiveness of Vietnam’s enterprises, especially the SME sector which accounts for a large part of the economy. Among the many initiatives being proposed to improve the competitiveness of Vietnam’s SMEs, innovation policy has attracted attention not only from policy makers, but also from researchers and the business community (Nguyen *et al*., 2008). These initiatives are based on the assumption that innovation can affect a firm’s competitiveness and hence export status by increasing productivity (and reducing costs), and by developing new goods for the international market.[5]

In this paper, we use the conceptual frameworks of a number of recently developed models (e.g. Sutton, 2007) to examine the determinants of innovation by Vietnamese SMEs in the context of increased competition and linkages resulting from trade liberalization. Specifically, we focus on the effect of competition and transfer of capabilities stemming from globalization, which may be brought about through various channels, including the spillover effects of FDI, exposure to international trade, and

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[4] The acquisition of knowledge and intelligence, technological innovation and human capital accumulation are the main reasons for the economic growth of the newly industrialized economies (Bassanini and Scarpetta, 2002; Hu & Mathews, 2005; Mueller, 2006, Nguyen and Nguyen 2010).

[5] This can be analyzed in the context of firms that compete in markets with differentiated products. Firms sell low-quality goods in domestic markets, but if they want to sell abroad then they must upgrade technologies to produce high-quality goods.

increased competitive responses by domestic firms. After briefly reviewing the previous studies in section 2, we present our data and econometric specification in section 3. We discuss our empirical results in section 4 while we conclude in section 5.

2. Trade Liberalization and SME Development in Vietnam

The evolution of globalization for Vietnam in the last 20 years is also illustrated in Figure 1. Vietnam has substantially liberalized its trade and investment policies since the late 1980s. During the early years of economic reform, Vietnam liberalized its trade regime through signing trade agreement with around 60 countries. It has also implemented a preferential trade agreement with the European Union since 1992. Later on, the country actively sought membership of regional and global organizations.[6] Vietnam has been a member of the Association of South East Asian Nations (ASEAN) since June 1995 and the Asia Pacific Economic Co-operation (APEC) since 1998. In 2000 Vietnam signed a historic comprehensive trade agreement with the USA to normalize trade relations between the two countries. Recently, Vietnam has also joined regional integration clubs such as ASEAN - China Free Trade Area and ASEAN-Japan Comprehensive Economic Partnership. Most recently, in 2007 Vietnam became the latest member of the World Trade Organization.

This process of trade regime liberalization has led to increased trade flows, and in particular export, for the country. In a recent paper, Abbott *et al*. (2009) observe that each time Vietnam reached a significant bilateral agreement, trade flows with that partner surged. Vietnam has also seen a steady growth in its international trade over the period. The average growth rate of export and import is around 20%. The total value of international trade over the GDP, which is one indicator of the openness of an economy, reached 150 per cent in 2007, up from 61 per cent in 1994. The structure of import and

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[6] International integration processes picked up from the early 1990s after the collapse of the Berlin wall, and Vietnam lost its traditional markets in Eastern Europe and The Soviet Union in the late 1980s. The US trade embargo against Vietnam was only lifted in 1994, and the relationship with the US was normalized in 1995. Another important achievement and event is that since 1993 Vietnam has begun to receive overseas development assistance (ODA) from foreign governments which have contributed to the substantial increase in financial resources for Vietnam's development.

export has substantially changed in comparison with the previous period. Vietnam has exported oil, various manufacturing and agriculture-processing products, and imported not only consumption goods, but mainly raw materials for domestic production and initially progressive techniques and technology to promote the growth and efficiency of the economy. The composition of Vietnamese exports has gradually reflected the success of the industrialization process. The share of manufactured products, particularly labor intensive products like textiles and garments, footwear, and seafood, has been increasing and replacing the traditional agricultural products. In 2005, the share of manufactured handicraft products alone accounted for more than 40 per cent of total export value (CIEM 2005).

The Law on Foreign Direct Investment (FDI) was first promulgated in 1987 and later amended in 1990, 1992, 1996 and 2000 which helped Vietnam to attract a large volume of foreign capital when domestic savings were insufficient to meet investment needs. By 1987, the private sector virtually did not exist in Vietnam. By allowing foreign direct investment, Vietnam in effect imported/implanted the private sector of its own for the first time after the unification of the country. Since then, FDI has indeed become an integrated part of the Vietnamese economy and an important factor in Vietnam's economic growth during the 1990s. In order to create a more level playing field and to ensure that its laws allowed for national treatment for FDI enterprises prior to Vietnam's 2006 accession to the World Trade Organization, in 2006 Vietnam promulgated two important laws, the Investment Law and the new Enterprise Law[7,] creating a corporate law regime that applies to both foreign and domestic enterprises.[8]

Thanks to the progressively liberalized regulations toward FDI, the FDI sector has now become an important part of the national economy. After a slowdown in FDI inflow in the aftermath of the Asian financial crisis, recently, new large FDI inflows have emerged, in part as a result of reforms committed to as part of WTO accession that

[7] Specifically, on November 29, 2005, the National Assembly of Vietnam adopted the Law on Investment No. 59/2005/QH11 ("New LOI") and Law on Enterprises No. 60/2005/QH11 ("New LOE") which apply to all enterprises established by domestic and/or foreign investors.

[8] Besides FDI, Vietnam also started to receive the ODA from international donors in 1993 and the amount committed and disbursed has been increasing since then. These capital sources constitute a positive assistance to infrastructural construction such as transport and communication, information, agricultural and rural development, public health, education and training, administrative reform, legislation, and structural reform.

relaxed rules restricting FDI, making Vietnam a more attractive FDI destination. The sudden increases in the share of the FDI sector during the period 2007-2008 can be partly explained by the WTO accession of Vietnam which generated hype among foreign investors about the prospect of doing business in Vietnam.[9] Although Vietnam has been successful in attracting FDI in recent years, the real benefits from FDI still seem controversial. Previous studies have found little evidence of technical spillover from FDI enterprises to local counterparts (Nguyen *et al.,* 2008). In addition, the country has become heavily dependent on FDI capital as an important source of input to sustain economic growth.

As discussed above, the last 20 years have witnessed comprehensive reforms being implemented in Vietnam which, together with an open-door policy to attract foreign direct investment and trade liberalization with the culmination of WTO accession in 2007, have created a growing dynamic private sector in Vietnam. However, the vibrant emergence of the private sector and SMEs is a recent development in Vietnam. When Vietnam opened up to outside world under its Doi Moi, starting with some timid reforms, the Vietnamese government officially granted its recognition of private enterprises in the early 1990s with the introduction of the Company Law and the Law on Private Enterprises. Despite this early official recognition for the private business sector, private enterprises developed slowly with only 39,600 enterprises established during the 1990s. Major growth in the formal private sector came with the 1999 Enterprise Law, which gave a much clearer legal status for the private sector. Since the Law became effective on 1 January 2000 the country has experienced a boom in private SMEs. They have now become a strong part of the national economy and have made a significant contribution to economic growth, job creation, exports and poverty reduction.

Small and medium-sized enterprises (SMEs) are a very heterogeneous group [10] and their definition varies by country. Usually the definition is based on the number of

[9] Vietnam requires registration of intended FDI, and not all of those registrations are implemented.
[10] SMEs operate in a wide array of business sectors, ranging from handicraft producers for village markets, coffee shops on the street, and Internet cafés in a small town to small sophisticated engineering or software firms selling to overseas markets and a medium-sized manufacturers supplying inputs to multinational automakers in both domestic and foreign markets.

employees, and value of sales and/or value of assets. The most commonly used criteria among a large number countries (both developed and developing) are the number of employees, for which the upper limit of number of employees in SMEs is set at between 200 and 250, with a few exceptions such as in Japan (300 employees) and the USA (500 employees).[11] In Vietnam, SMEs are defined using two criteria: number of employees and registered capital. According to Vietnamese laws and regulations (Government Decree 90/2001/ND-CP), Vietnamese SMEs are legally defined as "independent production and business establishments" with registered capital not exceeding VND 10 billion[12] or annual labor not exceeding 300 people. Based on this definition, the SMEs in Vietnam account for 97 percent of the total number of Vietnamese enterprises (calculated based on annual labor) or some 85 percent (calculated based on capital), given by the latest statistical data of the Vietnam General Office of Statistics.

Economic reform during the last decades has directly stimulated the development and performance of Vietnamese SMEs. As can be seen in Table 1 which classifies SMEs by the number of employees, the SMEs account for 97 percent of the total number of firms in 2008, an increase from 92 percent in 2000. The average growth rate of the SMEs under this classification was 23 percent in contrast with the average rate of just seven percent for the large enterprises. Under the capital classification criteria used in Table 2, the SME sector also account for 96% of the total number of firms with an average growth rate of 22 percent. In contrast to the employment classification, the SMEs' growth rate is still higher than 20 percent but two percentage point lower than the large enterprises. Vietnamese SMEs have been outperforming other enterprises in exploiting Vietnam's comparative advantage in labor-intensive production (Harvie, 2001).

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[11] See Promoting SMEs for Development http://www.oecd.org/dataoecd/6/7/31919278.pdf

[12] At current exchange rate equivalent to around USD 450,000 decreasing from USD 600,000 due to the Dong's depreciation.

Table 1a. Distribution of Small and Medium Enterprises 2000-2008 (by Employees)

	Total Number of Firms (including SME)	SME	Micro Enterprises	Small Enterprises	Medium Enterprises	Large Enterprises
2000	42288	92%	54%	34%	4%	8%
2001	51680	93%	54%	35%	4%	7%
2002	62908	93%	53%	37%	4%	7%
2003	72012	94%	51%	39%	3%	6%
2004	91756	95%	53%	38%	3%	5%
2005	112950	96%	56%	37%	3%	4%
2006	131318	96%	61%	32%	3%	4%
2007	155771	96%	61%	33%	3%	4%
2008	205689	97%	62%	33%	2%	3%

Table 1b. Growth Rate of Firms 2001-2008

	Total Number of Firms (including SME)	SME Average	Micro Enterprises	Small Enterprises	Medium Enterprises	Large Enterprises
2001	51680	23%	23%	25%	7%	9%
2002	62908	22%	18%	29%	16%	15%
2003	72012	15%	12%	20%	9%	6%
2004	91756	29%	33%	25%	16%	6%
2005	112950	24%	29%	18%	11%	4%
2006	131318	17%	26%	3%	7%	5%
2007	155771	19%	19%	19%	19%	8%
2008	205689	33%	33%	34%	10%	6%

Source: GSO. Calculation by authors. Classification by number of employees.

Table 2a. Distribution of Small and Medium Enterprises 2000-2008 (by Capital)

	Total number of Firms (including SME)	SME	Small Enterprises	Medium Enterprises	Large Enterprises
2000	42288	97%	88.8%	7.9%	3.3%
2001	51680	97%	89.2%	7.6%	3.1%
2002	62908	97%	89.0%	7.8%	3.1%
2003	72012	97%	89.0%	7.8%	3.2%
2004	91756	97%	89.3%	7.6%	3.1%
2005	112950	97%	89.7%	7.4%	3.0%
2006	131318	97%	89.6%	7.4%	2.9%
2007	155771	96%	87.8%	8.6%	3.6%
2008	205689	96%	86.4%	9.9%	3.7%

Table 2b. Growth Rate of Firms 2001-2008 (by Capital)

	Total number of Firms (including SME)	SME	Small Enterprises	Medium Enterprises	Large Enterprises
2001	51680	22%	23%	18%	16%
2002	62908	22%	21%	25%	22%
2003	72012	14%	14%	14%	16%
2004	91756	28%	28%	24%	23%
2005	112950	23%	24%	19%	19%
2006	131318	16%	16%	17%	15%
2007	155771	18%	16%	37%	46%
2008	205689	32%	30%	52%	34%

Source: GSO. Calculation by authors. Classification by capital.

Table 3 presents a **breakdown of Vietnamese SMEs, categorised in terms of ownership,** for the period 2000-2008. The first row shows the total number of SMEs. The data indicates that, after a period of 9 years up to 2008, the numbers of SMEs increased by more than five times from 39897 in 2000 to 201590 in 2008. In the last three rows, the number of SMEs is computed as a share of each ownership type on total. The ownership structure of SMEs indicates that **most SMEs are non-state owned**. The number of state-sector SMEs decreased due to the progress of privatization. In 2000, nearly 11% of SMEs were state owned versus only 3% foreign-owned. In 2008, the SMEs in these two ownership sectors represent only 3.3 percent of the total number.

Table 3. Number and Ownership Structure of Vietnamese SMEs 2000-2008

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	39897	49062	59831	68687	88222	109336	127593	151780	201580
Ownership structure									
State owned enterprise	10.5	7.6	6.1	4.6	3.4	2.4	1.9	1.5	1.1
Non-state enterprise	86.4	89.0	90.9	92.5	93.9	94.9	95.5	95.9	96.7
Foreign investment enterprise	3.0	3.4	3.0	2.9	2.7	2.6	2.6	2.5	2.2

Unit: %
Source: Author's elaboration based on Enterprise Census 2000-2008 of GSO of Vietnam.

Table 4 presents the percentage of the total number of firms in Vietnam which are SMEs. The first row shows the share of total SMEs on total firms. The data shows that almost 98 percent of the total number of existing firms in Vietnam are SMEs. Broken down into type of ownership, the last three rows indicate the share of SMEs in each ownership sector. The fact is that SMEs constitute an overwhelming share of the private sector in Vietnam (99%). Share of SMEs in foreign owned firms (joint venture or 100% foreign owned) decreased slightly, but still made up more than three quarters of the firms in that sector. Share of state-owned SMEs decreased due to privatization.

Table 4. Share of Vietnamese SMEs in Total Firms by Type of Ownership

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	94.3	94.9	95.1	95.4	96.1	96.8	97.2	97.4	98.0
Ownership structure									
State owned enterprise	72.8	70.1	67.7	64.9	64.4	65.5	66.3	67.0	67.1
Non-state enterprise	98.5	98.5	98.5	98.4	98.6	98.7	98.8	98.8	99.1
Foreign investment enterprise	79.5	81.8	78.0	76.4	76.8	77.6	77.3	77.7	79.2

Unit: %.
Source: Author's elaboration based on Enterprise Census 2000-2008 of GSO of Vietnam.

Table 5 presents the sectoral structural change of Vietnamese SMEs. The data shows that most of structural changes occurred in 2000-2008 within the fishing and services sectors. The number of SMEs working in the fishing industry decreased remarkably during the last nine years. Less than 1% of SMEs remain in fishing (compared to about 6% in 2000). In contrast, more SMEs engage in the service sector (about 21% in 2008 compared to 15.4% in 2000).

Table 5. Sectoral Structure of Vietnamese SMEs

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total (100%)	39897	49062	59831	68687	88222	109336	127593	151780	201580
Agriculture and forestry	1.96	1.48	1.37	1.15	0.99	0.86	0.75	0.68	3.54
Fishing	6.14	5.21	4.01	2.13	1.53	1.24	1.02	0.85	0.67
Mining and quarrying	0.86	1.16	1.34	1.39	1.27	1.11	1.02	1.07	1.05
Manufacturing	22.93	22.38	21.97	21.84	20.90	19.98	19.24	18.80	17.78
Electricity, gas and water supply	0.25	0.27	0.28	0.34	1.64	2.18	1.98	1.83	1.53
Construction	8.89	10.54	12.02	13.22	13.23	13.39	13.48	13.46	13.73
Trade	43.48	41.81	41.08	41.03	40.67	40.66	41.00	40.41	40.17
Services	15.48	17.15	17.93	18.91	19.79	20.60	21.51	22.90	21.53

Unit: %.
Source: Author's elaboration based on Enterprise Census 2000-2008 of GSO of Vietnam.

SMEs in Vietnam have an important role to play in the country's economic development and industrialization process. The performance of SMEs can be observed though the state, non-state (largely comprising of SMEs) and foreign-owned sectors. Regarding GDP contribution, according to CIEM (2005), in 2005 the state-sector firms' contribution to GDP at current prices was almost the same as it was in 2000 (38.42% vs.

38.52% respectively). Non-state-sector contribution to GDP reduced from 48.2% in 2000 to 46.03% in 2005. As a result, the foreign investment sector contribution increased (15.89% in 2005 vs. 13.27% in 2000).[13] CIEM (2005) also reported the investment behavior by ownership. Interestingly, share of non-state-sector investment increased remarkably, with 32.2% of total 2005 investment versus 22.6% in 2000. This implies that the private sector, or SMEs, are now paying more attention to investment into their production. Hansen (2006) studied the determinants of growth and survival of SMEs. A study, which was based on a panel data of Vietnamese SMEs from 1990 to 2000, shows that innovation has positive and significant effect on survival of SMEs.

The development of SMEs is limited in many aspects, especially by market constraints and by SMEs' internal limitations, including capital shortage,[14] old equipment, outdated technology, and lack of skills and management experience [15](Webster and Taussig, 1999) and also by lack of appropriate government support.[16] In Vietnam, SMEs have received comparatively little support and attention. Until now, the most comprehensive document that lays out the details of the government action plan to develop the SME sector is the Decision No: 236/2006/QD-TTg on the 5-year SME development plan 2006-2010 by the Prime Minister, issued on October 23, 2006. [17] Though some legal documents have been issued to support the SMEs, in practice they are not yet fully implemented. The recent Decree 56/2009/ND-CP on SME development support in 2009, for example, enumerates the types of support SMEs can receive from the government, but does not provide guidance on how to actually receive that support.

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13 More recent estimates suggest that the SMEs contribute about 45% of Vietnam's GDP. http://cab.org.in/CAB%20Calling%20Content/Financial%20Cooperatives%20in%20India%20-%20Where%20are%20the%20Members/Innovative%20Ways%20in%20Financing%20SMEs.pdf

14 http://www.devoutreach.com/mar03/article/tabid/1373/Default.aspx

15 Modern corporate governance practices, such as those applicable in OECD countries are not yet fully adhered to by Vietnamese private SMEs.

16 http://www.adb.org/Media/Articles/2010/13364-vietnam-sme-reforms/

17 http://www.business.gov.vn/uploadedFiles/Decision%20236-2006.pdf

3. A Literature Review

Successful innovation in new products and processes is increasingly being regarded as the central issue in economic development (Porter, 1998).[18] The concept of innovation was first studied by Schumpeter (1943) which was later developed by generations of economists into what now can be referred to as "innovation theory" thanks to the pioneering work of Nelson and Winter (1982), Dosi (1984) and Pavitt (1984). Historically, innovation literature was focused on the role of internal research and development (R&D) on firm innovation (Griliches, 1979). However, despite the fact that R&D is often a cornerstone of an effective innovation strategy, internal R&D expenditures played only a partial role in firm innovation rates.[19] It is now increasingly recognized that the ability to exploit external knowledge is critical to firm innovation (Cohen and Levinthal, 1990; Henderson and Cockburn, 1994; Teece *et al.*, 1997).

Traditionally, only those firms involved in R&D activities for new processes and products are considered technologically innovative firms.[20] But Mansfield (1968) suggests that both the firm that introduces new equipment in the market and the firm that first uses it are considered innovative. De Propris (2002) separates the innovation into four types: product, process, incremental and radical innovation. Relevant to our study, according to this author (De Propris, 2002) product innovation corresponds to the introduction to the market of new or improved products, whereas process innovation relates to the sequences and nature of the production process. Process innovation is

[18] According to Rothwell (1994) there are five generations of innovation models. The first generation model of innovation is also known as "technology push". The second generation innovation model – "need pull" – implies a shift toward a market/customer focus. The third generation is called the "coupling model" - a coupling of the push and pulls models. The fourth generation model of innovation, the "integrated model" suggests the coupling of marketing and R&D activities, together with strong supplier linkages and close coupling with leading customers. Finally, the fifth generation innovation is the "networking model".

[19] There is a large amount of literature on R&D and firm performance commonly referred to as the CDM models. However, the relationship between a firm's performance and R&D spending is often imperfectly understood.

[20] Molero *et al.* (1998) characterize them as firms that execute activities on a regular basis, formally or informally, pursuing either the creation of new product and process technologies or their improvement, in order to obtain results –quantitative or qualitative- that could increase their competitive capacity against other firms that work in the same market, or open for them new markets, that is, supporting the growth of the firm.

often more difficult to detect but it is very important, especially for buyer-supplier transactions. Both radical and incremental innovations can be either in product or process.[21]

There are numerous studies on the process of innovation itself (i.e the process leading to innovation) as its measurement is critical for both practitioners and academics. Yet the literature is characterized by a diversity of approaches, prescriptions and practices that can be confusing and contradictory. It is, however, generally believed that the innovation process consists of a complex sequence of decisions. Examples include the CDM model literature structuring the firm's decisions on how, and how much to innovate in a multi-stepped process. According to De Propris (2002), it seems that the idea that innovation is a linear and sequential process proceeding through specific steps has been replaced by a systemic approach to innovation. Edquist and McKelvey (2000) and Lundvall (1992) argue that the innovation process should rather be considered as a circular and complex system embracing interactive elements.

Faced with increasing international competition, innovation has become a central focus in firms' long-term strategies. Firms competing in global markets face the challenges and opportunities of change in markets and technologies. According to Veugelers and Cassiman (1999), one important aspect within innovation management is the optimal integration of external knowledge, since innovation increasingly derives from a network of companies interacting in a variety of ways.

A large volume of literature exists on the expected impact of trade liberalization on domestic economic performance. In general, there is consensus on the fact that trade openness leads to economic growth beyond that expected when no policy change occurs (Rodrik 1999). It is generally believed that trade liberalization should be beneficial for the domestic economy as well as the world as a whole. The reasons behind this include greater consumer welfare despite any loss in fiscal revenue, greater access to technology, the dynamic effects of competitiveness, inflows of investment, and

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[21] Fernández (2005) suggests that a radical innovation occurs when the technological knowledge needed, in order to exploit it, is very different of the already existent knowledge while incremental innovation refers to improvements due to use or experience; it can often take the form of smaller enhancements around major radical innovations. Freeman and Perez (1988) argue that the incremental innovation is crucial for firms' productivity growth even though it is often underestimated in comparison to radical innovation.

improved resource allocation; access to better technologies, inputs and intermediate goods; economies of scale and scope; greater domestic competition; availability of favorable growth externalities like transfer of know-how, and many others.

At the firm level, trade liberalization could affect domestic enterprises and their innovation. Increased competition: lower import barriers (tariffs, quotas and other non-tariff barriers) would lead to increased foreign competition in the domestic market which will force inefficient domestic firms to try to improve their productivity by eliminating waste, exploiting external economies of scale and scope, and adopting more innovative technologies, or they may shut down. Lower production costs due to cheaper imported inputs which allow them to compete more effectively both against imports in domestic markets and in export markets. Another strand of the literature emphasizes the importance of international exposure through exporting as a source of new knowledge accumulation. Being exposed to international competition, the exporting firms can acquire important new knowledge through the process of learning-by-exporting. In addition, international competition can also be a stimulus for the firm to innovate for itself. Girma *et al.* (2004) report that exporters are more productive and they do select themselves in exporting although they also report that exporting increases a firm's productivity.

As with trade liberalization, investment liberalization also has positive and negative impacts on domestic firms and the SMEs. Sutton (2007) develops an industrial organization model to explain the impact of trade liberalization on the behavior of firms in the emerging market economies. The model assumes that a firm's competitiveness depends not only on its productivity but also on the quality of its product, with productivity and quality jointly determining a firm's "capability." Sutton's model (2007) predicts that after an initial shakeout, firms in emerging markets will strive to adjust by raising their capabilities, which may be improved by the vertical transfer of capabilities to the emerging market economies through the supply chain of multinational enterprises (MNEs). With the characteristic of public goods, knowledge and technologies that MNEs bring along when they invest abroad could have long-run impacts on the host country through the externality generated as suggested in endogeneous growth models (Grossman and Helpman 1991, Lucas 1988, Romer 1990).

It is commonly recognized that MNEs possess more advanced technology. When MNEs choose to penetrate a foreign market through direct investment, they are likely to bring along more sophisticated technology and superior managerial practices. These give them a competitive advantage over indigenous firms which tend to be more familiar with consumer preferences, business practices, and government policies in the host country market (Blomstrom and Sjoholm, 1999). It is possible that a portion of the technologies and experiences transported by MNEs will be diffused from their affiliates to the indigenous establishments in the host economy. Business associations with MNEs provide important learning opportunities for the domestic firms. They could reduce the costs of innovation and imitation for local firms, which will in turn speed up productivity improvement (Helpman, 1999). FDI may raise productivity levels of domestic firms in the industries which they enter by improving the allocation of resources in those industries. The presence of multinationals, together with their new products and advanced technologies, may force domestic firms to imitate or innovate. The threat of competition may also encourage domestic firms which might otherwise have been laggards to look for new technology. Another route for the diffusion of technology is the movement of labor from foreign subsidiaries to locally-owned firms. For example, local firms may learn to imitate a new process or improve the quality of their product through observation, interaction with foreign managers in business chambers, and from former employees of foreign multinational enterprises (MNEs). Local firms may also benefit from the entry of new professional services or suppliers as a result of the MNE entry. Foreign firms may act as catalysts for domestic suppliers to improve the quality or time efficiency of their goods or services by demanding higher standards. On the other hand, foreign firms may have a negative effect on domestic firms' output and productivity, especially in the short run, if they compete with domestic firms and "steal" their market or their best human capital. As domestic firms cut back production they may experience a higher average cost as fixed costs are spread over a smaller scale of production (Aitken and Harrison, 1998).

4. Data and Econometric Methodology

In this paper, we use the Vietnam Small and Medium Enterprise Survey conducted in 2007 and 2009 to investigate the link between innovation activities and exporting. The survey has been conducted four times: in 1991, 1997, 2002, 2005, 2007 and 2009 by the Ministry of Labor, Invalid and Social Affairs (MOLISA) and the Stockholm School of Economics, and in 2005 by MOLISA and University of Copenhagen. Although the SME survey is a longitudinal survey, we only have access to the data in 2005, 2007 and 2009. In our study, we chose to focus specifically on 2007 and 2009 data as the period under study is the period that Vietnam experienced increased trade liberalization.[22] The SME survey was meant to be a national representative survey, and was conducted in ten provinces in Vietnam. In all areas covered by the survey, the sample was stratified by ownership to ensure that all types of non-state firms were included. The SME survey is a rich dataset, containing a battery of information about firms' characteristics including enterprise dynamics and growth, bureaucracy, informality, tax, employment, education, social insurance, innovation, export, investment and finance.

In Vietnam, the survey is the only source of data that contains innovation information for enterprises in general, and SMEs in particular. An important advantage of our data is that firms self-report various types of innovation activity. The survey distinguishes between whether the firm introduced new products (product innovation), improved existing products (product modification) or introduced new production process/new technology (process innovation). These are the measures of innovation we used in this paper. [23]

[22] While data from previous waves are not available, the SME survey in 2002 did not distinguish between product vs. process innovation.

[23] Most studies on innovation use patent data or R&D expenditures, which are problematic. Patents are generally viewed as having several weaknesses: 1) patents measure inventions rather than innovations; 2) the tendency to patent varies across countries, industries and processes; and 3) firms often use methods other than patents to protect their innovations (such as technological complexity, industrial secrecy, and maintaining lead time over competitors). Using R&D expenditures may also be problematic because not all innovations are generated by R&D expenditures, R&D does not necessarily lead to innovation, and formal R&D measures are biased against small firms (Michie, 1998; Archibugi and Sirilli, 2001). Perhaps most important for the purposes of this paper is that in

For empirical analysis, basically, we estimate the following equation

$$Innovation = \gamma' Z + competition' \beta + spillover' \varphi + \varepsilon \qquad (1)$$

where *Innovation* is an indicator taking value of 1 if firm *i* is an innovator in the survey year and 0 otherwise, Z is a vector which includes a firm's characteristics such as firm size (**numwork**) proxied by the number of workers, firm age (**lnfirmage**), skill of the labor force (**skillratio**), capacity utilization (**over_cap**). Regional dummies and ε is an error term. As the dependent variable is a binary response variable, the equation (1) is estimated as a probit or logit model. As discussed above, our data allows us to distinguish between product innovation, process innovation and product modification, *Innovation* in (1) is a generic measure of innovation. In particular, in the empirical investigation, we consider three measures of innovations:

- *Product Innovation:* This is a dichotomous variable that takes the value 1 when the firm introduces new products in the survey year; and 0 otherwise.
- *Process Innovation*: This is a dichotomous variable that takes the value 1 if the firm introduces new production processes/new technology; and 0 otherwise.
- *Product modification*: This is a dichotomous variable that takes the value 1 if the firm introduces any major improvement to existing products or changed specification in the survey year; and 0 otherwise.

The SME survey data also allow us to capture the degree of competition faced by each firm in various ways. Firms that are able to charge a larger markup are deemed to have less competition. We are able to observe the pricing strategy of individual firms, i.e. if they price their products/services according to their competitors (**com_price**). We are also able to capture the effects of Foreign Competition (**foreign_com**) with a dummy variable. As discussed above, foreign firms can spur innovation among domestic firms through competition but they can also directly transfer capabilities. The SME survey also permits us to capture in various ways the extent to which there may be a spillover from foreign firms to domestic firms. We use three variables to capture the linkages and exposure to foreign firms and international trade. In particular we use the

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emerging-market economies these types of innovations are less likely to be observed as firms are expected to engage more in imitation and adaptation of already created and tested innovations, rather than in generating new inventions, and are less likely to expend resources on R&D.

percentage of sales to FDI firms (**sale_mne**), the share of inputs imported (**input_import**), and whether a firm exports (**export**).

The argument for including firm size (**numwork**) is that large companies have more resources to innovate and can benefit from economies of scale in R&D production and marketing. Capacity utilization has been found to be a strong predictor of innovations (Becheikh *et al.,* 2006), the effect of capacity over-utilization (**over_cap**) on innovation is a priori indeterminate. If firms are too busy fulfilling demand, they may be more interested in extending their current capacity than finding new ways of producing goods and services. At the same time, if firms are at capacity they may need to innovate. The skill level of the labor force (**skillratio**), captures the human capital available within the firm. This variable might be expected to be positively correlated with innovation as it reflects the involvement of workers in R&D and more skilled workers are able to give feedback to the firm on how to improve a product. Age of the firm in number of years since the firm began operations (**lnfirmage**) is included because older firms developed routines that are resistant to innovation and/or older firms will accumulate the knowledge necessary to innovate. We report in Appendix 1 a detailed description of the variables.

5. Empirical Results

The estimation results for 2007 and 2009 are presented in Table 6 and 7 respectively. Many interesting findings are contained in these two tables that we will now discuss. We first focus on the competition effects. As can be seen in Table 6, the effects of competition, both domestic and international, have important impacts on innovation activities. The competitors' pricing (**com_price**) has a positive impact on product innovation but not on process innovation or product modification. But foreign pressure (**foreign_com**) also had positive impacts on all kinds of innovation activities in 2007. Sales to MNEs lead to improvement in the innovation activities of domestic firms in all aspects (i.e. new products, new process, and product improvement). In 2009, however, the results are a bit different. Although pressure from price competition (**com_price**) helps to improve innovation in terms of product modification/improvement, it has no effect on product innovation and process innovation. However, still resembling the effect in 2007, foreign competition pressure helps firms to improve their innovation activities in terms of process and product improvement, not new product innovation. Different from the results in 2007, sales to MNEs and imported inputs seem to lose their importance. The estimated parameters are not statistically significant. However, the estimated effect of exporting is still statistically significant.

Table 6. Estimation Results for 2007

	New Product			New Process			Product Modification		
	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
sale_mne	0.01*	0.00	0.08	0.01*	0.00	0.01	0.00	0.00	0.71
input_import	0.00	0.00	0.66	0.00	0.00	0.32	0.00	0.00	0.72
over_cap	-0.25*	0.14	0.07	-0.14	0.09	0.13	-0.23**	0.07	0.00
lnfirmage	-0.16	0.08	0.04	-0.14**	0.05	0.01	-0.13***	0.04	0.00
skillratio	0.08**	0.06	0.14	-0.04	0.05	0.42	-0.19***	0.04	0.00
export	0.41**	0.18	0.02	0.26**	0.13	0.04	0.42***	0.13	0.00
com_price	0.21*	0.12	0.09	-0.08	0.10	0.41	-0.13	0.08	0.12
numworker	0.00*	0.00	0.07	0.00***	0.00	0.00	0.00***	0.00	0.00
foreign_com	0.10	0.10	0.29	0.29***	0.07	0.00	0.32***	0.06	0.00
HN	0.53	0.17	0.00	0.43	0.10	0.00	0.50	0.09	0.00
Haiphong	1.10	0.16	0.00	-0.02	0.13	0.86	0.43	0.11	0.00
Hatay	0.38	0.17	0.03	0.19	0.10	0.06	0.21	0.09	0.02
Longan	0.89	0.19	0.00	0.09	0.15	0.57	0.02	0.13	0.85
Phutho	0.35	0.20	0.08	-0.51	0.15	0.00	-0.08	0.10	0.43
Quangnam	0.57	0.21	0.01	0.03	0.14	0.83	-0.07	0.12	0.58
Nghean	0.35	0.18	0.05	-0.31	0.12	0.01	0.21	0.09	0.02
Khanhhoa	0.08	0.33	0.81	-0.28	0.20	0.16	-0.44	0.16	0.01
Lamdong	0.53	0.24	0.03	0.14	0.17	0.43	0.42	0.15	0.01
Constants	-1.83	0.23	0.00	-0.81	0.16	0.00	0.04	0.13	0.77
	Number of obs = 2537 LR chi2(18) = 97.56 Prob > chi2 = 0.0000 Log likelihood = -481.456 Pseudo R2 = 0.0920			Number of obs = 2537 LR chi2(18) = 179.92 Prob > chi2 = 0.0000 Log likelihood = -1022.29 Pseudo R2 = 0.0809			Number of obs = 2537 LR chi2(18) = 259.73 Prob > chi2 = 0.0000 Log likelihood = -1613.93 Pseudo R2 = 0.0745		

Table 7. Estimation Results for 2009

	New product			New process			Product modification		
	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
sale_mne	0.00	0.00	0.87	0.00	0.00	0.44	0.00	0.00	0.41
input_import	0.00	0.00	0.11	0.00	0.00	0.44	0.00	0.00	0.82
over_cap	-0.02*	0.15	0.90	-0.25**	0.10	0.02	-0.17**	0.08	0.03
lnfirmage	0.04	0.08	0.67	-0.18***	0.05	0.00	-0.15***	0.04	0.00
skillratio	0.09	0.06	0.13	0.03	0.05	0.55	-0.15***	0.04	0.00
export	0.36**	0.18	0.04	0.47***	0.12	0.00	0.51***	0.12	0.00
com_price	0.09	0.17	0.60	-0.06	0.11	0.62	-0.32***	0.09	0.00
numworker	0.00**	0.00	0.06	0.01***	0.00	0.00	0.00**	0.00	0.01
foreign_com	0.19	0.12	0.11	0.23***	0.07	0.00	0.29***	0.06	0.00
HN	0.11	0.17	0.52	0.15	0.11	0.17	0.01	0.09	0.95
Haiphong	0.10	0.20	0.61	-0.21	0.13	0.12	0.05	0.10	0.60
Hatay	-0.13	0.19	0.52	-0.11	0.11	0.33	-0.10	0.09	0.23
Longan	-0.05	0.27	0.84	-0.23	0.17	0.17	-0.25	0.13	0.05
Phutho	0.07	0.22	0.74	-0.18	0.14	0.19	-0.01	0.10	0.93
Quangnam	0.23	0.22	0.31	0.02	0.15	0.88	0.04	0.12	0.75
Nghean	-0.71	0.35	0.04	0.09	0.11	0.41	-0.35	0.10	0.00
Khanhhoa	0.58	0.22	0.01	0.00	0.18	0.99	-0.22	0.15	0.13
Lamdong	0.41	0.27	0.13	-0.01	0.20	0.96	-0.26	0.16	0.11
Constant	-2.27	0.24	0.00	-0.80	0.14	0.00	0.18	0.12	0.13
	Number of obs = 2532 LR chi2(18) = 50.28 Prob > chi2 = 0.0001 Log likelihood = -316.1651 Pseudo R2 = 0.0737			Number of obs = 2532 LR chi2(18) = 147.23 Prob > chi2 = 0.0000 Log likelihood = -976.00 Pseudo R2 = 0.0701			Number of obs = 2532 LR chi2(18) = 192.50 Prob > chi2 = 0.0000 Log likelihood = -1623.801 Pseudo R2 = 0.0560		

6. Conclusion

In this paper, we attempted to investigate the impact of trade liberalization on innovation activities by SMEs in Vietnam. We identified two channels for the trade liberalization – innovation linkages: FDI and trade. We proxy for these two channels using various measures. The results indicate tentatively that the impacts of trade liberalization on innovation are significant and important, depending on the channels and proxies used. However, the current version of paper suffers from a number of limitations. First, we have not yet exploited the panel structure of the data set. We have not yet been able to obtain the necessary ID to link the data together. Secondly, there is a possibility of reverse causality between the proxies we used for trade liberalization and innovation activities that we have not yet fully investigated. It is expected that these issues will be taken up in the next version of the paper.

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Appendix 1: Variable Description

Variable	Description
Dependent variable	
NEWPRODUCT	1 if firm introduces new product(s), 0 otherwise
NEWPROCESS	1 if firm introduces new production process, 0 otherwise
MODIPRODUCT	1 if firm makes major improvements of existing product(s) or changes specification, 0 otherwise
Independent variables	
numwork	firm size - the number of workers
lnfirmage	firm age – years in operations
skillratio	skill of the labour force
over_cap	capacity utilization – 0/1 variable indicating if capacity is over used
com_price	a dummy variable, equal 1 if pricing according to competitor
foreign_com	a dummy variable, equal 1 if subject to foreign competition
sale_mne	percentage of sale to FDI firms
input_import	the share of inputs imported
export	a dummy variable, equal 1 if exporting, 0 otherwise

CHAPTER 10

What Explains Firms' Innovativeness in Korean Manufacturing? Global Activity and Knowledge Sources

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In this paper, we analyze whether there exists a positive relationship between a firm's global activity and its various innovation outputs and, if a relationship exists, what are the major factors that explain the global activity premium in terms of innovation output. By closely following the methodology used by CHS (2010), we find that the global activity premium is accounted for not only by firms' superior access to existing knowledge (especially for foreign MNC affiliates) but also by their active investment in new knowledge (especially for non-MNC exporters and domestic MNC parents). When we analyze product and process innovation separately, we find that for process innovation the information flow from existing knowledge is relatively more important, while for product innovation the investment in new knowledge, and the information flows from existing knowledge are almost equally important. Our analyses show that in Korea the sources of advantage come both from investing in new knowledge and utilizing information flows from existing knowledge. Thus, in Korea, policies that promote both direct R&D activities and information flows should be pursued at the same time to enhance firms' propensity to innovate.

Key Words: Product innovation, Process innovation, Exporting, Multinationality
JEL Classification F1, F2, O2

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1. Introduction

Globalization can take many modalities. From a firm's perspective, globalization means participating in the international market by exporting and/or importing, establishing a production or ownership network in other countries through FDI or portfolio investment, and so on. In recent years, much effort has been devoted to identifying whether this globalization process has been the cause or a consequence of firms' performance. The recent theoretical studies seem to support the direction of causality from firm's performance (measured by productivity) to global activity (measured by export participation or FDI engagement), which is now widely referred to as the 'self-selection' mechanism. Assuming heterogeneity in firms' productivity due to exogenous factors, these studies show that firms with higher productivity can cover the costs of entering export markets, and that firms with especially high productivity can cover even the higher costs of implementing foreign direct investment (FDI) (e.g., Melitz (2003), Helpman, Melitz and Yeaple (2004)).[3]

On the other hand, in contrast to the underlying assumption of exogenous factors of productivity in these models, a large body of theoretical and empirical research has treated productivity itself as endogenous, for example Romer (1990) and Grossman and Helpman (1991) for theoretical development and Griliches (1994) for empirical study. In these models, the increase in firm productivity is mainly determined by the firms' innovation activity (such as investment in new R&D or adopting flows of ideas from existing knowledge). By taking these two strands of work together, it can be inferred is that more innovative firms will be more productive and that in turn they will be engaged in more global activities (innovation → productivity → global activity).

However, there exist also ample theoretical background from which we can also expect the existence of the reverse causal link; that is from global activity to innovation (e.g. Grossman and Helpman (1991), Rivera-Batiz and Romer (1991)). According to this theory, a firm's global activity may generate more innovations for the firm by

[3] These theoretical models were partly motivated by previous empirical studies such as Bernard and Jensen (1999) for the US, Aw, Chung and Roberts (2000) for Taiwan and Clerides, Lach and Tybout (1998) for Colombia, Mexico and Morocco. All find evidence that more productive firms "self-select" into export markets. See Melitz (2003) section 1.

increasing the opportunity of transmission of new knowledge input, which in turn feeds into higher productivity.[4]

Our goal in this paper is to investigate this relationship between global activity and innovation by asking whether global activities make firms more innovative, and whether and what kind of knowledge sources are important in explaining firms' innovations, utilizing Korea's Innovation Survey (conducted three times in 2002, 2005 and 2008).[5] The structure of this Survey is very similar to that of the CIS (Community Innovation Surveys) by the European Union in a sense that it follows the Oslo Manual.[6] There exist a couple of studies that examined the relationship between global activity and innovation using the CIS data. For example, Frenz and Ietto-Gillies (2007) and Criscuolo, Haskel and Slaugter (hereafter CHS, 2010) used the CIS data for the United Kingdom and found that firms' global activity had a positive impact on their propensity to innovate.

The first aim of this paper is to examine whether the positive relationship between a firm's global engagement and its propensity to innovate, (as has been identified in recent empirical studies for specific countries), exists in the case of Korean manufacturing firms. Furthermore, we will examine whether the channeling effect of knowledge sources, which turned out to be important for the firms in UK according to the recent paper by CHS (2010), can also be observed for the case of Korea, and what types of knowledge source are important for the firm's product and process innovation. Korea's Innovation Survey contains information about the major sources of knowledge flows: information within the firm, within the group, from vertical suppliers, from customers, from universities and so on. Documenting the role of knowledge sources in the firms' innovation activities may shed light on the best direction for innovation policy.

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[4] Coe and Helpman (1995) and Keller (2002) provide useful reviews of the country- or industry-level empirical studies based on this theory.

[5] As is well known, there exist many empirical studies examining the causality from globalization (especially export participation) to productivity: the so-called "learning-by-exporting" effect. Although Bernard and Jensen (1999) found little evidence in favor of this effect, more recent works such as Girma, Greenaway and Kneller (2004), De Loecker (2007) and Hahn and Park (2009) found the existence of the learning effect. In this paper, we do not directly deal with this issue and focus instead on the relationship between globalization and innovation.

[6] The Oslo Manual is a guideline for collecting and interpreting technological innovation data proposed by the OECD and Eurostat.

2. Previous Literature

The global engagement of firms can take various forms. One form is participation in international trade through exporting, and another is affiliation with foreign multinational companies (MNCs). Economic theories have suggested that international trade and FDI through MNCs may have positive effects on the productivity of firms involved in these processes (cf. Grossman and Helpman, 1991).

On the basis of theoretical arguments presupposing causality between international trade and productivity, many studies have tried to examine whether this causality is observed in reality and what its direction is. The underlying presumption is that firms involved in global activities are confronted with a wider market than local firms without any global activity, and this experience can facilitate the globally engaged firms' efforts to enhance productivity. In this mechanism, the information about foreign markets or customers obtained through participating in the global market can play an important role.

While it is generally observed that the firms actively participating in exporting tend to be more productive, the results of empirical studies have not been conclusive: though some studies found a positive association between firms' global engagement and productivity (especially for some developing countries), many studies concluded that the higher productivity among firms with global engagement seems to be a result of 'self-selection' (Keller, 2004). In other words, the firms that already showed greater productivity were more likely to participate in the world market and, in this case, the so-called 'learning by exporting' (LBE) effect does not exist.

At the same time, many studies have tried to examine the spillover effect of FDI to the firms in the host country.[7] The channels through which the FDI influences the firms' productivity are regarded as being: *imitation, acquisition of human capital, competition, and export spillovers*. A firm in the host country affiliated with MNCs may have a greater chance of imitating the parent company's products even i when core products are not transferred. They can also expect the inflow of high-quality personnel from the parent company, or skill upgrades for workers through being in contact with

[7] See reviews by Hanson (2000), Saggi (2002) and Görg and Greenaway (2003).

them. The affiliated firms are generally confronted with severe competition from other local firms, since the parent company usually tries to penetrate competitive markets, and this can provide the affiliated firm with incentives for new product development or cost reduction. Lastly, the affiliated firms are more likely to be involved in global production networks, and this exporting experience can induce some spillover effects. However, the results of empirical studies on the effect of FDI are also ambiguous: some studies in developing countries find positive spillover effects from FDI on the productivity of affiliated firms in the host country, while other studies do not identify any significant effects, and even find negative effects in transition countries (Görg and Greenaway, 2003).[8]

However, this paucity of empirical evidence for LBE may be due to various causes (Salomon and Shaver, 2005): (1) the mechanism for LBE described above (knowledge spillovers) may not be realized in the form of enhanced productivity for a variety of reasons. For example, market information about the foreign customers might help the local firms tailor products to meet the specific needs of foreign customers, but have a negligible impact on productivity. (2) If the "intra-national" spillover is great, the firms participating in the global market may have difficulties in gaining real advantage from the learning they derive from exporting. These arguments underscore the fact that the relationship between firms' global engagement and their productivity is more complex than anticipated, and we should consider firms' other investment, such as R&D or human capital-building, that may have endogenous effects on their productivity.

Against this background, some recent studies consider firms' R&D investment or innovation activity as an alternative to the productivity variable (cf. Salomon and Shaver, 2005; Liu and Buck, 2007; Aw *et al.*, 2008; CHS, 2010). This relatively new research direction starts from the expectation that firms' global activity will have more prevailing effects on R&D or innovation than on productivity, which can be seen as the end-result of complex interactions between various factors. These studies generally use the 'knowledge production function', in which the flow of knowledge is considered an important factor. Thus, these studies see that the positive spillover effect of firms'

[8] Görg and Greenaway (2003) argue that the contradicting results of previous studies partly resulted from lack of appropriate data sets, which could control time-invariant characteristics, and that they could not identify the positive effects of FDI, if only the studies using appropriate data sets such as panel data were considered.

global engagement is, along with other channels such as increased competition, channeled mainly through increased the accessibility or acquisition of exterior knowledge.[9]

The importance of knowledge flow can be explained from the perspective of firms' strategic behavior. It has already been argued that R&D conducted by a firm has 'two faces', namely the aim of achieving technological competitiveness through the firm's own efforts, and the aim of enhancing its capability to utilize exterior knowledge (Cohen and Levinthal, 1989). Since disruptive innovations are rare and most innovations build on the already existing pool of knowledge, the capability of firms to use exterior knowledge effectively is very important for the successful implementation of innovation.[10] In recent years, which are characterized by an ever increasing speed of technological change and the market environment, firms are increasingly using information or knowledge created externally, and outsourcing a considerable part of their R&D activities to external partners through strategic collaboration.[11] In this 'open innovation' process, the knowledge flows play a pivotal role for firms who are trying to enhance their competitiveness through new product development.[12]

This aspect of knowledge flows may have important implications, especially in the context of developing countries (cf. Kim and Nelson, 2000). It is often argued that late-comers may benefit from their backward position, because they can rely on existing knowledge stocks. International trade and FDI may be channels to facilitate the transfer of knowledge. However, it should be noted that the 'absorptive capacity' of the firms is also very important, because too large a gap to the frontiers may hinder the appropriate utilization of existing knowledge (Furman *et al*., 2002). Increased exposure to advanced exterior knowledge does not necessarily guarantee successful absorption of it,

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9 See especially CHS (2010) for this theoretical argument.

10 In the innovation literature, this systemic nature of knowledge production has been captured by researchers who have tried to show the innovation process as interactions of different actors (cf. Nelson, 1993).

11 See Chesbrough (2003) for the concept of 'open innovation' (cited from Laursen and Salter (2006)).

12 However, it should be noted that too much effort to collaborate with external partners may increase the firm's costs substantially and, thus, have negative impact on its overall performance. Therefore, it is expected that there exists a curvilinear (inverted-U-shape) relationship between the openness of firms (or the amounts of effort devoted to the networking) and their innovation performance.

and local firms need to build up their own capability in order to appropriate the knowledge properly.

Absorptive capacity is important not only at the national level but also at the firm level. It is theoretically grounded on the tacit nature of knowledge (Keller, 2004). Certain kinds of knowledge are already codified and easily transferable from one place to another. However, there are certain types of knowledge that are hardly transferable. This kind of 'tacit' knowledge has to be internalized in the receiving firms.[13] Therefore, it is required that the firms build their own innovation capability, in order to internalize the knowledge spillovers arising from their global engagement.

Studies addressing the relationship between firms' global engagement and innovation have used various data sets and indicators for innovation. One alternative is patent data on the firm level, and another is micro data collected through directly questioning innovative activities of firms in the form of the Community Innovation Surveys (for European countries) or other CIS-compatible national surveys. These two approaches have advantages and disadvantages respectively, but the latter approach has the advantage that it can directly measure the innovation performance of firms, which is expected to be more closely associated with knowledge spillovers than in the case of patents.

There exists vast literature using European CIS data to explore the correlation between innovation measures and other variables.[14] Most of these studies focus only on the relationship between innovation and export status. For example, Janz and Peters (2002) find a positive but insignificant relationship between the share of innovative products' sales and exporting, and Veugelers and Cassiman (1999) report a significant positive effect of export intensity on a firm's innovation activity. More recently, Damijan, Kostevc and Polanec (2008) examine the bi-directional causality between innovation and exporting, and find evidence supporting the idea that exporting is likely to lead to process innovation.

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[13] An example may be the general trend in the second half of the 20th century, in which many companies tried to internalize and secure their knowledge production through creating in-house R&D units.

[14] We do not describe all the details of this type of literature here. For an excellent review see Hall and Mairesse (2006).

To our knowledge, there exist only two studies that investigate the relationship between innovation and multinationality: Frenz and Ietto-Gillies (2007) and CHS (2010) as mentioned earlier. Frenz and Ietto-Gillies (2007) assess whether multinationality affects the innovation propensity of CIS-surveyed UK firms. They find that the enterprises belonging to a multinational corporation tend to exhibit greater innovation propensity, and that they are also more likely to be engaged in innovation activities on a continuous basis. CHS (2010) also find similar results: they additionally find that the relative importance of knowledge sources varies systematically with the type of innovation. For patents, information flows from universities are important, while flows from customers and suppliers are not. For broader process or product innovations, the reverse is true.

Thus our study is closely related to these two previous works. Since we would like to see whether similar findings can be observed in the firms in Korea's Innovation Survey, we follow the methodological framework suggested by CHS (2010). However, there are some differences between this paper and CHS (2010). First, we are dealing only with firms in the manufacturing sector in Korea, while CHS (2010) encompass both manufacturing and service firms. As firms in the service sector are expected to show quite different innovation patterns or activities compared to the firms in the manufacturing sector, we decided to concentrate on the firms in the manufacturing sector.[15] Secondly, we categorize the types of a firm's global engagement more specifically than CHS (2010) by combining the Innovation Survey data with Korean FDI data. In this way, we could distinguish the affiliated firms of foreign MNCs from the parent companies of MNCs in Korea, and obtain more detail of their types of global engagement. Thirdly, the model used in CHS (2010) includes investment in the production of new knowledge by using the number of R&D personnel, but we explicitly consider the R&D expenditure of firms, since it is widely accepted that capital investment in R&D plays an important role in the firm's innovation activities.

[15] As can be seen in the empirical part of this paper, we think that the aggregation of manufacturing and service firms may be the reason that CHS (2010) shows some ambiguous results.

3. Data and Methodology

3.1. Data

The main data source for this study is the KIS (Korean Innovation Survey) carried out by STEPI (Science and Technology Policy Institute).[16] This survey has been conducted every three years (in 2002, 2005 and 2008) on manufacturing firms' innovation activities for the previous three years (i.e., KIS-2005 contains firms' innovation information for the period 2002~2004). Unfortunately, however, these surveys were not constructed in a panel data setting, which makes it impossible to take advantage of panel data analyses in our study.[17] Thus, the cross-section data of KIS-2005 will be intensively used in our empirical analyses although we will use some information from KIS-2002 in order to mitigate the potential endogeneity problem in the next section.[18][19]

The KIS dataset contains quantitative as well as qualitative information about the following:

1 status of the firm:

- domestic independent firm/domestic firm within a group/foreign MNC affiliate
- exporting status

2 innovation output

- numbers of product and process innovations
- numbers of patent applications related to product and process innovation

3 innovation input

- R&D expenditure , number of R&D personnel , existence of R&D department

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[16] As mentioned in Section 1, the structure and contents of KIS are very similar to those of the European CIS, following the Oslo manual. KIS was approved as one of the national statistics by the Korean National Statistics Office in 2003.

[17] The number of firms in each survey is 3,775 in 2002, 2,743 in 2005 and 3,081 in 2008. However, the number of firms that participated in all three surveys is only 102.

[18] The number of firms that participated in the surveys both in 2002 and in 2005 is 439. Although the number of individual firms is small, we will utilize this information as much as possible in our empirical analysis.

[19] The reason why we cannot use KIS-2008 is that a domestic firm's multinationality (i.e., whether that firm implemented outward FDI or not) cannot be identified for these firms in KIS-2008. As explained below, the data source for a domestic firm's multinationality is Korea EXIM bank's data set which ends in 2004.

4 knowledge sources

- importance of knowledge flows in innovation activity from self-information, information from group, vertical information (suppliers or customers), commercial information, information from competitors, free information, information from universities and government

The KIS dataset does not provide exact information on whether each firm is a multinational firm or not, since it does not collect the data on foreign direct investment. In order to identify which domestic firm has multinational characteristics, we obtained another data source from the Korea EXIM bank. In Korea, any firm that wants to establish foreign subsidiaries through outward FDI should register with the primary creditor bank. In turn, these registered banks should report to the Korea EXIM bank with information about investing firms, amount of investment, destination country and so on. By merging these two data sets using a common corporate identification number, we identify which domestic firm is also a multinational parent company.

By combining this data from the Korea EXIIM bank and the information about the status of the firm from the KIS dataset, we can divide our sample firms into the following six different categories: ① purely domestic firms, ② non-multinational exporters, ③ foreign MNC affiliates without export, ④ domestic MNC parents without export, ⑤ foreign MNC affiliates with export, ⑥ domestic MNC parents with export.[20] Firms in the first category (purely domestic firms) may have the least experience in terms of global activity, since they are neither exporters nor multinationals. Firms in the second to the fourth categories (non-MNC exporters, foreign MNC affiliates and domestic MNC parents without export) are implementing just one of the two global activities that we consider in this study. Firms in the last two categories (foreign MNC affiliates and domestic MNC parents with export) are exposed to the global environment

[20] One limitation of the Korea EXIM data is that it covers outward FDI activities only between 1990~2004. Thus in principle, if any firm implemented outward FDI before 1990 and did not invest additionally during 1990~2004, this firm will categorized as a purely domestic firm or as a non-multinational exporter in our sample. However, in Korea outward FDI by domestic firms was highly regulated until the late 1980s and it has been liberalized only since 1990. This historical fact may reduce the possibility of this mismatching problem in our sample.

most significantly, since they are dealing with both exporting and multinational business.

In our empirical analyses, we will document whether innovation output, innovation input and the importance of knowledge sources are different according to the different levels of global activities categorized above.

3.2. Methodology

Our main empirical specification follows CHS (2010)'s KPF (knowledge production function) approach developed earlier in Griliches (1979) which can be written as

$$\Delta K_i = f(G_i, H_i, K_i', K_{-i}', X_i)$$

where ΔKi represents innovation output (increase of knowledge stock), Gi global activities, Hi investment in innovation input (R&D expenditure, number of R&D personnel), Ki' information flow within the firm, K-i' information flow from outside the firm, Xi other control variables such as firm's size and industry dummies.

In our simplest specification, we will run the regression of innovation output on five different indicators of global activity (i.e., non-MNC exporters, foreign MNC affiliates without export, domestic MNC parents without export, foreign MNC affiliates with export, domestic MNC parents with export). This will tell us whether firms with any global activity generate more innovation output than does the benchmark case (i.e., purely domestic firms).

Suppose that more global activities appear to promote more innovation output with this simplest specification. Then what are the causes of this 'global activity premium' in terms of innovation output? The KPF framework implies that there are two main sources: by investing more in new knowledge (Hi) or by utilizing existing knowledge from inside and outside the firms more extensively (Ki'and K-i'). Thus by adding these variables in the regression and looking at the changes in the 'global activity premium', we can assess the major causes of the premium.

In estimating above equation, we may encounter endogeneity problems. Investment in new knowledge (Hi) or seeking information flows from existing knowledge (Ki' and K-i') may be correlated with the error term if some unobserved firm specific factors (such as the firm's high evaluation of innovation activity) that can affect innovation output also affect these regressors. Unfortunately, the limitation of our cross-section data means that we cannot provide solutions to this problem with confidence. However, as in CHS (2010) we try to mitigate this endogeneity problem as much as possible in the empirical analyses by using the instrumental variable method and by combining panel information from both KIS-2002 and KIS-2005.

4. Empirical Results

4.1. Summary Statistics

Before we report our regression results, it would be worthwhile to see how innovation-related variables are different depending on the degree of global activities, which are shown in Table 1 through Table 3. First, the mean values of various innovation outputs are reported in Table 1a ~1b, including innovation (either product or process innovation) dummy, patent dummy, number of innovation and number of patent.

Table 1a. Innovation Outputs

	Innovation Dummy	Product Innovation Dummy	Process Innovation Dummy	Patent Dummy
Purely Domestic Firms (no. of firms = 1,062)	0.310 (0.463)	0.249 (0.432)	0.182 (0.386)	0.153 (0.361)
Non-MNC Exporters (no. of firms = 990)	0.587 (0.493)	0.519 (0.500)	0.384 (0.487)	0.355 (0.479)
MNC without Export : Foreign Affiliates (no. of firms = 37)	0.486 (0.507)	0.432 (0.502)	0.243 (0.435)	0.297 (0.463)
MNC without Export : Domestic Parents (no. of firms = 136)	0.471 (0.501)	0.382 (0.488)	0.324 (0.470)	0.287 (0.454)
MNC with Export : Foreign Affiliates (no. of firms = 92)	0.620 (0.488)	0.554 (0.500)	0.457 (0.501)	0.304 (0.463)
MNC with Export : Domestic Parents (no. of firms = 426)	0.662 (0.474)	0.599 (0.491)	0.418 (0.494)	0.521 (0.500)
All Firms (no. of firms = 2,743)	0.485 (0.500)	0.420 (0.494)	0.308 (0.462)	0.297 (0.457)

Note: All figures are means of the variables and standard deviations are in parentheses.

Table 1b (continued). Innovation Outputs

	Innovation Dummy	Product Innovation Dummy	Process Innovation Dummy	Patent Dummy
Purely Domestic Firms (no. of firms = 1,062)	7.4 (47.5)	6.5 (46.9)	0.9 (4.3)	0.6 (3.7)
Non-MNC Exporters (no. of firms = 990)	20.3 (118.7)	18.2 (116.5)	2.1 (8.1)	4.3 (24.0)
MNC without Export : Foreign Affiliates (no. of firms = 37)	10.6 (19.1)	9.4 (18.4)	1.2 (4.0)	8.4 (31.6)
MNC without Export : Domestic Parents (no. of firms = 136)	26.4 (105.3)	24.9 (105.2)	1.5 (3.7)	2.7 (10.6)
MNC with Export : Foreign Affiliates (no. of firms = 92)	41.7 (192.1)	39.0 (190.8)	2.7 (6.5)	3.7 (10.2)
MNC with Export : Domestic Parents (no. of firms = 426)	35.0 (156.5)	31.4 (146.5)	3.6 (18.5)	19.1 (114.9)
All Firms (no. of firms = 2,743)	18.5 (107.9)	16.6 (104.5)	1.8 (9.3)	5.1 (48.2)

Note: All figures are means of the variables and standard deviations are in parentheses.

From these tables we can see that performance in terms of generating innovation outputs is highest when the firm is a domestic MNC parent (or foreign MNC affiliate) with export and the lowest when it is a purely domestic firm. The performances of all other groups are in between these two cases.

For example, 31.0% of purely domestic firms reported that they introduced any (either product or process) innovation, while in the case of domestic MNC parents with export the positive response rate was 66.2% (the first column of Table 1a). At the same time, the number of patent applications was highest with domestic MNC parents with export (19.1) and the lowest with purely domestic firms (0.6) (the last column of Table 1b). On the other hand, foreign MNC affiliates with export have the highest positive response rate in process innovation (45.7%) and the highest number of product innovations (39.0).

For other groups of firms, the performances of innovation output are mixed. In the case of innovation and patent dummies, non-multinational exporters seem to outperform non-exporting multinationals. But in the case of numbers of innovations and patents, non-exporting multinationals have higher values than non-multinational exporters.

Overall, the mean values of innovation output in these tables suggest that there exists a global activity premium in innovation output. (i.e., the performance in terms of innovation output could be ordered as: purely domestic firms <either exporting or multinational firms < both exporting and multinational firms).

Secondly, Table 2 shows that investment in new knowledge, such as R&D expenditure and number of R&D personnel, has a similar pattern to innovation output. It is highest with domestic MNC parents with export and, lowest with purely domestic firms. The number of R&D personnel of purely domestic firms was on average 4.9, while that of domestic MNC parents with exports was 31.7. R&D expenditure of purely domestic firms was 124.8 million Won (around US$0.1 million) and that of domestic MNC parents 1,509.9 million Won (around US$1.2 million).

Table 2. Innovation Inputs

	R&D Expenditure (Mill. Won)	Internal R&D Expenditure (Mill .Won)	External R&D Expenditure (Mill. Won)	Number Of R&D Personnel
Purely Domestic Firms (no. of firms = 1,062)	124.8 (874.7)	104.7 (693.8)	20.1 (216.8)	4.9 (17.5)
Non-MNC Exporters (no. of firms = 990)	642.7 (3,909.2)	569.2 (3,494.3)	73.5 (606.6)	13.6 (41.5)
MNC without Export : Foreign Affiliates (no. of firms = 37)	1,153.6 (3,564.1)	1,011.5 (3,427.4)	142.0 (680.9)	23.2 (35.0)
MNC without Export : Domestic Parents (no. of firms = 136)	441.1 (1,670.0)	413.3 (1,606.7)	27.7 (157.4)	14.1 (28.7)
MNC with Export : Foreign Affiliates (no. of firms = 92)	646.0 (1,585.2)	582.0 (1,456.8)	62.6 (263.6)	20.5 (31.0)
MNC with Export : Domestic Parents (no. of firms = 426)	1,509.9 (6,649.7)	1,372.1 (6,386.4)	137.8 (527.7)	31.7 (75.8)
All Firms (no. of firms = 2,743)	574.2 (3,645.2)	512.9 (3,385.6)	61.2 (453.4)	13.4 (42.4)

Note: All figures are means of the variables, and standard deviations are in parentheses.

Finally, Table 3 shows the mean values of each category of firm on the importance of each knowledge flow in innovation activities, with median values in parentheses.[21] Again we observe that existing knowledge stocks are utilized by purely domestic firms at the lowest level. In fact, the median purely-domestic firm learns nothing from all existing knowledge sources (the median values of all eight knowledge sources in the parentheses are zero). The domestic MNC parents with exports enjoy the most benefit from existing knowledge stocks inside and outside the firm, except the knowledge flow from the group. It seems that the information from the group is most well taken up by foreign MNC affiliates (both with and without exports): the mean values of this indicator are 2.478 and 1.919 for foreign MNC affiliates with exports and without exports, respectively. This is not surprising because this is consistent with the standard knowledge capital model of multinationals: knowledge is created by parents and the direction of knowledge flows is mainly from parents to affiliates.

Table 3. Knowledge Sources

	Self	Group	Vertical	Compe-Titor	Comm-Ercial	Free Info	Univ.	Gov't
Purely Domestic Firms (no. of firms = 988)	0.814 (0.000)	0.310 (0.000)	0.587 (0.000)	0.534 (0.000)	0.338 (0.000)	0.605 (0.000)	0.430 (0.000)	0.318 (0.000)
Non-MNC Exporters (no. of firms = 1,064)	1.729 (1.600)	0.718 (0.000)	1.259 (0.000)	1.123 (0.000)	0.733 (0.000)	1.288 (1.000)	1.044 (0.000)	0.852 (0.000)
MNC without Export : Foreign Affiliates (no. of firms = 24)	1.595 (0.000)	1.919 (0.000)	0.865 (0.000)	0.851 (0.000)	0.505 (0.000)	1.108 (0.000)	0.541 (0.000)	0.486 (0.000)
MNC without Export : Domestic Parents (no. of firms = 108)	1.241 (0.000)	0.735 (0.000)	1.005 (0.000)	1.011 (0.000)	0.667 (0.000)	1.008 (0.438)	0.713 (0.000)	0.507 (0.000)
MNC with Export : Foreign Affiliates (no. of firms = 105)	2.041 (2.400)	2.478 (3.000)	1.496 (1.167)	1.190 (0.000)	0.862 (0.000)	1.450 (1.563)	0.804 (0.000)	0.761 (0.000)
MNC with Export : Domestic Parents (no. of firms = 454)	2.122 (2.400)	1.129 (0.000)	1.543 (1.333)	1.468 (1.500)	0.931 (0.000)	1.623 (1.625)	1.279 (0.000)	1.085 (0.000)
All Firms (no. of firms = 2,743)	1.420 (0.600)	0.700 (0.000)	1.033 (0.000)	0.941 (0.000)	0.609 (0.000)	1.065 (0.125)	0.812 (0.000)	0.656 (0.000)

Note: All figures are means of the variables, and medians are in parentheses. Each variable is a categorical indicator of the importance of each knowledge source in innovation activities. Each variable takes possible integer values from 0 to 5 (higher values indicate greater importance).

[21] For each indicator, firms can respond by taking possible integer values from 0 to 5 with higher values representing greater importance.

In sum, by looking at the simple correlation between innovation output and the global activities of firms, it appears that the global activity premium does exist in our sample. And it seems to be also true that more globally active firms invest more in the production of new knowledge and at the same time utilize existing knowledge capital more extensively. Now we turn to the regression results which may help us to identify the sources of such a global activity premium as explained in the previous section.

4.2. Regression Results

The regression results for various innovation outputs are reported in Table 4 through Table 7. First, probit estimation results of the innovation dummy (a binary response variable which takes 1 if the firm introduced any product or process innovation during three years prior to the survey year, and 0 otherwise) are shown in columns (i)-(iii) Table 4.[22]

In the first column, we run this probit regression only on global activity indicator dummies (foreign MNC affiliate without exports, domestic MNC parent without export, non-multinational exporters, foreign MNC affiliate with export and domestic MNC parent with export) plus unreported other control variables (size measured by number of workers and 23 industry dummy variables). The coefficients for the MNC without exports (both foreign affiliates and domestic parents) are not significantly different from zero: their innovation output is not statistically different from that of purely domestic firms.

[22] In all of these specifications including IV-probit estimation in columns (iv) and (v), marginal effects of each regressor on the probability of innovation (instead of actual coefficients of the probit estimation) are reported.

Table 4. Regression Results for Innovation Dummy

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
MNC without Export	0.009	0.090	0.081	-0.066	0.073	1.049
: Foreign Affiliates	(0.086)	(0.096)	(0.095)	(0.075)	(0.097)	(1.812)
MNC without Export	0.073	0.005	0.030	0.042	0.052	-0.678
: Domestic Parents	(0.047)	(0.058)	(0.058)	(0.047)	(0.057)	(1.895)
Non-MNC Exporters	0.211***	0.096***	0.074**	0.113***	0.096***	-1.447
	(0.024)	(0.028)	(0.031)	(0.030)	(0.030)	(1.273)
MNC with Export	0.163***	0.142**	0.090	0.158**	0.089	-2.382
: Foreign Affiliates	(0.055)	(0.070)	(0.077)	(0.063)	(0.074)	(2.086)
MNC with Export	0.227***	0.058	0.015	0.075*	0.051	-1.084
: Domestic Parents	(0.031)	(0.043)	(0.048)	(0.042)	(0.047)	(1.478)
R&D Expenditure		0.106***	0.066***	0.023*	0.029***	0.145
		(0.004)	(0.004)	(0.012)	(0.011)	(0.094)
Self info			0.113***		0.139***	1.259***
			(0.018)		(0.018)	(0.379)
Group info			0.006		0.008	-0.441*
			(0.013)		(0.013)	(0.268)
Vertical info			0.044**		0.049**	0.624
			(0.020)		(0.020)	(0.428)
Competitor			0.044**		0.049***	-0.037
			(0.017)		(0.017)	(0.237)
Commercial info			-0.085***		-0.095***	-0.269
			(0.027)		(0.027)	(0.346)
Free info			0.077***		0.093***	-0.433
			(0.026)		(0.025)	(0.471)
University			0.019		0.030**	0.666***
			(0.015)		(0.015)	(0.211)
Government			0.001		0.004	0.025
			(0.015)		(0.015)	(0.226)
Observation	2,737	2,722	2,722	2,722	2,722	300
Pseudo-R^2	0.104	0.404	0.511			0.730

Note: *, **, and *** represent statistical significance at the 10%, 5% and 1% levels, respectively. All specifications include unreported other control variables: size (measured by number of workers) and industry dummy variables (23 industries at 2-digit industry codes assigned by STEPI). (i)-(iii) are the probit estimation results for KIS 2005. (iv) and (v)are the IV-probit estimation results. (vi) is the result of the fixed effect conditional logit model using both KIS 2002 and 2005. For (i)-(v), marginal impacts for the indicated regressors are reported with robust standard errors in parentheses.

These results may not be surprising if we think about the general business objectives of domestic and foreign MNCs without exports. Presumably, the foreign MNC affiliates without exports are located in Korea largely for distributional purposes (e.g., Dell Computer in Korea). At the same time, the domestic MNC without exports may have only managerial headquarters in Korea and all other production facilities can be located in foreign countries. In these situations, the innovation output of both domestic and foreign MNCs without export have no reason to be generated in the entities located in Korea.[23]

On the other hand, the coefficients on the non-multinational MNC exporters, foreign MNC affiliates with exports and domestic MNC parents with exports are all estimated to be positive and statistically significant. This shows that other things being equal (after controlling for firm size and industry dummies) domestic MNC parents with exports have the highest probability of innovating, followed by non-multinational exporters and then by foreign MNC affiliates with exports.[24] Thus even after firm size and industry characteristics are taken into account, the global activity premium seems to exist in this estimation result.

Next, in specification (ii) we added R&D expenditure as an additional regressor to capture the impact of investment in new knowledge. While the estimated coefficient on R&D expenditure is positively and significantly estimated at 1% level, the magnitude and significance level of the coefficients on non-MNC exporters and domestic MNC parents with exports has been reduced significantly: the coefficient on non-MNC exporter was reduced by more than half and that on domestic MNC parents lost its significance. On the other hand the reduction of the coefficient magnitude on foreign MNC affiliates with exports is relatively moderate: the likelihood of generating innovation in a foreign MNC affiliate with export compared to the benchmark domestic firms (non-multinational and non-exporting firm) has changed only by 2.1%.

[23] Whether domestic and foreign MNCs without export in Korea have these characteristics cannot be confirmed with our limited dataset. More detailed analyses of this matter must be left for the future research agenda.

[24] Note that the rank in terms of innovation dummy has changed after controlling for firm size and industry dummies. In Table 1a which shows the raw difference without any control, the ranking order in terms of innovation dummy was higher for domestic MNC parents with exports than for foreign MNC affiliates with exports. This means that the innovation output advantage of foreign MNC with exports can be explained by size or industry-specific effects more than that of non-MNC exporters.

Column (iii) adds various indicators regarding the flows of existing knowledge to the regression. In this case, the most substantial change of the coefficients on global activity indicators is observed in the case of foreign MNC affiliates with export: the likelihood of generating innovation has reduced by more than 30% after we take into account information flows from existing knowledge. For non-MNC exporters and domestic MNC parent with export, adding information flow variables in the regression changes the coefficient but at lesser degree than before.

Comparing these results with those of CHS (2000), we find substantial differences in the estimation results between Korea and the UK. In the case of the UK, adding only R&D personnel changed the magnitudes of the coefficients on global activity indicators little, while adding information flow variables reduced them substantially. By these findings, CHS (2000) conclude that the global activity premium comes mainly from utilizing information flows from existing knowledge, but not from investing in new knowledge. But in the case of Korea, both new knowledge and existing knowledge can help explain the global activity premium but in different ways depending on the characteristics of global activities. For non-MNC exporters and domestic MNC parents with export, investing in new knowledge (R&D expenditure variable) seems to be more important than utilizing existing knowledge flows (knowledge source variable) in explaining their innovation output premium. On the other hand, for foreign MNC affiliates with export utilizing existing knowledge flows seems to be much more important than investing in new knowledge.

Thus our finding is in sharp contrast to the results from UK data. In the case of the UK, the majority of the superior innovative output of globally engaged firms is accounted for by their superior access to information from existing knowledge. But in the case of Korea, this global activity premium is accounted for not only by their superior information access to existing knowledge (especially for foreign MNC affiliates) but also by their active investment in new knowledge (especially for non-MNC exporters and domestic MNC parents).

To complete the comparison with the results of CHS (2010), we note the differences between the UK and Korea in terms of the estimated coefficients on information flow variables from existing knowledge capital. In the case of the UK, the coefficient on information from competitors was estimated to be negative and that on commercial information positive. But in the case of Korea, the reverse is true. In the survey, commercial information means commercial support from a business service such as legal, technical, accounting and consulting services. This may imply that in UK where those business service sectors are much more developed, getting such commercial information may boost the innovativeness of firms, but not in Korea.

For the negatively estimated coefficient on information from competitors, CHS (2010) noted that it was not expected, but that firms learning from competitors might be innovation laggards. But learning from competitors (other firms in the same market) is not inconsistent with productivity studies searching for knowledge spillovers across firms. And such learning from competitors is expected to exist at least in process innovation.[25]

The next two columns (iv) and (v) in Table 4 show the result of probit estimation with instrumental variable. The endogeneity problem of a standard probit estimation may arise due to unobserved firm fixed-effect (such as a firm's culture valuing R&D efforts). Thus as in CHS (2010), we instrumented R&D expenditure by an instrumental variable of industry average R&D expenditure constructed by KIS-2002. These IV probit estimation results are very similar to those of the standard probit estimation in columns (ii) and (iii). Still, we can conclude that for non-MNC exporters and domestic MNC parents with export, investing in new knowledge seems to be more important than utilizing existing knowledge flows in explaining their innovation output premium, and *vice versa* for foreign MNC affiliate.[26]

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[25] In the following analyses of this section where product innovation and process innovation were analyzed separately, we have indeed fond a significantly positive coefficient on information from competitors in the case of process innovation (and an insignificant but positive coefficient in the case of product innovation).

[26] In order to control the endogeneity problem in information flow variables, we run additional regression with a conditional logit model with fixed effect in the specification (vi) in Table 4. This conditional logit regression was run with panel data constructed by using both KIS-2002 and KIS-2005. But because only 439 firms participated in both surveys, the number of observations has reduced significantly. Moreover, since a conditional logit model can be estimated only with firms that responded differently in the innovation dummy variable, the sample size was reduced further: this is why we have only 300 observations in this regression (300 firms mean 150 firms in each panel). Although our sample size in this additional regression is too small, we run this regression for the purpose of comparison with CHS (2010) (where the sample of UK firms was also only 494, meaning 247 firms in each panel). In CHS (2010), only the coefficient on self-information was significantly estimated with a positive sign. In our case, the coefficients on self-information and university info were significantly positive.

The innovation dummy regressed in Table 4 was constructed by using the product innovation dummy and the process innovation dummy. Thus in principle we can run the same probit regression for product and process innovation dummies separately, as shown in Tables 5 and 6. If we look at the changes of the coefficient magnitudes along the specifications (i), (ii) and (iii), we can derive the same conclusion as in Table 4 for both product and process innovation: investing in new knowledge is relatively more important in explaining the innovation output advantage of non-MNC exporters and domestic MNC parents with export while utilizing their existing knowledge stock is relatively more important in explaining innovation output advantage of foreign MNC affiliates.

But if we look at the changes of the coefficient magnitudes along the specifications (i), (iv) and (v), it seems that, for product innovation, investment in new knowledge and information flows from existing knowledge are almost equally important in explaining the global activity premium. On the other hand in the case of process innovation, information flows from existing knowledge are relatively more important, as expected.

One more thing to note is that for the product innovation dummy only self-information and free information are the important information sources while for the process innovation dummy most of the information sources turned out to be important (in specification (v) in Table 6) and more importantly group information is significantly positively estimated.

Table 5. Regression Results for Product Innovation Dummy

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
MNC without Export : Foreign Affiliates	0.027 (0.084)	0.101 (0.091)	0.091 (0.073)	0.075 (0.097)	0.084 (0.077)	2.132 (2.275)
MNC without Export : Domestic Parents	0.066 (0.049)	0.005 (0.056)	0.047 (0.056)	0.03 (0.055)	0.064 (0.057)	-0.490 (1.323)
Non-MNC Exporters	0.219*** (0.024)	0.109*** (0.028)	0.084*** (0.030)	0.151*** (0.028)	0.102*** (0.030)	-1.468 (1.016)
MNC with Export : Foreign Affiliates	0.189*** (0.057)	0.181*** (0.069)	0.138* (0.071)	0.162** (0.065)	0.136** (0.068)	-4.053 (2.484)
MNC with Export : Domestic Parents	0.250*** (0.032)	0.094** (0.041)	0.069 (0.043)	0.134*** (0.042)	0.098** (0.044)	-1.239 (1.166)

Table 5 (continued). Regression Results for Product Innovation Dummy

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
R&D Expenditure		0.095*** (0.003)	0.063*** (0.004)	0.063*** (0.008)	0.033*** (0.012)	0.039 (0.065)
Self info			0.099*** (0.016)		0.122*** ('0.017)	1.021*** (0.284)
Group info			0.001 (0.011)		0.002 (0.011)	-0.240 (0.190)
Vertical info			0.019 (0.016)		0.024 (0.016)	0.374 (0.277)
Competitor			0.005 (0.015)		0.010 (0.015)	-0.195 (0.187)
Commercial info			-0.063*** (0.022)		-0.072*** (0.022)	-0.149 (0.265)
Free info			0.082*** (0.022)		0.096*** (0.022)	0.147 (0.384)
University			0.008 (0.012)		0.017 (0.013)	0.436** (0.181)
Government			0.010 (0.012)		0.013 (0.012)	0.013 (0.197)
Observation	2,737	2,722	2,722	2,722	2,722	306
Pseudo-R^2	0.106	0.389	0.469			0.643

Note: *, **, and *** represent statistical significance at the 10%, 5% and 1% levels, respectively. All specifications include other unreported control variables: size (measured by number of workers) and industry dummy variables (23 industries at 2-digit industry codes assigned by STEPI). (i)-(iii) are the probit estimation results for KIS 2005. (iv) and (v) are the IV-probit estimation results. (vi) is the result of the fixed effect conditional logit model using both KIS 2002 and 2005. For (i)-(v), marginal impacts for the indicated regressors are reported with robust standard errors in parentheses.

Table 6. Regression Results for Process Innovation Dummy

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
MNC without Export : Foreign Affiliates	-0.054 (0.073)	-0.061 (0.075)	-0.074 (0.073)	0.088 (0.093)	-0.076 (0.074)	1.925 (2.110)
MNC without Export : Domestic Parents	0.075 (0.046)	0.027 (0.045)	0.041 (0.046)	0.025 (0.055)	0.055 (0.049)	-2.379 (1.483)
Non-MNC Exporters	0.152*** (0.023)	0.069*** (0.024)	0.045* (0.024)	0.157*** (0.029)	0.061** (0.026)	-0.117 (0.671)
MNC with Export : Foreign Affiliates	0.147** (0.058)	0.142** (0.063)	0.057 (0.059)	0.197*** (0.066)	0.055 (0.058)	1.924 (2.156)
MNC with Export : Domestic Parents	0.128*** (0.033)	0.014 (0.032)	-0.016 (0.031)	0.162*** (0.042)	0.009 (0.035)	-2.455** (1.066)
R&D Expenditure		0.051*** (0.003)	0.026*** (0.003)	0.059*** (0.009)	0.001 (0.014)	0.163** (0.065)
Self info			0.054*** (0.012)		0.074*** (0.016)	0.299 (0.206)
Group info			0.021*** (0.008)		0.022*** (0.008)	0.235 (0.150)
Vertical info			0.043*** (0.012)		0.047*** (0.012)	0.314 (0.199)
Competitor			0.017* (0.010)		0.022** (0.010)	0.222 (0.160)
Commercial info			-0.023 (0.015)		-0.033** (0.015)	-0.417 (0.261)
Free info			0.025 (0.016)		0.037** (0.018)	-0.247 (0.251)
University			0.015* (0.008)		0.024** (0.009)	0.341** (0.159)
Government			-0.014* (0.008)		-0.011 (0.009)	-0.184 (0.193)
Observation	2,743	2,722	2,722	2,722	2,722	302
Pseudo-R^2	0.0582	0.222	0301			0.461

Note: *, **, and *** represent statistical significance at the 10%, 5% and 1% levels, respectively. All specifications include other unreported control variables: size (measured by number of workers) and industry dummy variables (23 industries at 2-digit industry codes assigned by STEPI). (i)-(iii) are the probit estimation results for KIS 2005. (iv) and (v) are the IV-probit estimation results. (vi) is the result of the fixed effect conditional logit model using both KIS 2002 and 2005. For (i)-(v), marginal impacts for the indicated regressors are reported with robust standard errors in parentheses.

Finally, Table 7 is the estimation results for number of patents. Since the dependent variable of number of patents takes positive integers with many zeros, we used a Poisson regression model.[27] In this case, foreign MNC affiliates with export have no advantage in patent applications after firm size and industry dummies are controlled for. Only non-MNC exporters and domestic MNC parents with export can enjoy a global activity premium in terms of patent applications. On top of that, the advantage of non-MNC exporters in patent applications is mainly explained by investment in new knowledge (decrease of the coefficient from (i) to (iv)) not by utilizing existing knowledge flows (no decrease from (iv) to (v)). On the other hand, in the case of domestic MNC parents investing in new knowledge and utilizing existing knowledge flows are almost equally important.[28] Again this result is in contrast to CHS (2010)'s finding with UK data where information sources rather than investment in new knowledge are much more important in explaining global activity premium in all cases.

[27] The assumption required in a Poisson regression model (no over dispersion) is often too restricted and thus many patent-R&D expenditure literatures use a negative binomial model. But in the case of the negative binomial model, the IV-estimation method is somewhat complicated, while for the Poisson model IV estimation is already established (*ivpois* command in STATA). When we run the specifications (i) to (iii) in Table 7 both with Poisson and negative binomial models, the statistical significance and the magnitudes of all the coefficients did not change much. Thus to compare the results with the IV estimation with the previous tables, we report Poisson results instead of those of negative binomial.

[28] The last column in Table 7 (specification (vi)) is analogous to the same specifications in the previous tables. Here, a panel fixed effect Poisson regression is regressed on the panel constructed by KIS- 2002 and 2005. Again the sample size is only 434 (meaning 217 firms in each panel). Here the results suggest that self-information, information from competitors, free information and information from universities are important knowledge sources.

Table 7. Regression Results for Number of Patents

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
MNC without Export : Foreign Affiliates	2.333 (2.182)	2.244 (1.802)	1.890* (1.107)	0.065 (0.522)	0.101 (0.669)	
MNC without Export : Domestic Parents	0.680 (0.633)	0.667 (0.558)	0.382 (0.384)	1.239*** (0.410)	0.680* (0.363)	0.288 (0.232)
Non-MNC Exporters	1.153*** (0.314)	0.818*** (0.289)	0.357* (0.195)	0.922*** (0.191)	0.925*** (0.248)	0.168* (0.098)
MNC with Export : Foreign Affiliates	0.257 (0.401)	-0.007 (0.249)	-0.034 (0.163)	0.275 (0.451)	-0.412 (0.562)	1.295*** (0.336)
MNC with Export : Domestic Parents	1.964*** (0.677)	1.430** (0.580)	0.792** (0.338)	1.186*** (0.247)	0.504** (0.257)	0.097 (0.138)
R&D Expenditure		0.097*** (0.028)	0.038** (0.019)	0.258*** (0.030)	0.177*** (0.045)	0.089*** (0.012)
Self info			-0.114* (0.065)		0.517*** (0.111)	0.130*** (0.036)
Group info			0.012 (0.025)		0.109 (0.068)	-0.014 (0.548)
Vertical info			0.073 (0.048)		0.199* (0.107)	0.019 (0.034)
Competitor			0.025 (0.035)		0.231** (0.090)	0.042* (0.023)
Commercial info			0.040 (0.050)		-0.863*** (0.135)	-0.268 (0.043)
Free info			0.298*** (0.091)		0.533*** (0.147)	0.183*** (0.046)
University			0.072** (0.036)		0.323*** (0.065)	0.220*** (0.031)
Government			-0.030 (0.027)		0.016*** (0.067)	-0.049* (0.026)
Observation	2,737	2,722	2,722	2,722	2,722	434
Pseudo-R^2	0.581	0.611	0.679			

Note: *, **, and *** represent statistical significance at the 10%, 5% and 1% levels, respectively. All specifications include other unreported control variables: size (measured by number of workers) and industry dummy variables (23 industries at 2-digit industry codes assigned by STEPI). (i)-(iii) are the poisson estimation results for KIS 2005. (iv) and (v) are the IV-poisson estimation results. (vi) is the result of the fixed effect poisson model using both KIS 2002 and 2005. For (i)-(v), marginal impacts for the indicated regressors are reported with robust standard errors in parentheses.

5. Summary and Policy Implications

In this paper, we analyze whether there exists a positive relation between a firm's global activity and a variety of innovation outputs and, if it exists, what are the major factors that explain the global activity premium in terms of innovation output. In doing so, we closely follow the methodology used by CHS (2010) in order to see whether there exist substantial difference between the UK and Korea.

In the case of the UK, the lion's share of the global activity premium can be accounted for by utilizing more knowledge flows from inside and outside the firm, not by investing more in new knowledge input. But, in the case of Korea, this global activity premium is accounted for not only by firms' superior information access to existing knowledge (especially for foreign MNC affiliates) but also by their active investment in new knowledge (especially for non-MNC exporters and domestic MNC parents). This means that especially for non-MNC exporters and domestic MNC parents with export, investing in new knowledge seems to be more important than utilizing existing knowledge flows in explaining their innovation output premium. When we analyze the product and process innovations separately, we find that for process innovation, the information flows from existing knowledge are relatively more important while, for product innovation, investment in new knowledge and information flows from existing knowledge are almost equally important.

Given the positive relationship between innovation output and global activity, it is important to know why firms with more global activities have advantages in generating innovation. Our analyses show that in Korea the sources of those advantages come both from investing in new knowledge and utilizing information flows from existing knowledge. The policy implications from our findings are clear: in order for the global players to become more innovative, policies that can enhance information flows from existing knowledge are important just as in the case of the UK. And these types of policy are more effective and relevant for process innovation and for foreign MNC affiliates located in Korea. On the other hand, unlike the case of the UK, industry policies to increase direct R&D inputs (by investing more in new knowledge with more R&D expenditures or by using more skilled R&D personnel) should also be encouraged, especially for domestic exporters and multinational parents and for product innovation. Promoting both direct R&D activities and information flows at the same time is not an easy task, but they should be pursued at the same time so as to enhance firms' propensity to innovate in Korea.

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CHAPTER 11

Knowledge Flows, Organization and Innovation: Firm-Level Evidence from Malaysia

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Technological upgrading of a country's manufacturing sector requires the enhancement of firm-level capabilities. Knowledge flows within firms and that between firms and other entities are important aspects of this process. The nature and significance of such knowledge flows for innovation-related activities (such as in-house R&D, acquisition of technology-embedded investments and training) are likely to differ for each type of activity. The link between innovation and knowledge flows are particularly important for innovation activities in the form of acquisition of machinery, equipment and software There is also some weak evidence that globalization-related variables such as foreign direct investment and exporting can affect certain types of innovation activities such as training and acquisition of machinery, equipment and software. This study also finds that firm-level organizational dimensions and innovations are related to both internal and external knowledge flows. However, there is evidence that the links between innovative firms in Malaysia and other firms abroad in terms of co-operative activities is relatively weak. This raises the issue of whether such firms are able to tap the global technological-pool effectively.

Keywords: Innovation, Knowledge Flows and Organization

JEL Classification: 032, L60

1. Introduction

Many developing countries today actively engage in globalization to achieve sustained economic growth and development. A number of these countries have sought to implement industrial and trade policies aimed at promoting export-oriented industrialization processes. In Southeast Asia, countries such as Malaysia, Thailand and Vietnam have successfully developed export-oriented manufacturing bases comprising low to semi-skilled manufacturing assembly operations with some basic research and development activities. Despite such successes, there is a growing cognizance among policymakers in these countries of the need to upgrade their manufacturing base by producing higher value-added and more technologically sophisticated products.

How can developing countries upgrade the technological profile of their manufacturing sector? What role does globalization play in this process? Irrespective of what policy measures are proposed and implemented, it is clear that the process of technological upgrading will have to take place at the firm-level (Lall, 2000, p.19). The process of technological upgrading occurs through the accumulation of knowledge that is internally generated as well as sourced from external parties, such as suppliers, customers and universities (Griliches, 1979). Furthermore, the process of technological upgrading depends on factors that are both internal and external to the firm. Internal factors include the structure of incentives and organization within the firm. External factors include government incentives for innovation (such as tax incentives for R&D activities), investment climate, infrastructure and market competition.

Given that the majority of advanced technology resides in more developed countries, globalization clearly plays an important role in the process of technological upgrading amongst firms in developing countries (Keller, 2004). This could take place through knowledge flows resulting from the import of technologically-embedded inputs, export participation, foreign direct investment (FDI), cross-border movement of workers and training (Goldberg *et al.,* 2008, p.1). Furthermore, a useful approach to analyze the sources of knowledge flows and their impact on technological capability is in conjunction with the organizational aspect of a firm (Teece, 2000). After all, the firm is an organization - one characterized by internal hierarchies (with multiple principalagent relationships between owners, board of directors, managers and employees) and structures (divisions and departments). The boundaries of the firm are also fluid - leading to flows of technological knowledge from external parties, such as customers, suppliers, competitors and research centres. The usefulness of taking the organizational and knowledge flow perspectives is that it allows an analysis of innovation to go beyond conceptualizing the firm as a black box (or production function).

Despite the potential usefulness of examining innovation from the organizational and knowledge flow perspectives, these approaches are relatively empirically under-researched, due to a lack of suitable data. Until recently, most studies have utilized firm-level data in the form of R&D expenditures, value-added and patent counts. This has lead to most studies concentrating on investigating the linkages between innovation and productivity levels. However, more recent survey data sets, such as those from the EU's Community Innovation Surveys (CIS) have provided opportunities for scholars to empirically examine the nature and significance of organization and knowledge flows for innovating firms.

The objective of this study is to undertake an empirical analysis of the importance of knowledge flows and organization to innovation. Given the outward orientation of the Malaysian economy, a key focus will be an investigation of how these elements are related to aspects of globalization, such as exporting, foreign ownership and collaboration with foreign partners. In addition to strengthening the literature in this area, an understanding of these micro-dimensional aspects of the innovation process is also crucial for policymakers as they provide insights into how firms build up technological capabilities.

The data utilized for this study comes from the National Survey of Innovation conducted by the Malaysian government. The firm-level survey data covers the Malaysian manufacturing sector during the period 2002-2004. The outline of the paper is as follows. Section 2 provides a review of the related literature. Methodological issues are discussed in Section 3. The empirical results are discussed in Section 4. A number of policy implications are drawn out in Section 5. Section 6 concludes.

2. Literature Review

The micro-level empirical literature on knowledge flows, organization and innovation is fairly diverse. Theoretical and empirical contributions in this area come from a number of areas, such as international trade, innovation studies and strategic management. Each of these areas has a distinct methodological orientation and focus but share the common objective of understanding the process of innovation. Each strand of this literature is briefly discussed in this section.

2.1. International Trade

The first strand of literature, which comes from the area of international trade, relates to theoretical and empirical investigations of the relationships between productivity and trade using a "heterogeneous firms" framework. The empirical evidence based primarily on panel data from industrial surveys has thus far supported the self-selection theory. This theory argues that the more productive firms are the more likely they are to self-select into export markets (Greenaway and Kneller, 2004). Subsequent empirical works have incorporated innovation (in the form of investments in R&D) as a factor that affects productivity and hence, export participation e.g. Baldwin and Gu (2004), Aw *et al.* (2007) and Aw *et al.* (2010). In many of these works, the firm has been primarily modelled as production function.

More recently, trade theorists have emphasized the importance of organization in understanding not only the nature of firms' decisions to export but also to engage in foreign direct investment (FDI) (e.g. Antras and Helpman (2004), Helpman (2006) and Antras and Rossi-Hansberg (2009)). The organization is primarily analyzed in terms of the vertical boundaries of a firm which entails the decision whether to make (vertical integration) or buy (outsource/vertical disintegration).[1] Adding cross-border dimensions to such decisions takes into account the trade (outsourcing abroad) and FDI (vertical integration or insourcing abroad) phenomena. The theoretical findings in this area suggest that not only are the make and buy decisions of firms important in

[1] The theoretical framework is that of the incomplete contract approach to the theory of the firm e.g. Hart (1995).

explaining trade and FDI, these decisions are also simultaneously determined. In addition, the quality of contracting institutions matters (as they impact hold-up problems). There is some empirical evidence that productivity is related to firms' decisions to outsource, export or invests abroad (Tomuira, 2007). Decisions on vertical boundaries involving domestic production, FDI or outsourcing domestically or internationally have also been estimated by Tomuira (2009) - with such decisions being found to be positively influenced by firm size and R&D intensity.

The incorporation of innovation within a trade/FDI and organization framework is still at a very early stage of theorization e.g. Naghavi and Ottaviano (2009) and Naghavi and Ottaviano (2010). Most of the recent advances made on the investigation of the relationships between trade, organization and innovation have been theoretical in nature. Empirical work in this area has been hampered by the lack of micro data with sufficient detail on both the innovational and organizational aspects. Productivity and innovation related variables are usually available in census data but organization-related data is not. There have been very few attempts to derive proxy-variables for organization e.g. Nunn and Trefler (2008). Despite such data-related problems, the emerging empirical literature on ownership, production structure and trade suggests that this area of research is likely to continue to be important (see Hayakawa *et al.* (2010)'s review of the literature).

2.2. Innovation Studies

The second strand of literature is based on innovation studies. In contrast to the international trade literature (which primarily uses census data), innovation studies usually use cross sectional data from innovation surveys such as the EU's *Community Innovation Survey* (CIS). The literature focuses primarily on the investigation of the relationship between innovation and productivity using an innovation production function (e.g. OECD, 2009 and Mairesse and Mohnen, 2010). The benchmark model in this literature is the "CDM Model" which is a structural model that links research investment to innovation output and productivity (Crepon *et al.*, 1998).[2] Subsequent studies have involved an estimation of an extended version of the CDM model by the

[2] Applications of the model to the case of Malaysia have been undertaken by Lee (2008).

inclusion of other explanatory variables, such as external information and knowledge linkages (Griffith *et al.*, 2006).

In more recent works, a great deal of effort has gone into more explicit modelling and empirical testing of the importance of knowledge flows in the innovation process. This approach is consistent with the early work by Griliches (1979) who emphasized the multiple sources of knowledge in the innovation process, namely, new and existing knowledge within a firm and from outside the firm. The importance of knowledge management policies to innovation and productivity was investigated and found to be statistically significant in Kremp and Mairesse (2004).[3] The studies by Loof and Heshmati (2002), Criscuolo *et al.* (2005), Munier (2006) and Crespi *et al.* (2008) confirm the importance of internal (intra-firm) and external (competitors and suppliers) sources of knowledge flows for innovation. The importance of internal and external production and information networks to innovation is also emphasized in a recent study by Machikita and Ueki (2010) based on micro data collected in Indonesia, Thailand, the Philippines, and Vietnam.

2.3. Strategic Management

A third strand of relevant literature comes from strategic management in the form of emphasis on the resources and capabilities of firms. Proponents of the resource-based theory argue that a firm’s superior performance is driven by the use of strategic and unique resources that are valuable, rare, difficult to imitate and non-substitutable (Barney, 1991). In terms of innovation, key research emphasis could be on unique organizational elements (structures, processes and routines) and the accumulation of some of the firm’s unique resource via knowledge flows.

The dynamic capabilities approach goes beyond the accumulation of valuable and distinctive resources. It focuses on the adaptability of firms in environments which are characterized by rapid technological change. More specifically, a dynamic capability is defined as a firm’s “ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments” (Teece *et al.*, 1997, p.516).

[3] The knowledge management policies covered in Kremp and Mairesse (2004) includes written policy of knowledge management, culture of knowledge management, policy of retaining employees and alliances as well as partnerships for knowledge acquisition.

The organization aspects that are emphasized in the dynamic capabilities approach include organizational learning and the ability to undertake reconfiguration and transformation in a changing environment (ibid, p.520).

Undertaking empirical work on innovation and organization within a framework suggested in the value-based theory and dynamic capability approaches is very difficult and challenging. Such studies have had to rely on detailed micro data containing proxies for a small subset of variables in these theories. Most of the empirical work that are loosely related to these theories examine the knowledge flows between firms and the type of collaborative arrangements (e.g. alliance) that make them possible e.g. Decarolis and Deeds (1999).

3. Methodology

The diversity of the literature related to this research suggests the need for an eclectic framework of analysis that incorporates the various elements related to innovation, knowledge flows and organization. The framework contains elements that are found in the different theories, without comparing and testing which theory would best fit the data. This is because each theory tends to focus on different factors that may be complementary to each other. Furthermore, even if alternative explanations are available to explain some of the factors, the data is not rich enough to empirically test the validity of the different theories and approaches.

3.1.Framework of Analysis

3.1.1. Innovation and Knowledge Flows

Innovation is a complex process. Most studies on innovation have attempted to model the process of innovation as comprising of a number of inter-linked components starting from factors determining innovation activities (inputs such as R&D expenditures) to some measure of firm performance (namely: outputs, such as patents, sale of new products and/or productivity).

A number of factors, such as financial constraints, firm size and market competition, may influence a firm's decision to undertake investments in innovation activities/inputs (such as R&D expenditures and training). If successful, such activities could produce product innovations and/or process innovations which could be accompanied by new patents or industrial designs. These innovation outcomes or outputs have impacts on the firm's performance in the form of productivity improvements or increases in revenues.

The linear innovation model provides a convenient way to model innovation and firm performance using a production function approach:

$$\text{Output} = f(T, K, L, \varepsilon) \tag{1}$$

where T is innovation output (e.g. patents, product or process innovations), K physical capital and L employment and ε other unobservables. This productivity equation can be estimated together with the research and innovation equation using the Heckman selection approach in the CDM model (Crepon *et al.* (1998)).

Incorporating knowledge flows in the linear innovation model requires an understanding of the different sources of knowledge flows and how they might impact the innovation process. In this regard, Griliches (1979) postulates three sources of knowledge in the innovation process, namely:

1. New knowledge generated within the firm via new investments such as R&D;
2. Use of existing knowledge (within a firm or from related firms in the same group, such a parent or subsidiary company); and
3. Knowledge from outside the firm (e.g. sellers, buyers and other sources, such as universities).

One approach that has been used to incorporate these different types of knowledge flows is by including them as explanatory variables in the productivity equation. For example, in Criscuolo *et al.* (2005) and Crespi *et al.* (2008), the productivity equation and changes in knowledge stock of a firm i is modeled as follows:

$$T\dot{F}P_i = f(\dot{A}_i, \varepsilon_{1i}) \tag{2}$$

and

$$\dot{A}_i = f(R_i, A'_i, A'_{-i}, \varepsilon_{2i}) \tag{3}$$

where $\dot{TFP}_i$ is total factor productivity (TFP) growth, R_i investment in new knowledge, such as R&D and training, A'_i knowledge flows within the firm, A'_{-i} knowledge flows from outside the firm, and ε_{1i} and ε_{2i} unmeasured changes that affect TFP growth and knowledge production, respectively. The variable $\dot{A}_i$ is proxied by patents in Crespi *et al.* (2008). However, the information from the strategic management literature clearly suggests a more complex view of knowledge flows. Knowledge flows could affect decisions to undertake innovation. They could also be inputs in the innovation process. It also implies that it would very difficult to find a single proxy variable for changes in knowledge stock $\dot{A}_i$.

Given the complexity of knowledge flows and the difficulties in finding a single proxy for knowledge stock, it may perhaps be useful to just model the decisions to invest in innovation activities R_i and innovation production by incorporating knowledge flows. One possible approach is to incorporate them into a set of research and innovation equations, such as those used in the CDM model.

Another potential useful approach to analyzing the importance of knowledge flows is in terms of firms' technology absorption capacity. Goldberg *et al.* (2008) makes a distinction between innovation and absorption. Innovation is defined as involving new-to-the-world knowledge and can be characterized by an outward shift in the technological frontier. In contrast, improvements in absorption capacity moves a firm closer to the technological frontier. Examples of absorption include the adoption and upgrading of new products and process developed elsewhere, upgrading licensing technology, and improving organizational efficiency (Goldberg *et al.*, 2008, p.2). Knowledge flows is likely to be an important determinant of the absorption capacity of firms.

3.1.2. Knowledge Flows and Organization

Finally, it may still be a useful exercise to examine what factors influence the channels of knowledge flows used, for both knowledge flows within the firm (A'_i) and knowledge flows from outside the firm (A'_{-i}). Such factors may include those related to globalization, such as import of machinery, exporting and foreign direct investment/foreign ownership. The determinants for the different types of knowledge flows could be expressed as follows:

$$A'_i = f(M, E, F, X, \varepsilon_{3i}) \tag{4}$$

$$A'_{-i} = f(M, E, F, X, \varepsilon_{4i}) \tag{5}$$

where M is import of machinery, E export participation, F foreign direct investment/foreign ownership, X the set of control variables and, ε_{3i} and ε_{4i} unmeasured factors affecting knowledge flows.

Another important set of factors are those related to organizations. Organization as a concept is in itself complex and multi-dimensional. This is evidenced by the different ways in which the notion of organization has featured in the different literatures. It could be modelled in terms of vertical boundaries as it is done in the international trade literature. One possible approach is to model decisions on vertical boundaries as a two-stage process, the first stage involving the decision to make or buy and the second stage involving the decision to either source it domestically or from foreign markets.

This is the approach taken in Tomuira (2009). Organization could also take on hybrid-forms, such as alliances and joint ventures - these being subsets of external linkages discussed in innovation studies literature. Alternatively, it could be conceptualized in terms of internal organizational structures and routines (as in the resource-based view) or in terms of some measures of structures, procedures and designs that enhance the adaptability of the firm (as in the dynamic capabilities view). The model and definitions used for model organization are ultimately constrained by data availability - this study is no exception in this respect. This is discussed in greater detail in the next section.

3.2. Econometric Specifications

Based on the general framework of analysis discussed earlier, the econometric analysis of the relationships between knowledge flows, organization and innovation is undertaken in a number of distinct steps.

3.2.1. Innovation and Knowledge Flows

As discussed earlier, knowledge flows can influence the decision to undertake innovation activities such as R&D. In addition, knowledge flows can be an input in the innovation process. The decision to invest in innovation activities d_R of firm *i* can be specified as:

$$d_R = \begin{cases} 1 & \text{if} \quad d_R^* = \alpha_1 KNOWF_i + \alpha_2 w_i + \eta > 0 \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

where d_R^* is a latent variable associated with d_R, $KNOWF_i$ is the vector of knowledge flow variables, $\boldsymbol{w}_i$ the vector of other variables affecting the decision to undertake innovation activities and η other unmeasured variables affecting d_R.

Knowledge flow can be modeled as an input in the innovation process in terms of the observed amount of R&D investment by firm *i*:

$$R_i = \begin{cases} \beta_1 KNOWF_i + \beta_2 \mathbf{x}_i + \delta_1 & \text{if} \quad d_R = 1 \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

where $KNOWF_i$ is the vector of knowledge flow variables, $\boldsymbol{x}i$ the vector of other variables affecting the total amount of investment in knowledge and δ_1 unmeasured variables affecting R_i. Both equations can be jointly estimated using the Heckman selection method.

There a number of proxies for innovation activities (R_i) that can be used. Three proxies for innovation activities are used in this study, namely, in-house R&D activity (RNDINTRA), acquisition of machinery, equipment and software (ACQMACH) and training (TRAINING). The different types of knowledge flows are expected to be related to each of these innovation activities in a different manner. While in-house R&D may be related to building internal capabilities, acquisitions could be related to embodied technology.

Training, on the other hand, is an investment in the purely human capital aspects of innovation. Following Crespi *et al*. (2008), knowledge flows are proxied by the different sources of information used for innovation. The major categories are information from within the company itself (KNOWFOWN), other companies within the same group (KNOWFGRP), suppliers (KNOWFSUP), customers (KNOWFCUS), competitors (KNOWFCOM), consultants (KNOWFCON), private and commercial research laboratories or centres (KNOWFPRI), universities (KNOWFUNI) and government or public research institutes (KNOWPUB). Based on the earlier discussions, the knowledge flows can be classified as follows:

- internally generated knowledge flows (A_i') such as NOWFOWN and NOWFGRP, and
- knowledge flows from outside the firm (A_{-i}'), namely, KNOWFSUP, KNOWFCUS, KNOWFCOM, KNOWFCON, KNOWFPRI, KNOWFUNI and KNOWPUB.

Two sets of control variables are used for the above estimations. The first include firm-level variables such as firm size (SIZE, SIZE2), age of firm (AGE, AGE2), extent of foreign ownership (FOREIGN) and whether firms are limited liability listed companies (OWNLIMLIST), limited liability unlisted companies (OWNLIMUNLIST) or unlimited liability firms (OWNUNLIM). Industry-level control variables take the form of market concentration (HHI) and industry dummies. A useful industry variable which is not available, due to data constraints is import penetration ratio.

Finally, as innovation activities could be influenced by the assistance and support from government agencies, six explanatory variables are included to capture such effects. These are extracted from the survey and can be classified into two categories. The first category is a broad measure of government-related variables comprising non-tax incentives (NONTAXINCT) and tax incentives (TAXINCT). The second set includes more specific government-related assistance and support measures. These include technical consulting services (TECHCON), technical support services

(TECHSUP), duty-free import of machinery (DUTYFREE) and R&D Commercialization Fund (RNDFUND). Given the possible overlap between the two categories of government-related variables, they are included separately in the regression equations.

3.2.2. Knowledge Flows and Organization

Knowledge flows occur within given organizational structures. Even though the choice of organization may be considered to be endogenous in the long run, it is more plausible to assume it as an exogenous variable compared to knowledge flows.

A general specification of this relationship for a given firm *i*'s knowledge flow $KNOWF_i$ can be expressed as:

$$KNOWF_i = f(ORG_i, \mathbf{X}_i, e_i) \quad (8)$$

where ORG_i is the vector representing organization variables, $\mathbf{X}_i$ the vector of control variables and e_i the error term. The above equation can be estimated using probit. The set of control variables used is similar to those used in estimating the relationship between innovation and knowledge flows.

The discussions in the previous studies suggest that organization is a complex concept with diverse meanings in different research literatures. Thus, several types of organization variables can be used in this study. They include the following:

1. The first relates to vertical boundaries of the firm. Detailed information on vertical relationship is not available. Instead this variable is proxied by a dummy variable FIRMSUB which takes the value of one if a firm is a subsidiary of another firm and zero otherwise.
2. A second type of variable for organization relates to organizational innovations that improves the adaptability of the firm to a changing environment (as in the dynamic capabilities literature). These include organizational innovations that:
    - Reduce the time to respond to customer or supplier needs (ORGTIME);
    - Improve the quality of goods and services (ORGGOOD);
    - Reduce cost per unit of output or service (ORGCOST); and

- Improve employee satisfaction and reduce employee turnover (ORGSATI).

3. A third set of variable relates to collaborative activities with external parties. In the survey data used, it is possible to identify to identify firms that engage in co-operative arrangements on innovation activities. This variable can be further classified in greater detail according to the different types of partners involved in such activities and whether they involve domestic (D) or external partners (F). The variables used in this study include co-operative arrangements with other companies within company group (COOPGRPF for foreign partners, COOPGRPD for domestic partners), suppliers (COOPSUPF, COOPSUPD), customers (COOPCUSF, COOPCUSD), competitors (COOPCOMF, COOPCOMD), consultants (COOPCONF, COOPCOND), private and commercial research laboratories or centres (COOPPRIF, COOPPRID), universities (COOPUNIF, COOPUNID) and government or public research institutes (COOPPUBF, COOPPUBD). The inclusion of this set of variables could provide some insights into the relative importance of foreign vs. domestic collaborations.

Finally, six variables representing government assistance and support for innovation-related activities are also included to capture their effects on knowledge flows within and between firms. They are identical to the ones used in the previous section.

3.3. Data

3.3.1. Data Source and Description

The micro data that will be used for this study is a firm-level cross-section data set from the National Survey of Innovation (NSI) conducted by the Malaysian Science and Technology Information Centre (MASTIC), Ministry of Science, Technology and Innovation. The survey covers the Malaysian manufacturing sector during the period 2002-2004. The survey was carried out in two stages - the first used a one-page questionnaire addressed to both innovating and non-innovating firms. In the second stage, a more detailed questionnaire was completed by innovating firms. The dataset used for this study comes from the second stage which covers only firms that innovated during the period 2002-2004.

Three variables are used to proxy innovation activities in this study, namely, in-house R&D activity (RNDINTRA), acquisition of machinery, equipment and software (ACQMACH) and training (TRAINING). This data is expenditure incurred for each activity during the period 2002-2004. Natural logarithmic of per-capita expenditure for these activities is used in the regressions.

The knowledge flow variables are binary variables derived from a three point Likert-type scale (low, medium and high importance) for the different sources of information. Each of the knowledge flow variables (e.g. KNOWFOWN) assumes a value of one for a firm if it indicates the source as of high importance and zero otherwise. The organization variable FIRMSUB is also a binary variable, assuming the value of one for firms indicating they are part of a company group and zero otherwise. The four organizational innovation variables (ORGTIME, ORGGOOD, ORGCOST and ORGSAT) are binary variables that assume the value of one if they are considered of high importance.

Innovation co-operation variables take the form of binary variables. In addition, there are some firms with both foreign and domestic collaborative partners. There are sixteen dummy variables - two (foreign, local) for each type of partner. The four control variables used in this study are all firm-level variables. Firm size (SIZE) is measured in terms of the (natural logarithmic of) number of employees in 2004. The age of the firm (AGE variable) is measured by the number of years established as of 31 December 2004. The variable FOREIGN measures the degree of foreign ownership - it is a binary variable with the value of one if 10% or more of the ownership equity in the firm is in the hands of foreigners. The exporting variable (EXPORT) takes the form of a dummy variable which assumes the value of one if the value of exports is positive and zero otherwise. Three ownership variables are used in this study - OWNUNLIM (sole proprietorship and partnership with unlimited liability), OWNLIMPRI (private companies with limited liability) and OWNLIMLIST (public listed companies with limited liability).

Data on industry market concentration comes from a separate source, namely the Department of Statistics. The most recent estimates of the Herfindahl-Hirschman Index

(HHI) that could be obtained are for year 2000. Estimates of the HHI at the aggregated level (2-digit) are derived from disaggregated 5-digit HHI estimates (computed by the Department of Statistics) using a weighted approach. The weights used are based on turnover figures for the various industries obtained from the Department of Statistics' Census of Manufacturing Industries 2001.

3.3.2. Descriptive Statistics

The descriptive statistics for the sample data used in this study are summarized in **Table 1**. The firm size distribution (measured in terms of total number of employees) suggests that most firms in the sample are small and medium enterprises (SMEs). Close to half of the firms in the sample have between 50 to 249 employees. The age of the firms ranges between 2 years and 76 years with the average age being 14 years. A relatively smaller proportion of the firms (17.5%) in the sample data are foreign-related companies (defined as equity equal to or more than 10% in the hands of foreigners). About 64% of the firms in the sample data are engaged in export markets. The predominant mode of ownership amongst firms in the sample is private limited (90%). Only a very small proportion (3.4%) is public listed companies.

Table 1. Basic Descriptive Statistics

Size (no. employees)	**1 to 19**	**20 to 49**	**50 to 249**	**> 249**	**Total**
Number of firms	58	89	208	84	439
Percentage	13.2%	20.3%	47.4%	19.1%	100.0%
Age (years)	**1 to 5**	**6 to 10**	**10 to 20**	**> 20**	**Total**
Number of firms	30	180	151	78	439
Percentage	6.8%	41.0%	34.4%	17.8%	100.0%
Foreign Ownership (% equity)	**FO=0**	**0 < FO < 11**	**10 < FO < 51**	**50 < FO**	**Total**
Number of firms	362	6	24	47	439
Percentage	82.5%	1.4%	5.5%	10.7%	100.0%
Exporting	**Exporters**	**Non Exporters**			
Number of firms	279	160			439
Percentage	63.6%	36.4%			100.0%
Subsidiary	**YES**	**NO**			**Total**
Number of firms	96	343			439
Percentage	21.9%	78.1%			100.0%
Ownership Type	**Sole-Proprietor**	**Partnership**	**Private Limited**	**Public Listed**	**Total**
Number of firms	18	11	395	15	439
Percentage	4.1%	2.5%	90.0%	3.4%	100.0%

Table 1 (continued). Basic Descriptive Statistics

Importance of Information Source (%)	Not Used	Low	Medium	High	Total
Within company	10.8	28.28	28.79	32.13	100.00
Other company within group	67.53	6.44	14.95	11.08	100.00
Suppliers	10.8	26.99	40.36	21.85	100.00
Customers	6.96	40.46	36.86	15.72	100.00
Competitors	29.82	24.68	22.62	22.88	100.00
Consultants	52.31	15.13	15.64	16.92	100.00
Private Research Institutes	77.84	6.44	7.99	7.73	100.00
Universities	85.53	6.2	5.43	2.84	100.00
Publlic Research Institutes	66.93	14.47	10.59	8.01	100.00
Importance of Organizational Innovation (%)	**Not Relevant**	**Low**	**Medium**	**High**	**Total**
Time Responsiveness	7.75	29.58	39.2	23.47	100.00
Quality Improvement	5.16	46.95	30.05	17.84	100.00
Cost Reduction	6.35	44.00	28.00	21.65	100.00
Employee Satisfaction	7.57	36.88	29.08	26.48	100.01
Innovation Activities (Ringgit Malaysia)	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
In-House R&D	300	264297.8	901593.7	0	1.00E+07
Acquisition of Machinery etc.	347	448593.6	1586439	0	1.50E+07
Training	304	40052.69	135721.9	0	2000000

Source: MASTIC.

Knowledge flows are proxied by sources of information for innovation. The major sources of information that are regarded as 'highly important' include those originating from within the company itself, from competitors and from suppliers. Interestingly, research institutes (both private and public) and universities are not considered to be important sources of information for innovation. In terms of organization, only 22% of the firms in the sample are subsidiaries (i.e. belonging to a group of companies). More than 20% of firms regard three of the categories of organizational innovation effects, those relating to time, cost and employee satisfaction as highly important.

In terms of innovation activities, all three variables used in this study have very high standard deviations compared to the mean, indicating significant variations as well as very unequal distribution across firms in the sample.

The sample data used in this study covers some 22 industries in the manufacturing sector (**Table 2**). Given the relatively small sample size, there is some concern regarding the sample representativeness of the data, as a whole and in terms of each industry in the sector. This is an important issue as it determines whether the findings from this study represent a valid description of the sector. The size of the sample is compared to the size of the sample frame and the larger-sized manufacturing survey. Remember that the sample used in this study covers only innovating firms. Despite this, the sample coverage seems to be high in a few industries with an either relatively low number of total employees or number of firms, or both. The relatively small number of firms (less than 30) suggests that any attempts to undertake an industry-level analysis is likely to be constrained by the number of observations in each industry.

Table 2. Statistics on Sample Representativeness

	(1)	(2)	(3)	(4)	(5) = (1)/(2)	(6) = (3)/(4)
	No. of firms in Sample	**No. of firms in Sample Frame**	**Total Employees in Sample**	**Total Employees in 2004 Manufacturing Survey**	**(%)**	**(%)**
Food products and beverage	46	2,346	10,534	133,402	1.96	7.90
Textiles	2	339	913	37,483	0.59	2.44
Wearing Apparel	19	726	2,959	81,152	2.62	3.65
Leather	12	147	5,723	8,080	8.16	70.83
Wood and cork	21	1,025	2,777	116,329	2.05	2.39
Paper	28	377	8,376	34,821	7.43	24.05
Publishing	17	724	4,895	37,721	2.35	12.98
Coke, refined petroleum	19	47	2,767	4,353	40.43	63.57
Chemical	27	634	8,294	52,687	4.26	15.74
Rubber, plastic	35	1,509	5,471	174,568	2.32	3.13
Non-metalic minerals	25	728	2,637	56,427	3.43	4.67
Basic metals	19	501	2,281	42,941	3.79	5.31
Fabricated metal	27	1,509	2,599	73,703	1.79	3.53
Machinery, equipment	23	813	3,838	53,836	2.83	7.13
Office, accounting, computing machinery	4	65	1,798	64,293	6.15	2.80
Electrical machinery	20	425	2,126	68,131	4.71	3.12
Radio, TV, communication equipment	30	439	9,906	285,243	6.83	3.47
Medical, precision, optical instrument	10	50	3,573	24,956	20.00	14.32
Motor vehicle, trailers	9	253	3,318	51,128	3.56	6.49
Other transport	22	183	3,322	29,679	12.02	11.19
Furniture	22	1,340	3,988	101,361	1.64	3.93
Recycling	2	14	301	544	14.29	55.33
Total	**439**	**14,194**	**92,396**	**1,532,838**	**3.09**	**6.03**

Source: Data (1)-(3) from MASTIC, Data (4) from Ramstetter and Sharazat (2009).

4. Empirical Results

4.1. Innovation and Knowledge Flows

The relationship between innovation and knowledge flows are investigated for three types of innovation activities, namely, in-house R&D, acquisition of machinery and training. The results are discussed in terms of internal vs. external knowledge flows.

In-House R&D

In the case of in-house R&D, internal knowledge flows in terms of knowledge flows from other firms within the same group (KNOWFGRP) is negative and significantly related to the decision to undertake in-house R&D (selection equation) (**Table 3**). This suggests that firms in which such knowledge flows are important are less inclined to undertake in-house R&D. Knowledge flows from external parties appear to be more important, especially knowledge flows from customers (KNOWFCUS) – the variable being significant in both the intensity and selection equations. The negative sign for this variable suggests that the greater importance assigned to knowledge flows from customers is associated with lower propensity and intensity in in-house R&D. This could mean that firms which get good information and feedback from their customers do not see the need for in-house R&D.

Table 3. In-House R&D and Knowledge Flows

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	RNDINTRA	select	RNDINTRA	select	RNDINTRA	select
SIZE	-0.864	1.897***	-1.025*	1.890***	-0.800	1.685***
	(0.676)	(0.364)	(0.572)	(0.380)	(0.572)	(0.362)
SIZE2	0.0328	-0.152***	0.0426	-0.148***	0.0265	-0.130***
	(0.0602)	(0.0364)	(0.0529)	(0.0386)	(0.0523)	(0.0364)
AGE	0.0793**	-0.00791	0.0705*	0.0407	0.0882**	0.0534*
	(0.0386)	(0.0237)	(0.0379)	(0.0259)	(0.0412)	(0.0273)
AGE2	-0.00156*	-0.000301	-0.00148	-0.00101*	-0.00182*	-0.00117**
	(0.000918)	(0.000511)	(0.000903)	(0.000553)	(0.000959)	(0.000587)
FOREIGN	0.0861	-0.579***	-0.161	-0.272	0.0199	-0.399*
	(0.283)	(0.191)	(0.253)	(0.204)	(0.249)	(0.205)

Table 3 (continued). In-House R&D and Knowledge Flows

VARIABLES	(1) RNDINTRA	(2) select	(3) RNDINTRA	(4) select	(5) RNDINTRA	(6) select
EXPORT	-0.363*	-0.209	-0.334	-0.349*	-0.221	-0.282
	(0.213)	(0.176)	(0.209)	(0.187)	(0.216)	(0.190)
OWNUNLIM	0.0568	-0.124	0.195	-0.106	0.596	-0.435
	(0.888)	(0.457)	(0.865)	(0.465)	(0.874)	(0.496)
OWNLIMLIST	0.784*	0.277	0.620	0.218	0.777*	0.0888
	(0.437)	(0.407)	(0.423)	(0.407)	(0.421)	(0.408)
HHI	0.000605**	0.000269	0.000429	0.000324***	0.000623**	0.000327***
	(0.000273)	(0.000186)	(0.000275)	(9.15e-05)	(0.000266)	(9.31e-05)
KNOWFOWN	0.202	-0.142	0.220	-0.247	0.185	-0.265
	(0.206)	(0.178)	(0.199)	(0.168)	(0.200)	(0.169)
KNOWFGRP	-0.0214	-0.544**	-0.0525	-0.574**	-0.0698	-0.507**
	(0.344)	(0.261)	(0.320)	(0.254)	(0.322)	(0.251)
KNOWFSUP	-0.00571	0.433**	-0.136	0.243	0.0158	0.277
	(0.233)	(0.200)	(0.215)	(0.196)	(0.217)	(0.201)
KNOWFCUS	-1.487***	-0.263	-1.392***	-0.474**	-1.438***	-0.424*
	(0.330)	(0.224)	(0.322)	(0.220)	(0.325)	(0.222)
KNOWFCOM	0.440*	0.164	0.315	0.182	0.368	0.130
	(0.227)	(0.195)	(0.223)	(0.194)	(0.227)	(0.195)
KNOWFCON	0.0317	-0.0592	-0.00667	-0.110	0.0468	-0.168
	(0.237)	(0.218)	(0.232)	(0.218)	(0.232)	(0.222)
KNOWFPRI	-0.414	0.630*	-0.406	0.403	-0.427	0.570
	(0.297)	(0.353)	(0.276)	(0.342)	(0.276)	(0.348)
KNOWFUNI	0.188	-0.452	0.205	-0.324	0.123	-0.210
	(0.490)	(0.518)	(0.475)	(0.513)	(0.471)	(0.516)
KNOWFPUB	-0.350	0.620*	-0.165	0.105	-0.211	-0.0136
	(0.330)	(0.344)	(0.305)	(0.350)	(0.307)	(0.352)
NONTAXINCT			-0.673***	1.077***		
			(0.204)	(0.205)		
TAXINCT			0.503	-0.0598		
			(0.392)	(0.351)		
TECHCON					-0.268	1.196***
					(0.252)	(0.313)
TECHSUP					-0.384	0.320
					(0.285)	(0.371)
DUTYFREE					-0.535*	-0.00665
					(0.285)	(0.271)
RNDFUND					0.289	-0.318
					(0.255)	(0.444)
Constant	8.156***	-5.395***	9.220***	-5.609***	8.008***	-5.165***
	(2.125)	(0.990)	(1.673)	(0.944)	(1.688)	(0.911)

Table 3 (continued). In-House R&D and Knowledge Flows

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	RNDINTRA	select	RNDINTRA	select	RNDINTRA	select
Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	437	437	392	392	391	391

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Source: Author's computations based on data from MASTIC.

The market concentration (HHI) seems to be positively related to the decision to undertake as well as the amount (intensity) of in-house R&D expenditure. The significance and signs of the firm size and age variables suggests a nonlinear inverse-U relationship between in-house R&D and these variables. The importance of these variables to in-house R&D differs – age is significant in the intensity equation, while size is significant in the selection equation.

The significance of the two globalization-related variables, exporting (EXPORT) and FDI (FOREIGN) have negative signs and are not significant. Interestingly, government support and incentives in the form of non-tax seem to have a negative relationship with the intensity of in-house R&D.

Acquisition of Machinery, Equipment and Software

The acquisition of machinery, equipment and software should be considered to be a different type of innovation activity compared to in-house R&D. For this type of innovation activity, internal knowledge flows seem to be less important compared to external knowledge flows (**Table 4**). Knowledge flows from other firms within the same group are positively, albeit, weakly significant in relation to the acquisition of machinery, equipment and software. Four sources of external knowledge flows are important for acquisition of machinery, equipment and software, namely, suppliers (KNOWFSUP, positive), customers (KNOWFCUS, negative), competitors (KNOWFCOM, positive in intensity) and consultants (KNOWFCON, positive in selection). In contrast, the negative sign for the demand-oriented variable (KNOWCUS) suggests that when knowledge flows from customers are important, firms are not likely to spend on the acquisition of machinery, equipment and software that are related to innovation.

Table 4. Acquisition of Machinery, Equipment and Software, and Knowledge Flows

VARIABLES	(1) ACQMACH	(2) select	(3) ACQMACH	(4) select	(5) ACQMACH	(6) select
SIZE	-0.131	0.343	0.0824	0.373	0.104	0.302
	(0.344)	(0.278)	(0.335)	(0.313)	(0.332)	(0.308)
SIZE2	-0.0676*	-0.0314	-0.0921***	-0.0336	-0.0870**	-0.0287
	(0.0359)	(0.0287)	(0.0352)	(0.0327)	(0.0346)	(0.0317)
AGE	0.0864**	-0.0200	0.0791**	0.0307	0.0574	0.0319
	(0.0342)	(0.0194)	(0.0334)	(0.0235)	(0.0350)	(0.0236)
AGE2	-0.000827	-0.000139	-0.000822	-0.000859*	-0.000408	-0.000839*
	(0.000828)	(0.000398)	(0.000813)	(0.000471)	(0.000833)	(0.000469)
FOREIGN	0.453*	-0.523***	0.301	-0.211	0.189	-0.276
	(0.254)	(0.176)	(0.219)	(0.200)	(0.218)	(0.201)
EXPORT	-0.147	-0.0509	-0.208	-0.229	-0.144	-0.194
	(0.185)	(0.159)	(0.182)	(0.190)	(0.188)	(0.191)
OWNUNLIM	-0.435	0.331	-0.459	0.555	-0.270	0.425
	(0.358)	(0.328)	(0.347)	(0.384)	(0.346)	(0.390)
OWNLIMLIST	0.746*	0.290	0.749*	0.415	0.538	0.353
	(0.438)	(0.384)	(0.428)	(0.430)	(0.423)	(0.427)
HHI	0.000132	7.34e-05	0.000161	0.000109	0.000141	8.05e-05
	(0.000160)	(7.11e-05)	(0.000155)	(9.18e-05)	(0.000155)	(9.08e-05)
KNOWFOWN	-0.141	0.277*	-0.176	0.0724	-0.130	0.0739
	(0.183)	(0.162)	(0.172)	(0.172)	(0.171)	(0.172)
KNOWFGRP	0.448*	0.126	0.413*	0.0798	0.308	0.172
	(0.249)	(0.250)	(0.242)	(0.252)	(0.243)	(0.255)
KNOWFSUP	0.360*	0.347*	0.282	0.180	0.330*	0.189
	(0.200)	(0.194)	(0.183)	(0.200)	(0.183)	(0.204)
KNOWFCUS	-0.336	-0.150	-0.281	-0.256	-0.497**	-0.264
	(0.232)	(0.213)	(0.227)	(0.220)	(0.231)	(0.220)
KNOWFCOM	0.385**	-0.0214	0.350*	-0.0819	0.374**	-0.115
	(0.188)	(0.185)	(0.184)	(0.193)	(0.186)	(0.194)
KNOWFCON	-0.0189	0.511**	-0.0693	0.472*	-0.0605	0.426*
	(0.219)	(0.231)	(0.198)	(0.242)	(0.197)	(0.243)
KNOWFPRI	-0.328	-0.0145	-0.261	-0.421	-0.247	-0.214
	(0.296)	(0.321)	(0.293)	(0.342)	(0.288)	(0.348)
KNOWFUNI	0.403	-0.0899	0.285	-0.0555	0.459	0.0775
	(0.449)	(0.625)	(0.438)	(0.679)	(0.431)	(0.655)

Table 4 (continued). Acquisition of Machinery, Equipment and Software, and Knowledge Flows

VARIABLES	(1) ACQMACH	(2) select	(3) ACQMACH	(4) select	(5) ACQMACH	(6) select
KNOWFPUB	-0.263	0.659*	-0.236	0.558	-0.154	0.468
	(0.319)	(0.364)	(0.293)	(0.408)	(0.293)	(0.398)
NONTAXINCT			-0.376*	1.031***		
			(0.195)	(0.235)		
TAXINCT			1.377***	-0.501		
			(0.373)	(0.394)		
TECHCON					-0.396	1.272***
					(0.248)	(0.427)
TECHSUP					-0.595**	0.255
					(0.282)	(0.429)
DUTYFREE					0.657**	-0.0152
					(0.256)	(0.284)
RNDFUND					-0.375	-0.281
					(0.272)	(0.426)
Constant	7.742***	-0.199	7.536***	-0.574	7.496***	-0.347
	(0.984)	(0.682)	(0.911)	(0.764)	(0.911)	(0.762)
Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	437	437	392	392	391	391

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Author's computations based on data from MASTIC.

In general, the globalization-related variables such as foreign ownership (FOREIGN) and exporting (EXPORT) are relatively insignificant. The statistical significance of the negatively-signed size-squared-variable (SIZE2) suggests that large firms are less likely to spend on the acquisition of machinery, equipment and software. In contrast, younger firms (AGE) are more likely to spend greater amounts (per capita) on this type of activity.

Overall, government-related support and incentives are important (positive and significant), albeit, the manner in which they affect acquisition of machinery is fairly complex. Tax incentives are significant in intensity, whilst non-tax incentives are significant in selection. In the case of more specific government support and incentives for innovation, both technical consulting services (TECHCON, significant in selection) and duty-free import of machinery (DUTYFREE, significant in intensity) are positively related to the acquisition of machinery, equipment and software. Interestingly, technical support services (TECHSUP) from the government is negatively significant in relation to the acquisition of machinery, equipment and software. This implies that firms embarking on such acquisitions tend to assign less importance to these types of support services from the government.

Training

In the case of innovation-related training (TRAINING), both internal knowledge flows and external knowledge flows seem to be important. Knowledge flows sourced from another company within the same group (KNOWFGRP) is negatively related to the decision to undertake this type of training but is positively related to the amount spent on such activities (**Table 5**). As for external knowledge flows, the statistically significant variables in the intensity equations include knowledge flows from competitors (KNOWFCOM, positive) and knowledge flows from private research centres (KNOWFPRI, negative). The latter suggests that if firms consider knowledge flows from private research centres to be unimportant, the firms are likely to invest more in innovation-related training. The knowledge flow variables that are significant in the selection equation include KNOWFCOM (positive) and KNOWFCON (positive). Thus, knowledge flows from competitors (KNOWFCOM) is clearly an important source of external knowledge flows.

Table 5. Training and Knowledge Flows

VARIABLES	(1) TRAINING	(2) select	(3) TRAINING	(4) select	(5) TRAINING	(6) select
SIZE	-0.0413	0.602**	-0.102	0.645**	0.987**	0.482*
	(0.383)	(0.269)	(0.366)	(0.288)	(0.399)	(0.267)
SIZE2	-0.0611	-0.0522*	-0.0629*	-0.0555*	-0.148***	-0.0373
	(0.0384)	(0.0280)	(0.0366)	(0.0301)	(0.0406)	(0.0275)
AGE	0.0189	0.00112	0.00283	0.0364	-0.0319	0.0497*
	(0.0426)	(0.0220)	(0.0384)	(0.0266)	(0.0498)	(0.0290)
AGE2	-0.000266	-0.000332	0.000126	-0.000873	0.000804	-0.00118*
	(0.00108)	(0.000492)	(0.000960)	(0.000602)	(0.00123)	(0.000683)
FOREIGN	0.266	-0.134	-0.248	0.0931	0.0357	0.233
	(0.222)	(0.170)	(0.214)	(0.191)	(0.264)	(0.189)
EXPORT	0.00433	0.296**	0.0885	0.255	0.340	0.315*
	(0.208)	(0.150)	(0.194)	(0.161)	(0.236)	(0.162)
OWNUNLIM	0.125	0.103	-0.00104	0.207	0.594	-0.00491
	(0.433)	(0.315)	(0.392)	(0.336)	(0.491)	(0.328)
OWNLIMLIST	1.304**	-0.376	1.206**	-0.469	0.784	-0.640*
	(0.516)	(0.367)	(0.474)	(0.388)	(0.574)	(0.379)
HHI	-7.57e-05	0.000174***	0.000122	0.000212***	0.000186*	0.000192***
	(8.71e-05)	(6.64e-05)	(0.000256)	(7.56e-05)	(9.63e-05)	(7.34e-05)
KNOWFOWN	-0.160	0.158	-0.269	0.0360	-0.136	0.0134
	(0.187)	(0.147)	(0.173)	(0.150)	(0.212)	(0.148)
KNOWFGRP	0.633**	-0.377*	0.669**	-0.414*	0.0340	-0.434*
	(0.309)	(0.221)	(0.292)	(0.224)	(0.335)	(0.225)
KNOWFSUP	0.170	0.261	0.0884	0.162	0.244	0.150
	(0.204)	(0.177)	(0.186)	(0.181)	(0.240)	(0.175)
KNOWFCUS	-0.420*	0.129	-0.401*	0.0226	-0.333	-0.0344
	(0.242)	(0.201)	(0.218)	(0.202)	(0.279)	(0.199)
KNOWFCOM	0.337	0.321*	0.0682	0.298	0.618***	0.292*
	(0.211)	(0.174)	(0.185)	(0.185)	(0.238)	(0.170)
KNOWFCON	-0.0236	0.324*	-0.344	0.229	0.165	0.326*
	(0.231)	(0.193)	(0.223)	(0.196)	(0.256)	(0.189)
KNOWFPRI	-0.797**	-0.0832	-0.413	-0.125	-0.731*	-0.156
	(0.331)	(0.285)	(0.315)	(0.290)	(0.386)	(0.276)
KNOWFUNI	0.239	-0.297	0.207	-0.213	-0.0156	-0.0661
	(0.541)	(0.442)	(0.487)	(0.450)	(0.611)	(0.423)
KNOWFPUB	0.123	0.307	-0.0370	0.157	0.331	0.0575
	(0.327)	(0.299)	(0.296)	(0.298)	(0.386)	(0.282)
NONTAXINCT			-0.711***	0.149		
			(0.191)	(0.165)		

Table 5 (continued). Training and Knowledge Flows

VARIABLES	(1) TRAINING	(2) select	(3) TRAINING	(4) select	(5) TRAINING	(6) select
TAXINCT			0.127	0.00441		
			(0.372)	(0.357)		
TECHCON					0.00219	0.0635
					(0.322)	(0.222)
TECHSUP					-0.911**	-0.277
					(0.389)	(0.268)
DUTYFREE					0.298	-0.115
					(0.339)	(0.243)
RNDFUND					0.172	0.622
					(0.360)	(0.407)
Constant	7.030***	-2.053***	7.412***	-2.373***	2.783***	-2.098***
	(1.225)	(0.671)	(1.280)	(0.723)	(1.033)	(0.668)
Industry Dummies	No	No	Yes	Yes	No	No
Observations	437	437	392	392	391	391

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Author's computations based on data from MASTIC.

The relationship between innovation-related training and the size of a firm is non-linear, or inverse-U to be more precise. Of the two globalization-related control variables, only exporting (EXPORT) is statistically significant in the selection equation – the positive sign suggesting exporting is associated with higher investment in innovation-related training. The statistical significance of the positively-signed Herfindahl-Hirschman Index variable suggests that market concentration is associated with greater investment in training. Finally, government-related support and incentives are not important to a firm's decision to undertake and spend on innovation-related training.

4.2. Knowledge Flows and Organization

How are knowledge flows related to organization in the case of innovating firms? Are internal knowledge flows different from external knowledge flows in terms of organizational dimensions? The results from the econometric analysis of the relationship between the different types of knowledge flows and different aspects of organization are summarized in **Table 6**.

Overall, the relationship between the different types of knowledge flows and different aspects of organization appears to be a complex one.

Table 6. Organization and Knowledge Flows

VARIABLES	(1) KNOWFOWN	(2) KNOWFGRP	(3) KNOWFSUP	(4) KNOWFCUS	(5) KNOWFCOM	(6) KNOWFCON	(7) KNOWFPRI	(8) KNOWFUNI	(9) KNOWFPUB
SIZE	-0.0418	-0.280	-0.537	0.137	-0.676*	0.492	0.846	-0.962	1.728*
	(0.357)	(0.526)	(0.410)	(0.508)	(0.378)	(0.496)	(0.730)	(0.980)	(1.026)
SIZE2	-0.0199	0.0494	0.0477	-0.0118	0.0630	-0.0510	-0.0697	0.113	-0.150
	(0.0384)	(0.0529)	(0.0441)	(0.0528)	(0.0414)	(0.0544)	(0.0745)	(0.0981)	(0.104)
AGE	0.0886**	-0.0674	0.0203	0.0312	-0.00356	-0.0447	-0.00895	0.444	-0.0260
	(0.0429)	(0.0450)	(0.0314)	(0.0544)	(0.0316)	(0.0360)	(0.0686)	(0.591)	(0.0545)
AGE2	-0.00205*	0.00126	0.000352	-0.000364	-5.84e-06	0.00167**	-0.000615	-0.0244	-0.000159
	(0.00107)	(0.000914)	(0.000632)	(0.00127)	(0.000662)	(0.000793)	(0.00172)	(0.0275)	(0.00111)
FOREIGN	0.0958	-0.194	0.211	0.701**	0.145	-0.564*	0.207	-0.657	0.00239
	(0.253)	(0.342)	(0.280)	(0.316)	(0.265)	(0.324)	(0.443)	(1.096)	(0.448)
EXPORT	-0.274	-0.0802	-0.165	-0.742***	-0.402*	0.0860	-0.601*	-0.949	-0.445
	(0.193)	(0.283)	(0.231)	(0.273)	(0.212)	(0.222)	(0.323)	(0.690)	(0.338)
FIRMSUB	0.136	0.786**	0.0499	0.0472	0.265	0.0951	0.514	2.258*	1.277***
	(0.247)	(0.335)	(0.277)	(0.337)	(0.267)	(0.310)	(0.420)	(1.171)	(0.489)
OWNUNLIM	0.448	-0.0138	-0.315	0.489	0.222	0.260	Dropped	Dropped	Dropped
	(0.381)	(0.576)	(0.403)	(0.490)	(0.378)	(0.440)			
OWNLIMLIST	0.757	-1.351*	-0.136	0.954	0.647	-1.623	1.017	Dropped	-1.794
	(0.484)	(0.811)	(0.527)	(0.673)	(0.527)	(1.151)	(0.738)		(1.862)
HHI	0.000190	-5.87e-05	-9.34e-05	-0.000349	0.000124	0.000140	0.000182	0.000141	0.000285
	(0.000176)	(0.000235)	(0.000190)	(0.000238)	(0.000184)	(0.000185)	(0.000248)	(0.000341)	(0.000249)
ORGTIME	0.0364	-0.267	-0.646**	0.0670	0.261	0.0323	0.0758	-0.159	0.729
	(0.236)	(0.323)	(0.274)	(0.283)	(0.243)	(0.262)	(0.432)	(0.977)	(0.499)
ORGGOOD	0.445*	0.266	0.818***	0.816**	0.128	0.0578	0.759	0.652	-0.739

Table 6 (continued). Organization and Knowledge Flows

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	KNOWFOWN	KNOWFGRP	KNOWFSUP	KNOWFCUS	KNOWFCOM	KNOWFCON	KNOWFPRI	KNOWFUNI	KNOWFPUB
	(0.268)	(0.371)	(0.296)	(0.325)	(0.271)	(0.302)	(0.520)	(0.849)	(0.660)
ORGCOST	-0.00365	0.364	-0.0467	0.308	0.0587	-0.665**	-0.804	-0.180	-1.068**
	(0.249)	(0.344)	(0.275)	(0.307)	(0.258)	(0.294)	(0.510)	(0.773)	(0.544)
ORGSATI	-0.389*	0.0490	0.774***	0.238	0.111	0.406	-0.0268	1.431	-0.382
	(0.231)	(0.314)	(0.258)	(0.294)	(0.245)	(0.269)	(0.409)	(1.003)	(0.447)
COOPGRPF	-0.275	-1.345	-1.551	-11.83	-0.412	0.935	1.142	Dropped	0.375
	(0.641)	(1.364)	(1.223)	(826.6)	(0.711)	(0.821)	(1.232)		(1.065)
COOPGRPD	-0.479	-3.455	-4.436**	-28.70	-1.960**	-0.934	-4.998	Dropped	-4.836
	(0.748)	(2.157)	(2.065)	(1,738)	(0.965)	(1.071)	(569.3)		(3.413)
COOPSUPF	-0.00449	-2.083	1.439*	5.618	-0.0135	0.319	-5.375	Dropped	-0.855
	(0.670)	(1.504)	(0.770)	(752.0)	(0.668)	(0.943)	(0)		(1.446)
COOPSUPD	0.0283	-0.564	-0.911	-11.29	-1.231	-0.437	-9.690	Dropped	-5.698*
	(0.780)	(1.177)	(0.963)	(1,297)	(0.786)	(1.157)	(0)		(3.399)
COOPCUSF	-0.173	1.780**	-0.192	-4.589	1.226**	-1.192	-3.859	Dropped	0.796
	(0.609)	(0.907)	(0.731)	(752.0)	(0.623)	(0.986)	(681.1)		(1.372)
COOPCUSD	-0.373	1.575	2.437*	29.13	0.792	0.479	10.80	Dropped	5.713*
	(0.930)	(1.508)	(1.368)	(1,755)	(0.934)	(1.358)	(887.7)		(3.336)
COOPCOMF	-1.574	-16.72	1.569	8.416	-1.065	0.776	-11.07	Dropped	-2.727*
	(1.786)	(1,120)	(1.572)	(709.9)	(1.198)	(1.251)	(0)		(1.601)
COOPCONF	0.890	60.84	11.60	24.41	0.129	0.624	19.47	Dropped	-1.441
	(0.879)	(2,864)	(2,183)	(2,265)	(1.696)	(1.985)	(0)		(2.515)
COOPCOND	-0.868	-1.941	-1.242	-5.050	-0.338	0.567	0.0248	Dropped	0.722
	(1.154)	(1.790)	(1.385)	(495.7)	(0.831)	(1.128)	(0)		(1.446)

Table 6 (continued). Organization and Knowledge Flows

VARIABLES	(1) KNOWFOWN	(2) KNOWFGRP	(3) KNOWFSUP	(4) KNOWFCUS	(5) KNOWFCOM	(6) KNOWFCON	(7) KNOWFPRI	(8) KNOWFUNI	(9) KNOWFPUB
COOPCOND		-9.719	1.032	-34.80	-0.857	-1.513	4.392	Dropped	-0.611
		(487.0)	(1.273)	(2,235)	(0.982)	(1.521)	(0)		(2.365)
COOPPRIF	1.673	5.131**	18.14	14.31	1.318	-0.683	0.0207	Dropped	1.473
	(1.030)	(2.416)	(652.6)	(1,466)	(1.051)	(1.186)	(0)		(1.700)
COOPPRID	-5.239	-41.80	-18.45	-6.100	-6.535	-7.016	-25.82	Dropped	-12.14
	(194.8)	(2,162)	(2,208)	(2,506)	(130.3)	(244.1)	(0)		(228.1)
COOPUNIF	Dropped		-16.58	-12.66	Dropped			Dropped	5.218
			(565.5)	(1,916)					(3.237)
COOPUNID	2.081	18.26	1.709	41.13	4.164***	7.971	12.41	Dropped	
	(1.861)	(863.1)	(1.937)	(2,541)	(1.550)	(265.8)	(0)		
COOPPUBD	3.403	-41.25	10.32	-31.34	3.115	0.604	13.30	Dropped	9.241
	(194.9)	(2,200)	(460.9)	(2,116)	(130.3)	(360.9)	(0)		(228.1)
NONTAXINCT	-0.510**	-0.537	-0.364	-0.448	-0.697***	-0.285	0.629**	1.643*	0.825**
	(0.214)	(0.350)	(0.269)	(0.324)	(0.263)	(0.255)	(0.315)	(0.924)	(0.379)
TAXINCT	0.432	0.361	0.388	0.149	0.843	0.454	-5.433	Dropped	2.013**
	(0.499)	(0.722)	(0.516)	(0.823)	(0.527)	(0.529)	(0)		(0.902)
Constant	-0.686	-0.309	0.691	-0.856	1.054	-1.964	-3.748**	-2.521	-6.278**
	(0.953)	(1.353)	(1.034)	(1.325)	(0.984)	(1.226)	(1.885)	(4.010)	(2.666)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	382	339	391	336	363	353	295	142	278

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. *Note:* Variables are dropped due to collinearity.
Source: Author's computations based on data from MASTIC.

In the case of internal knowledge flows, such as those taking place within a firm (KNOWFOWN), the age of a firm plays an important role. The inverse-U relationship suggests that such knowledge flows are considered to be less important in the very youngest firms and the very oldest firms. As expected, there is a statistically significant relationship (with the correct positive sign) between knowledge flows from other companies within the same group (KNOWFGRP) if the firm is a subsidiary of a larger group of companies (FIRMSUB). Such knowledge flows are also associated with cooperative activities in innovation involving foreign customers (COOPCUSF) and foreign private research centres and labs (COOPPRIF).

Each type of external knowledge flow is influenced by a different set of factors. External knowledge flows that originate from suppliers (KNOWFSUP) are considered to be more important in firms that undertake organizational innovations aimed at improving the quality of the goods and services (ORGGOOD) and those that enhance employee welfare (ORGSATIS). Surprisingly, such knowledge flows are less important in firms that undertake organizational innovation that reduces the time to respond to customer or supplier needs (ORGTIME). These types of knowledge flows are also considered to be less important for firms that are engaged in cooperative activities with domestic firms outside their company group (COOPGRPD). In contrast, such knowledge flows are important for firms engaged in co-operative activities with foreign suppliers (COOPSUPF) and domestic customers (COOPCUSD).

The two globalization-related variables (FOREIGN and EXPORT) are significantly related to external knowledge flows originating from customers (KNOWFCUS). However, both have different signs. KNOWFCUS is more important in firms with foreign direct investment and less important in exporting firms. Organizational innovations aimed at improving the quality of goods and services (ORGGOOD) are positively and significantly related to this type of knowledge flow. Interestingly, this type of knowledge flow does not seem to be significantly related to the presence of cooperative activities.

Larger firms assign less importance to knowledge flows from competitors (KNOWFCOM). Cooperative activities in innovation with other domestic firms within the same group are associated with a lower emphasis on knowledge flows from competitors. Such knowledge flows receive greater emphasis in firms that have co-operative activities with their foreign customers and domestic universities. In contrast, firms with co-operative activities with domestic firms in the same group and those that consider non-tax incentives to be important will put less emphasis on knowledge flows from competitors.

Larger firms will tend to consider knowledge flows from consultants (KNOWFCON) as important. Firms with foreign direct investment will behave in an opposite manner. Firms undertaking organizational innovations to reduce costs would tend not to consider knowledge flows from consultants as important.

Very few of the firms in the dataset consider knowledge flows from universities and private research institutes to be important (see Table 1). As a result, the knowledge flows related to these sources do not exhibit significant relationships with organizational innovations, cooperative activities and general firm characteristics. However, knowledge flows from universities are positively affected by incentives from the government. Firms that are a subsidiary of another firm also consider such knowledge flows to be important.

To sum up, the different types of internal and external knowledge flows are likely to be driven by different organizational variables. Globalization-related variables such as FDI (positive) and exporting (negative) are generally found to be important for certain types of external knowledge flows especially those originating from customers. The impact of globalization on knowledge flows in terms of the relationship between external knowledge flows and cooperative activities with foreign parties are fairly limited. This is surprising given the significant number of exporters (63.6%) in the sample. It may imply that such firms are not sufficiently well integrated in the international production network.

5. Policy Implications

Technological upgrading of the manufacturing sector is a key challenge facing many policymakers today. How this is to be achieved and translated into a dynamic and competitive export sector remains a difficult question. The upgrading process obviously involves participating in the globalization process. At one end, firms need to source knowledge from the global technology pool which is located primarily in the more advanced and developed countries. At the other end, such firms need to know how to use such knowledge to enhance their competitiveness in their product markets.

The challenge is even greater for policymakers given the fact that such technological upgrading has to occur at the firm level. The traditional conception of innovation policy, for example, is that of solving a market failure problem where the firm is implicitly characterized as a black-box i.e. as a production function (hence, the focus on productivity as a measure of performance). This view is clearly incomplete as firms are heterogenous in many dimensions - in terms of the type of innovation activities that are carried out, the different types of knowledge flows that lead to the enhancement of technological capability, as well as the complexity of a firm's internal organization and its interactions with its environment. Findings from this paper provide some insights into these issues.

The factors driving the various types of innovation activities are likely to be different. As the sample data covers only innovating firms, the policy implications drawn are not aimed at transforming non-innovating firms into innovating firms. Instead, such policy implications are related to enhancing the innovativeness of already innovative firms.

Market concentration has a positive impact on in-house R&D – suggesting, perhaps, a conduct-based rather than structure-based competition policy is more conducive to enhancing firm-level in-house R&D. The existing government support and assistance schemes seem to have had limited links to in-house R&D. The same applies to innovation-related training. The relationship between machinery, equipment and software acquisition for innovation and governmental support and assistance is more encouraging. These findings suggest that government support and incentives for innovative activities are only relevant for physical capital deepening. This suggests that there is a need for a re-evaluation of existing policies with the view to encouraging more firms to undertake in-house R&D and training.

In terms of the role of globalization in technological upgrading, there is some evidence (albeit weak) that innovative firms with foreign direct investment do this via the acquisition of machinery, equipment and software that are innovation-related.

Similarly, exporting seems to be weakly related to innovation-related training. Thus, policymakers need encourage more in-house R&D activities amongst innovative firms that are exporting and involve foreign direct investment.

Of the different types of innovation activities, both acquisition of machinery, equipment and software and training are positively related to a number of different types of external knowledge flows. Thus, policy makers need to pay more attention to the role of these different types of external knowledge flows if they are interested in enhancing innovation activities. Evidence on this and on the significance of the co-operative activities related to them suggests that innovative firms in Malaysia have relatively weak knowledge-flow links with the global economy. Whether these factors limit technological upgrading by these firms is an important policy issue.

6. Concluding Remarks

Many developing countries today face the unenviable and difficult task of upgrading the technological base of their manufacturing sectors. For this to occur, technological capabilities have to be enhanced at the firm level. This requires a greater understanding of the process of innovation at the firm level. What this entails is an analysis of the organizational aspects of firms and their interactions with their external environment, which includes their customers, suppliers and competitors. Both are interrelated - the firm as an organization can influence its interactions with the outside world while at the same time being influenced by it too.

One way in which the firm-level capabilities (including technological ones) can be enhanced is through knowledge flows from within the firm (e.g. inhouse R&D) and from outside the firm. The research literature that analyzes some of these issues is fairly diverse in terms of its focus and methodology. In the past, empirical investigations of such issues have lagged behind theoretical discussions due to data constraints. More recently, such problems have been partially alleviated by the availability of innovation surveys, such as the EU's Community Innovation Surveys. This study uses a similar type of data set that covers innovating firms from the Malaysian manufacturing sector in order to empirically examine the relationship between knowledge flows, organization and innovation.

Two major issues are investigated in this study. The first issue pertains to the relationships between innovation and knowledge flows. The overall finding of this study on the issue is that this relationship is likely to depend on the type of innovation activities that are carried out.

For in-house R&D activity, knowledge flows from other firms within the same group of companies is negatively related to the decision to undertake such an activity. Interestingly, there could be less emphasis on in-house R&D investments if knowledge flows from customers are considered to be of high importance. Market concentration is likely to have a strong influence on in-house R&D.

In the case of acquisition of machinery, equipment and software, external knowledge flows are important especially those coming from suppliers, customers, competitors and consultants. However, globalization-related variables, such as foreign ownership (FOREIGN) and exporting (EXPORT) are relatively insignificant. Government-related support and incentives are important for this type of innovative activitiy.

In the case of training, if knowledge flows from other firms within the same group of companies are related to the propensity of and intensity in undertaking innovation-related training activities. Knowledge flows from competitors are also likely to be important. Furthermore, exporting and higher market concentration are associated with higher investment in innovation-related training. The statistically significance of the positively signed Herfindahl-Hirschman Index variable suggests that market concentration is associated with greater investment in training.

The relationship between knowledge flows and organization differs depending on the type of knowledge flow. Clearly, knowledge flows are related to organizational innovations. There is also evidence that the links between innovative firms in Malaysia and other firms abroad in terms of co-operative activities is relatively weak. This raises the issue of whether such firms are able to tap the global technological-pool effectively.

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CHAPTER 12

International R&D Collaborations in Asia: A First Look at Their Characteristics based on Patent Bibliographic Data

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This paper has analyzed whether and how international research collaboration in terms of co-inventions and co-ownership may affect invention performance in three Asian countries: Korea, China, and Taiwan. We focused on the patents which have been applied to the patent offices of a focused country (Korea / China / Taiwan) and also applied to the US Patent Office. Our major findings are the following. First, international collaboration is rare both in terms of co-invention (around 1% or less) and also co-application (less than 1%) in the three countries. Second, internationally co-owned patents tend to be more associated with international co-inventions in all three countries. In addition, more international co-inventions are realized under pure foreign ownership than international co-ownership in China and Taiwan. Third, international co-inventions are strongly associated with more science linkage, that is, more references to scientific literature in Korea and Taiwan, perhaps reflecting the strong absorptive power of these economies, but not in China. Fourth, international research collaborations are associated with higher patent quality, in terms of forward citation, in China and Taiwan, even after we control for the number of inventors and the literature cited.

Keywords: Research collaboration, International co-invention, Patent, Inventors, Research productivity

JEL Classification: O31, O32, O34

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1. Introduction

International research collaborations have become important, as more countries in the world, including East Asian countries such as Korea, China, and Taiwan have significantly strengthened their research capability and as firms globalize their research operations. They may also have become more important as R&D tasks have become more complex, so that they now often require a combination of diverse knowledge input and inventive capability (Jones, 2009).

This research analyzes how international research collaborations have become important and what their consequences are in East Asian countries, based on patent data. An important question is whether and how international research collaborations affect research performance. The combination of inventors from different countries would allow a firm to undertake research which might not have been possible if only the resources of a single-nation inventor could be used and would enlarge the pool of technological or scientific knowledge available for research. It might also facilitate better consideration of local market needs in R&D. Co-ownership by firms with different nationalities might be important for creating incentives for such firms to contribute various resources to the collaborative R&D, including their inventors and their tacit knowledge, even though co-ownership might create a free rider problem or an adverse selection problem.

There is a great deal of literature on research collaboration, focusing on the incidence of co-ownership (for an example, Cassiman and Reinhilde (2002), Hagedoorn, Link and Vonortas (2002) and Hagedoorn (2002)) and on the effects of such research cooperation on the economic performance of a firm (see, for example, Cockburn and Henderson (1998), Sakakibara (1997), Branstetter and Sakakibara (1998), Lerner and Merges (1998) and see a survey by Siegel (2002)). However, most studies are at firm level (One exception is Mowery, Oxley and Silverman (1996)). This makes it very difficult to assess how research collaboration actually affects the process of knowledge production, such as the scope of the knowledge used for the research.

Our research makes an attempt to grasp the incidence of international research collaborations and their effects in Asia, focusing on the effects on the scope of the use of existing knowledge as well as on the productivity of using such knowledge. Nagaoka and Tsukada (2011) examined international collaborations, using the triadic patent families from Japan, US, and three major European countries (Germany, France, and Great Britain). The major findings are as follows. First, international co-inventions have become increasingly important in recent years, especially in the high tech sectors with strong science linkage. Second, internationally co-applied patents are associated with significantly larger inventor size, except for Japan, indicating that international inter-firm alliances facilitate firms to undertake larger and more complex R&D. Third, international co-inventions are strongly associated with more science linkage per patent, although not with more backward patent citations (large number and lee time lag), indicating that going beyond a border in order to organize an international inventor team is especially important for science-driven inventions.

This research project makes another attempt to assess the effects of international research collaborations on invention performance at patent-family level, focusing on internationally co-invented and/or co-owned patents of the major Asian countries (Korea, Taiwan, Mainland China etc). The driving force for international collaborations may be different in these countries, since there is a fairly large international cost difference between these countries and the triadic countries. In addition, they may have different market requirements. International investment rather than international alliance may play an even more important role in the engagement of international research collaborations in these countries.

The channels of the effects of international research collaborations are similar to those for the major OECD countries: International collaborations might expand the size of a research team, and therefore the human capital available for research. They might also expand the scope of the knowledge used for invention by enhancing the absorptive capability of the research team and increasing the speed of research. Finally, they might also have a synergy or productivity enhancement effect, that is, they might enhance the productive combination of the knowledge used. The patent level study allows us to examine the effects of research collaborations through these various channels, in order to help us understand how international research collaboration may or may not work.

The paper is organized as follows. Section 2 provides the construction of data set and the description of the structure of invention and ownership of patents. Section 3 provides analysis of the effect of international collaboration on the size of research teams. Section 4 provides analysis of knowledge exploitation. In Section 5, performance of international collaboration is examined. And Section 6 concludes.

2. Structure of International Co-Invention and Co-Ownership

2.1. Data

For this objective, we have developed the data set, using the following patent database: EPO Worldwide Patent Statistical Database[2] (PATSTAT September 2009 version) released by the European Patent Office. Patent data provides important information: the addresses of the inventors and the owners (or assignees). If inventors of more than two different national addresses work together (international co-invention), it implies that the inventive human resources of different nations are combined. If firms of more than two different national addresses share the ownership of the patent (international co-ownership), it would typically imply that these firms collaborated on the R&D in term of finance, human resources or in another manner. Although co-invention or co-ownership does not cover all research collaborations[3], they would cover an important part of the research collaborations involving the combination of significant resources. Research collaboration defined in these terms has become important in recent years (Nagaoka, Motohashi, and Goto (2010), OECD (2009)).

The unit of analysis in this study is patent family. A new invention often has applications for patent protections in several countries[4]. The set of patent applications share one or more priority filings and is known as a patent family. There are several definitions of a patent family[5]. The difference mainly depends on how far the priority

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[2] PATSTAT database are compiled by the trilateral patent offices (European Patent Office, United States patent and Trademark Office, and Japanese Patent Office) and released from the European patent Office. The database contains patent bibliographic data of about 170 countries/regional patent offices.

[3] It is important to note that co-ownership significantly under-represents actual collaborations especially in the US (see Walsh and Nagaoka, 2009). See Hagedoorn (2003) for motivations for co-ownership or joint patenting. Since we use both international co-invention and international co-ownership as measures of international collaborations, our coverage of research collaborations is wider than that based only on international co-ownership.

[4] In addition, multiple patent applications derived from a single earlier patent application are filed to one patent office by using a priority claim based on domestic applications. For example, there is a system of continuing application (continuation application, continuation-in-part application, and divisional application) in the US, divisional application and priority claim based on Japanese application in Japan. There are similar application procedures in the other countries. An invention is often protected by multiple patents, derived by using these application procedures, even in one country.

[5] Martinez (2010) summarized many kinds of definition of patent family.

links among family members are stretched (OECD, 2009). We use the INPADOC patent family. The definition of INPADOC patent family is the following; "all the documents which are directly or indirectly linked via a priority document belong to the same patent family" (OECD, 2009). A patent family of this definition contains all patent application documents from D1 to D5 and priority documents P1, P2, P3 as a family shown in Table A1 of the Appendix.

The PATSTAT database covers the records of patents applied for at many Asian patent offices. It provides information on the patents, such as application number, application date, grant number, grant date, the priority relations, code identifying INPADOC family, although a lot of information is missing in some countries, such as the country code of inventors/applicants. By using INPADOC family as the unit of analysis, however, we can fill in such missing information by using that of corresponding foreign patents in the same family.

We focus on the patent families which have both at least one inventor and one assignee of the patent in one of the East Asian countries. We also extract the detailed citation information from the PATSTAT database, including the citation of non-patent literature (mainly scientific literature), available for US patents in each family (Duplications in forward and backward patent citation have to be removed). Thus, we have to restrict our sample to the patent families which include both the applications to the Patent Office of an Asian country and those to the US Patent & Trademark Office (See the following section for the share of such families). We use the technology classification and the earliest application year of the patents of the family. These patent data provide information both on the structure of inventors and owners, including whether a particular invention involves international co-inventions or whether it involves international co-ownership. In addition, the extensive citation information available for US patents allows us to assess the quality of the patent as well as the scope of knowledge relevant to the invention process. In particular, the number of forward citations, that is, the frequency by which a particular patent is cited, will tell us the quality of the patent, once we control for the technology and the length during which the citations can be made. The backward citation to the patent and non-patent literature indicates the level of exploitation of prior knowledge in the invention process, although it is an imperfect measure, given that the bulk of citations (especially backward citation to patent literature) are made by an examiner (not by an inventor himself).

2.2. Patent Applications to the Asian Countries

Table 1 shows the total number of patent applications to each Patent Office of all Asian countries, recorded in the PATSTAT database. The four East Asian countries (Japan, China, Korea, Taiwan) have received the largest number of patent applications in the region. The South East Asian countries (Singapore, the Philippines, Indonesia, Malaysia, Thailand and Vietnam) are second in terms of the number of patent applications, if excluding Israel, India, and Turkey. Table 2 shows the time trend of patent applications in 10 countries in East Asia and South East Asia. While most countries experienced a growth in patent applications, there are some exceptions. Malaysia received many patent applications in the 1950s, while the number of patent applications declined in the second period of the 1980s. This is because Malaysia used the *confirmation patent system*, which confirmed the patents granted in the UK, although it was abolished in 1986 (see Table 3 for a summary of a brief history of the patent system). Similarly, the Philippines experienced a decline in patent applications as recorded in the PATSTAT since the middle part of the 1980s.

Table 1. Total Number of Applications to Asian Countries Included in The EPO PATSTAT Database

Area	Country	appln_auth code	Num. of applications	Focus in the paper
ASEAN	Brunei Darussalam	BN	0	
ASEAN	Cambodia	KH	0	
ASEAN	Indonesia	ID	12,408	*
ASEAN	Lao People's Democratic Republic	LA	0	
ASEAN	Malaysia	MY	10,774	*
ASEAN	Myanmar	MM	0	
ASEAN	Philippines	PH	20,098	*
ASEAN	Singapore	SG	47,518	*
ASEAN	Thailand	TH	189	*
ASEAN	Vietnam	VN	148	*
East Asia	China (HongKong)	HK	68,829	
East Asia	China (Macao)	MO	1	
East Asia	China (Mainland)	CN	1,493,780	*
East Asia	Japan	JP	11,362,260	(*)
East Asia	Korea	KR	1,374,200	*
East Asia	Mongolia	MN	233	
East Asia	North Korea	KP	29	
East Asia	Taiwan	TW	191,114	*
Central Asia	Kazakhstan	KZ	346	
Central Asia	Kyrgyzstan	KG	12	
Central Asia	Tajikistan	TJ	353	
Central Asia	Turkmenistan	TM	1	
Central Asia	Uzbekistan	UZ	38	
South Asia	Afganistan	AF	1	
South Asia	Bangladesh	BD	5	
South Asia	Bhutan	BT	0	
South Asia	India	IN	61,813	
South Asia	Iran	IR	74	
South Asia	Maldives	MV	0	
South Asia	Nepal	NP	0	
South Asia	Pakistan	PK	33	
South Asia	Sri Lanka	LK	122	
West Asia	Armenia	AM	82	
West Asia	Azerbaijan	AZ	62	
West Asia	Bahrain	BH	1	
West Asia	Cyprus	CY	2,591	
West Asia	Georgia	GE	63	
West Asia	Iraq	IQ	14	
West Asia	Israel	IL	146,540	
West Asia	Jordan	JO	9	

Table 1 (continued). Total Number of Applications to Asian Countries Included in The EPO PATSTAT Database

Area	Country	appln_auth code	Num. of applications	Focus in the paper
West Asia	Kuwait	KW	0	
West Asia	Lebanon	LB	108	
West Asia	Oman	OM	1	
West Asia	Qatar	QA	0	
West Asia	Saudi Arabia	SA	9	
West Asia	Syrian Arab Republic	SY	28	
West Asia	Turkey	TR	32,137	
West Asia	United Arab Emirates	AE	36	
West Asia	Yemen	YE	1	

Note: Extracted from table: tls201_appln. Only appln_kind = 'A' or 'T'.
Source: Authors constructed from PATSTAT database.

Table 2. Number of Applications by Application Year

Application Year	Japan	Korea	China	Taiwan	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
before 1949	1,498	1	1	0	4	3	0	1	0	0
1950	62	0	0	0	0	0	0	0	0	0
1951	79	0	0	0	0	0	1	1	0	0
1952	96	0	0	0	0	0	0	0	0	0
1953	131	0	0	0	0	154	0	0	0	0
1954	145	0	0	0	0	58	0	0	0	1
1955	261	0	0	0	0	51	0	3	0	0
1956	325	0	0	0	0	47	0	0	0	0
1957	457	0	0	0	0	44	0	0	0	1
1958	772	0	0	0	0	48	1	0	0	0
1959	918	0	0	0	0	48	1	0	0	0
1960	1,180	0	0	0	0	74	1	0	0	0
1961	1,336	0	0	0	0	126	1	0	0	0
1962	2,065	0	0	0	0	106	2	0	0	0
1963	2,933	0	0	0	0	111	0	0	0	0
1964	3,527	0	0	0	0	140	2	0	0	0
1965	4,898	1	0	0	0	186	2	0	0	0
1966	7,090	4	0	0	0	144	10	0	0	0
1967	10,510	1	0	0	0	172	7	0	0	0
1968	21,645	2	0	0	0	119	38	0	1	0
1969	41,769	22	0	0	0	414	73	0	0	0
1970	68,247	66	0	1	0	169	143	1	0	1
1971	70,565	112	0	1	0	223	307	0	0	2
1972	120,279	143	1	0	0	129	486	2	0	0

Table 2 (continued). Number of Applications by Application Year

Application Year	Japan	Korea	China	Taiwan	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
1973	141,876	266	0	2	0	496	716	1	1	0
1974	145,623	1,591	0	2	0	332	823	0	0	0
1975	152,819	889	0	7	1	301	871	1	0	0
1976	158,055	1,090	0	2	0	282	976	2	0	0
1977	158,149	1,417	0	3	0	328	918	1	0	0
1978	163,322	2,244	0	2	0	484	943	1	0	0
1979	172,845	2,803	0	5	1	244	1,020	1	0	0
1980	188,475	3,186	0	6	0	282	1,070	0	0	1
1981	215,281	3,328	0	7	0	378	1,086	3	0	0
1982	233,756	4,752	0	1	8	282	1,109	160	0	2
1983	252,428	6,030	0	4	4	253	1,182	592	1	5
1984	281,634	8,235	5	5	12	400	1,112	848	0	10
1985	300,383	7,396	8,113	6	7	1,125	1,056	675	0	9
1986	316,915	8,362	7,454	15	7	740	1,037	317	0	8
1987	337,285	10,778	7,797	5	9	950	1,040	964	1	3
1988	337,623	12,449	8,917	13	9	166	981	625	1	6
1989	348,518	13,900	9,034	10	15	7	867	831	1	11
1990	367,099	15,334	9,520	18	0	11	541	1,280	0	7
1991	369,831	17,336	10,400	10	58	13	215	1,503	1	0
1992	371,458	19,138	13,349	39	113	22	266	2,562	0	5
1993	366,850	20,757	18,781	175	38	21	438	2,866	3	22
1994	354,975	23,529	23,256	530	32	23	446	4,173	0	17
1995	371,453	34,256	26,902	1,427	43	27	171	2,576	1	5
1996	380,946	39,372	32,252	3,289	477	56	20	2,413	2	0
1997	393,110	39,257	36,861	6,563	4,325	28	10	2,447	7	0
1998	403,434	46,371	40,687	14,698	3,511	30	3	2,289	6	1
1999	405,703	64,580	44,476	18,557	2,737	56	9	2,313	19	1
2000	432,458	79,829	57,623	21,446	906	75	14	2,448	8	0
2001	435,456	83,554	68,738	25,574	50	46	13	2,391	17	2
2002	418,338	85,875	89,880	23,671	4	102	6	1,886	12	6
2003	412,674	96,121	119,311	22,082	5	94	14	1,763	32	4
2004	420,050	118,439	142,547	21,151	5	99	12	2,545	21	1
2005	420,431	144,249	176,492	17,615	8	125	17	2,571	16	7
2006	395,783	149,016	202,872	7,637	6	109	12	1,901	14	2
2007	326,709	145,075	197,912	5,886	13	210	9	1,662	21	8

Table 2 (continued). Number of Applications by Application Year

Application Year	Japan	Korea	China	Taiwan	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
2008	47,065	56,230	131,271	628	0	11	0	899	3	0
2009	2,498	6,812	9,323	8	0	0	0	0	0	0
9999	164	2	5	13	0	0	0	0	0	0
Total	11,360,762	1,374,199	1,493,779	191,114	12,404	10,771	20,098	47,517	189	148

Source: Authors constructed from PATSTAT database.

Table 3. Intellectual Property Right in Asian Countries

	Establishment of patent law
Japan	The first act was published in 1871, but not enforced, and abolished the following year. The next action was taken in 1885. This is the basis of Japanese patent law. The present patent law is based on legislation from 1959, and has been revised several times.
Korea	Enforced in 1946.
China	Published in 1983, enforced in 1985.
Taiwan	Published in 1944, enforced in 1949.
Indonesia	(N/A)
Malaysia	Published in 1983, enforced in 1986.Under this law, the confirmation patents system, which confirms patents granted in UK, is abolished.
Philippines	Originally 1947. Reformed in 1968, 1998.
Singapore	(N/A)
Thailand	Originally 1979. Reformed in 1992, 1999.
Vietnam	In 1981 "Regulations on Innovations and Inventions". In 1989 "Ordinance on Protections of Industrial Property Rights". In 2006 "Law on Intellectual Property" enforced.

Source: Authors made based on information on the website of Japan Patent Office.

Table 4-(1) shows that the total number of families including applications to the Korean Patent Office, and the ratio of families with applications both to the Korean Patent Office and to the US Patent Office and other patent offices[6] relative to the total number of families including application to Korea. About 27% of families including a Korean patent are applied also to the US in 2005-2007. 20% of families are applied both to Korea and Japan, 22% both to Korea and China. In 1985-1989, larger shares of families were applied to both Korea and US/Japan (more than 60%). It is likely that the major part of these families were applied by US or Japanese firms, since US or Japanese firms considering patent applications to Korea are very likely to apply for patents in their home countries. Recently, the share of these two counties in Korean patents decreased. This might be due to two reasons; firms in many other countries come to apply to the Korean Patent Office, and, perhaps more importantly, Korean firms have increased the number of patent applications made both to the Korean Patent Office as well as to other foreign patent offices. Table 4-(2) provides similar data for China. The number of families including applications to the Chinese Patent Office has increased very significantly since 2000. During the period from 2005 to 2007, 30% of the families are applied to China and US, 25% to China and Japan, 22% to China and the European Patent Office. There are a rather large percentage of families applied to Australia. As shown in Table 4-(3), the share of families applied both to Taiwan and to the US is very large (68%). The families including an application to Singapore are applied not only to the US but also to many other countries (Table 4-(4)).

[6] US: United States, JP: Japan, EP: European Patent Office, KR: Korea, CN: China, TW: Taiwan, SG: Singapore, PH: Philippines, ID: Indonesia, MY: Malaysia, TH: Thailand, VN: Vietnam, AU: Australia.

Table 4. International Patent Applications

(1) Incidence of Families Which Applied to Both Korea and Each Patent Office

Earliest application year in family	Number of families including application to Korean Patent Office	US	JP	EP	CN	TW	SG	PH	ID	MY	TH	VN	AU
1985-1989	56,342	64.4%	69.1%	52.2%	13.8%	0.1%	3.6%	2.9%	0.1%	0.0%	0.0%	0.0%	22.3%
1990-1994	90,134	40.9%	44.0%	28.6%	12.1%	0.6%	2.5%	0.5%	0.1%	0.0%	0.0%	0.0%	9.8%
1995-1999	220,701	22.0%	21.8%	11.6%	10.8%	5.6%	1.2%	0.0%	0.8%	0.0%	0.0%	0.0%	2.9%
2000-2004	500,356	27.8%	24.7%	17.0%	21.5%	5.2%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	6.1%
2005-2007	386,874	26.5%	19.9%	16.7%	21.6%	0.4%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%

(2) Incidence of Families Which Applied to Both China and Each Patent Office

Earliest application year in family	Number of families including application to China Patent Office	US	JP	EP	KR	TW	SG	PH	ID	MY	TH	VN	AU
1985-1989	41,960	40.7%	42.5%	38.7%	18.5%	0.1%	2.5%	3.5%	0.1%	0.0%	0.0%	0.0%	21.2%
1990-1994	83,749	41.6%	42.4%	38.8%	13.1%	1.4%	4.3%	1.0%	0.2%	0.0%	0.0%	0.0%	17.4%
1995-1999	179,537	54.1%	55.8%	50.5%	13.3%	12.9%	2.9%	0.0%	4.4%	0.0%	0.0%	0.0%	17.0%
2000-2004	489,786	52.5%	47.2%	40.5%	21.9%	8.1%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	15.2%
2005-2007	518,148	30.3%	24.7%	22.0%	16.1%	0.2%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%

(3) Incidence of Families Which Applied to Both Taiwan and Each Patent Office

Earliest application year in family	Number of families including application to Taiwan Patent Office	US	JP	EP	KR	CN	SG	PH	ID	MY	TH	VN	AU
1985-1989	103	94.2%	0.1%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
1990-1994	2,081	90.1%	2.2%	2.0%	0.7%	1.4%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	1.2%
1995-1999	55,846	74.6%	72.6%	52.5%	22.3%	41.3%	5.5%	0.0%	5.7%	0.1%	0.0%	0.0%	14.7%
2000-2004	101,296	66.2%	10.6%	6.2%	5.3%	8.1%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%
2005-2007	25,741	67.9%	0.6%	0.1%	0.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

(4) Incidence of Families Which Applied to Both Singapore and Each Patent Office

Earliest application year in family	Number of families including application to Singapore Patent Office	US	JP	EP	KR	CN	TW	PH	ID	MY	TH	VN	AU
1985-1989	4,928	88.9%	81.5%	74.7%	41.3%	21.4%	0.4%	8.7%	0.3%	0.0%	0.0%	0.0%	43.0%
1990-1994	8,311	89.8%	86.7%	86.0%	27.3%	43.1%	3.5%	3.4%	0.5%	0.1%	0.0%	0.1%	38.3%
1995-1999	10,641	80.8%	77.7%	60.6%	24.2%	49.4%	28.7%	0.1%	8.1%	0.3%	0.1%	0.0%	18.4%
2000-2004	10,040	82.6%	66.5%	53.3%	40.4%	57.7%	25.3%	0.0%	0.1%	0.3%	0.0%	0.0%	19.6%
2005-2007	4,743	70.0%	56.2%	50.1%	41.1%	55.7%	1.9%	0.1%	0.1%	0.5%	0.0%	0.0%	17.3%

Source: Authors constructed from PATSTAT database.

2.3. Structure of Invention and Ownership

We focus on the patents which have both at least one inventor and one assignee of the patent in one of the three countries (Korea, China and Taiwan). We define international collaborative research to involve either foreign co-inventor, foreign co-owner or both. In this paper, we will analyze the effects of international collaborative research compared with purely domestic research. As shown in Table 5, we can classify inventor (ownership) structure by using patent bibliographic data into four types: domestic single-inventor invention, domestic co-invention, international co-invention, and invention by only inventor(s) residing in a foreign country. Ownership structure can be classified similarly. These bibliometric indicators are also used in Hagedoorn (2003), Hicks and Narin (2001). We do not focus on the patents invented by only foreigners and/or owned by only foreign firms. For example, the Korean sample consists of inventions with at least one Korean inventor and one Korean applicant (A+B+C+D in Table 5), which is applied both to the Korean Patent Office, and the US Patent and Trademark Office. The reason why we focus on the inventions with patent applications to the USPTO is due to the availability of extensive patent bibliographic information, such as citation information, country code of inventors/applicants. However, it should be noted that we have ignored a significant part of inventions for this selection. In addition, our analysis in this paper does not cover an important part of international research collaborations such as research outsourcing.

Table 5. Focus of the Sample

		Inventor structure			
		Domestic single inventor	Domestic co-invention	International co-invention	Invented by foreigner(s)
Ownership structure	Domestic single ownership	A: Purely domestic		B	-
	Domestic co-ownership				
	International co-ownership	C		D	-
	Owned by foreign firm(s)	-		-	-

Source: Authors.

Table 6 provides the percentage of the focus of this analysis; 33% of all the Korean and US patent offices' patents, only 2.7% of Chinese and US patent offices' patents, 31% of Taiwan and US patent offices' patents, for example in the year 2000-2006 in terms of the application year. Most of the rest of the patents were applications by foreign firms. Foreign firms owned 67% of these patents in Korea, 98% in China and 70% in Taiwan.

Table 6. The Incidence of Applications by Inventor and Ownership Structures (Application Year: 2000-2006)

Korea (Application year: 2000-2006)

	Single inventor	Domestic co-invention	International co-invention	Invention by foreigner(s)	Total
Single ownership	12.4%	18.0%	0.9%	0.5%	31.8%
Domestic co-ownership	0.2%	1.0%	0.0%	0.0%	1.2%
International co-ownership	0.0%	0.0%	0.1%	0.0%	0.2%
Owned by foreigner(s)	0.1%	0.1%	0.1%	66.6%	66.9%
Total	12.7%	19.1%	1.1%	67.2%	100.0%

Table 6. The Incidence of Applications by Inventor and Ownership Structures (Application Year: 2000-2006)

China (Application year: 2000-2006)

	Single inventor	Domestic co-invention	International co-invention	Invention by foreigner(s)	Total
Single ownership	1.4%	0.6%	0.0%	0.0%	2.1%
Domestic co-ownership	0.0%	0.1%	0.0%	0.0%	0.1%
International co-ownership	0.0%	0.0%	0.0%	0.0%	0.1%
Owned by foreigner(s)	0.1%	0.1%	0.2%	97.3%	97.7%
Total	1.5%	0.9%	0.3%	97.4%	100.0%

Taiwan (Application year: 2000-2006)

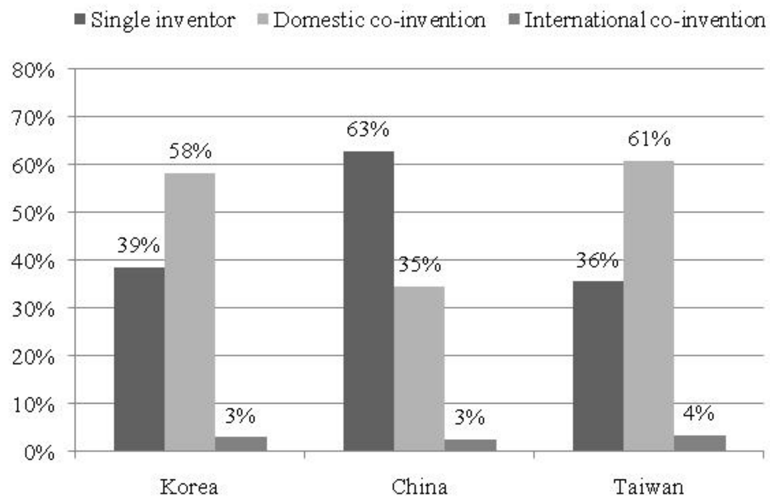
	Single inventor	Domestic co-invention	International co-invention	Invention by foreigner(s)	Total
Single ownership	10.4%	17.4%	0.9%	1.0%	29.7%
Domestic co-ownership	0.1%	0.5%	0.0%	0.0%	0.6%
International co-ownership	0.0%	0.1%	0.1%	0.2%	0.4%
Owned by foreigner(s)	0.2%	0.2%	0.2%	68.9%	69.3%
Total	10.6%	18.1%	1.2%	70.1%	100.0%

Source: Authors constructed from PATSTAT database.

Figure 1 shows the incidence of domestic or international co-inventions of three East Asian countries. Roughly speaking, one third of the patents in Korea and Taiwan involve single-inventors, while the rest are co-inventions involving more than two inventors in the years 2000-2006. In China, however, 63% of patents are invented by a single inventor. As to the percentage of international co-inventions, it is only 3% of patents in these three countries. These low ratios of international co-invention are similar to the invention structure of Japan (Figure 2). Moreover, more international co-inventions are realized under pure foreign ownership than international co-ownership in

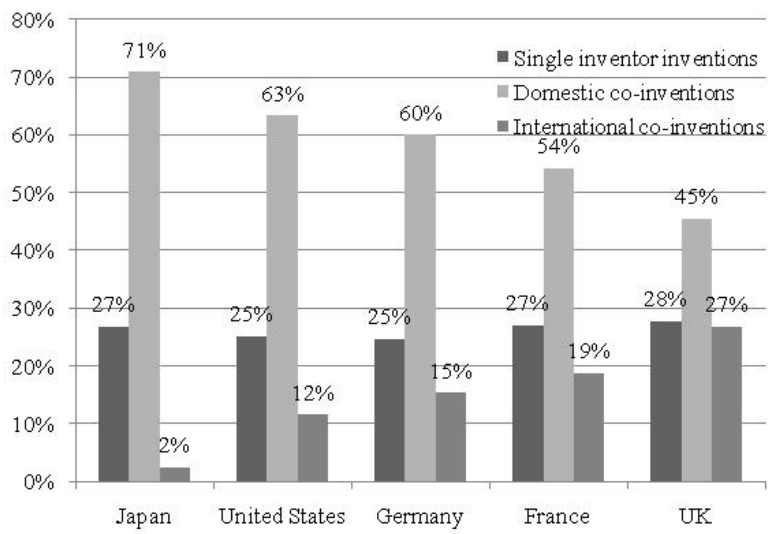
China and Taiwan. Thus, it can be said that international investment plays a more important role than international alliance when it comes to engaging in international co-invention collaborations in these countries.

Figure 1. Incidences of Co-Inventions of Three East Asian Countries (Application Year: 2000-2006)



Source: Authors constructed from PATSTAT database.

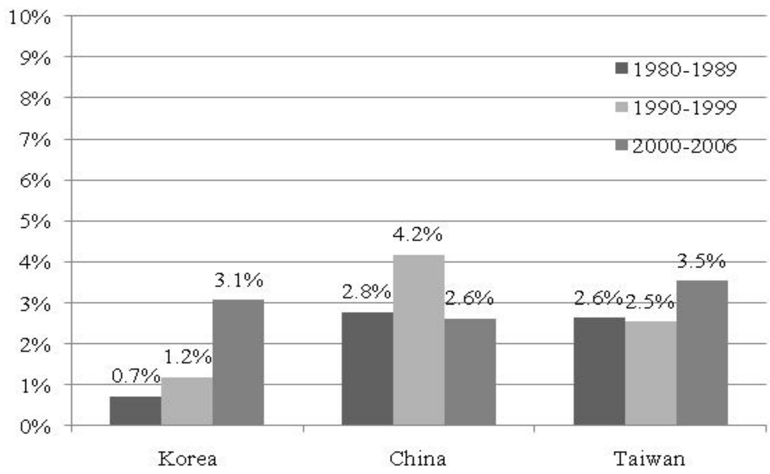
Figure 2. Incidence of Co-Inventions of The Five Industrialized Countries (Application Year: 2000-2006)



Source: Nagaoka and Tsukada (2011).

Figure 3 show the time trend of international co-inventions. In Korea, there is a significant increase from the 1980s to the 2000s; the incidence in the 2000s is 4.4 times greater than the incidence of the 1980s. But, it does not show any significant change in China and Taiwan.

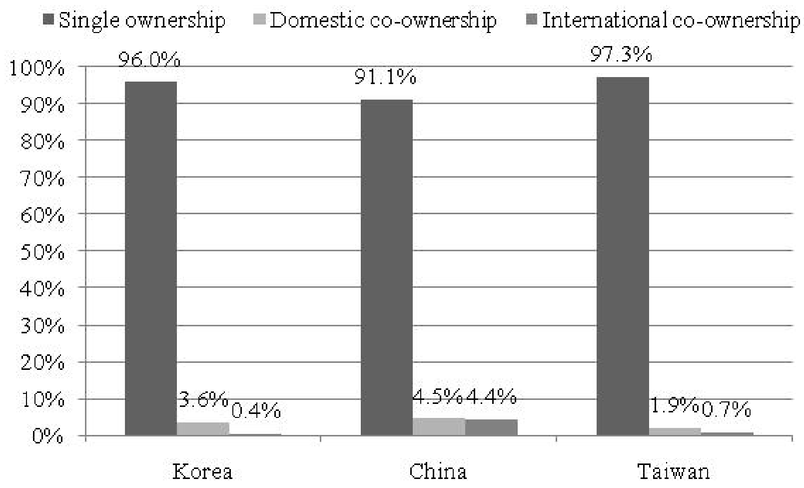
Figure 3. The Evolution of International Co-Inventions



Source: Authors constructed from PATSTAT database.

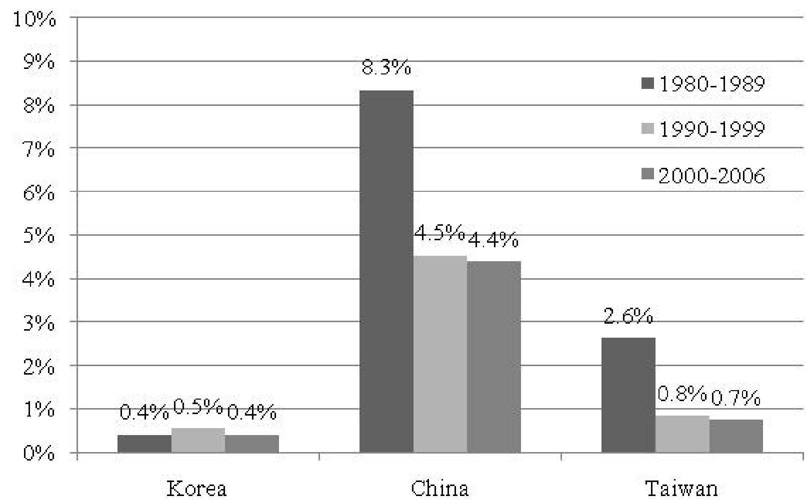
In these three countries, the share of international co-ownership is also small, as shown in Figure 4 and Figure 5. It is 0.4% for Korea, 4.4% for China and 0.7% for Taiwan for the period from 2000 to 2006.

Figure 4. Incidences of Co-Ownerships of Three East Asian Countries (Application Year: 2000-2006)



Source: Authors constructed from PATSTAT database.

Figure 5. The Trend of International Co-Ownerships



Source: Authors constructed from PATSTAT database.

3. International Co-Ownership and Size of Inventor Team

3.1. Framework[7]

In this section, we examine whether international collaboration in terms of co-ownership between national and foreign firms is associated with a larger number of inventors than purely domestic patents. We focus on the effect of international co-ownership on facilitating the expansion of the inventor team. We can examine this issue by looking at how international co-ownership is associated with a significantly larger number of inventors than purely domestic patents. The domestic inventive human resources would become more limiting as the research task becomes larger and more complex. That is, the marginal cost of hiring additional inventors increases more rapidly when the firm has to hire inventors only in the domestic labor market than when no such constraint exists[8]. Consequently, we would expect that especially as the size of the research task increases, it would become more efficient to hire foreign inventors and the incidence of international co-inventions would rise.

Since engaging a foreign firm as the co-owner of the invention would enable a domestic firm to gain better access to foreign researchers, we would expect a positive correlation between the size of the research team and the incidence of international co-ownership. Figure 6 shows the frequency distribution of the size of the inventor team by ownership type in the three countries (application year: 2000-2006). The horizontal axis is team size, and the vertical axis is the incidence of each size of inventor team by

[7] See Nagaoka and Tsukada (2011) for more details.

[8] Guellec and de la Potterie (2001) analyzed by using cross-county sample. They concluded that the degree of international collaboration is higher for small countries and for countries with lower R&D intensity. It implies that a firm in a small country needs to look for a collaborative partner in foreign countries.

ownership type. Inventions owned by a single firm are associated with smaller size of inventor team. A collaborative project of multiple firms tends more often to involve more than two inventors. In Korea, when the number of inventors is more than three, the possibility of collaborative projects with foreign firms tends to be higher than that of collaboration with domestic firms. We can observe a similar pattern in China too. Figure 7 shows that as the number of owners of the invention increases, the average size of the research team also increases. The patterns of the three countries are very similar to each other.

Figure 6. Incidence of Size of Inventor Team by Ownership Types (Application Year: 2000-2006)

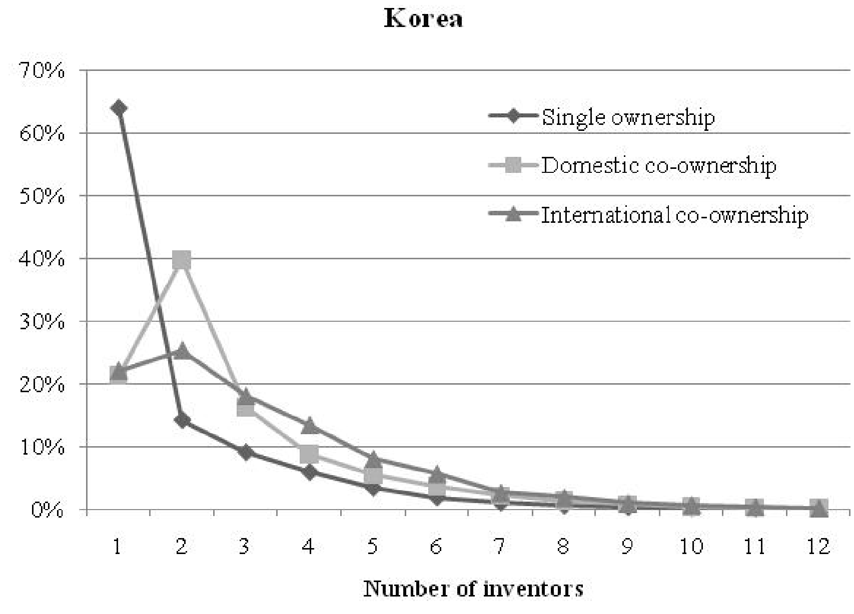
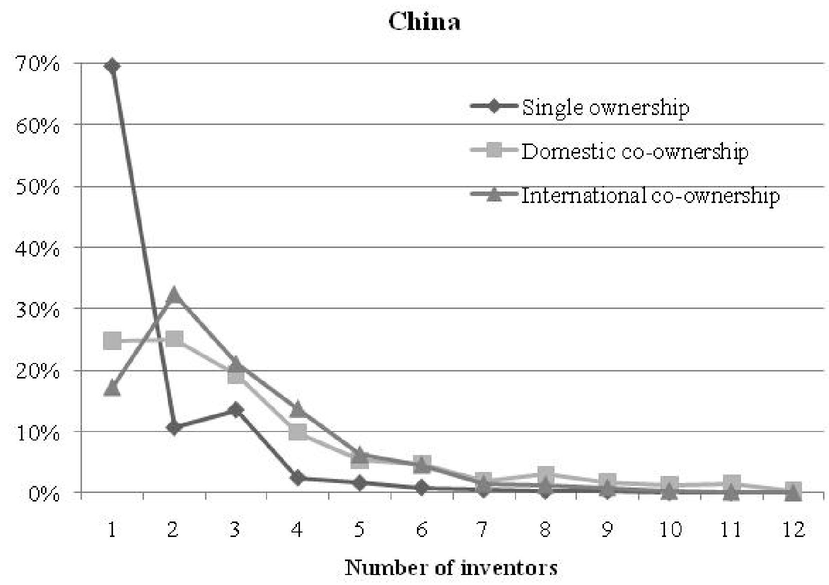
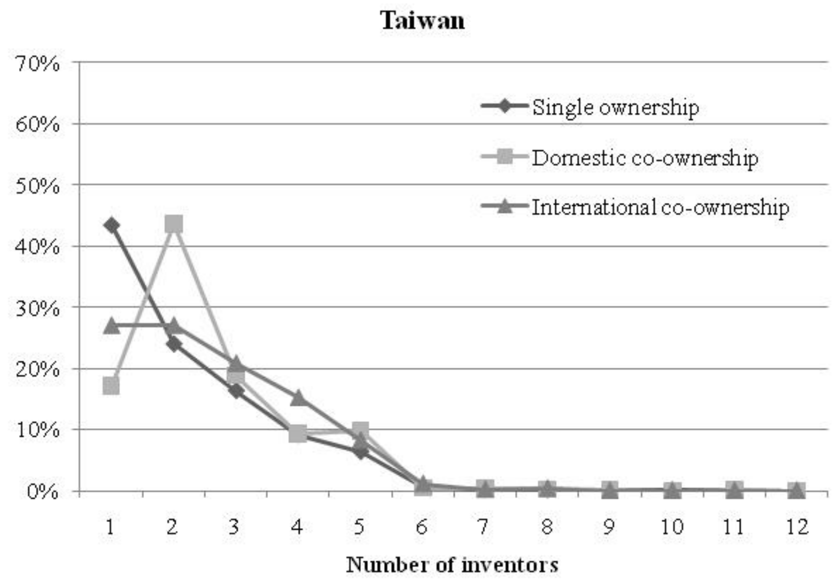


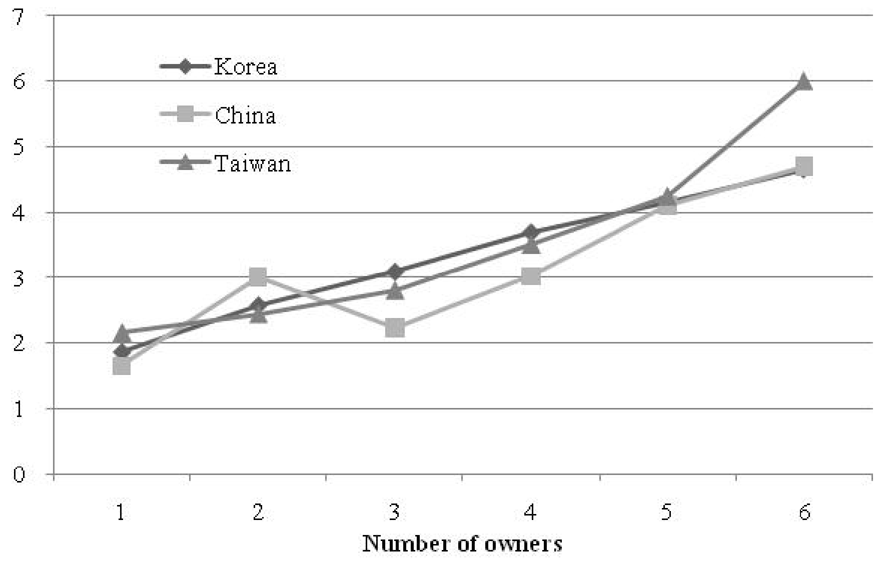
Figure 6 (continued). Incidence of Size of Inventor Team by Ownership Types (Application Year: 2000-2006)





Source: Authors constructed from PATSTAT database.

Figure 7. Number of Owners and Average Size of Inventor Team (Application Year: 2000-2006)



Source: Authors constructed from PATSTAT database.

3.2. Estimation

Figure 7 shows the results of the Probit estimation using the sample which consists of the patents with more than two inventors, according to the following model:

$$\begin{aligned}&\text{Dummy of international coinvention}\\&\quad = f\left(\text{Num. of inventors, Dummy of domestic coownership, Dummy of international coownership}\right), \quad (1)\\&\text{Dummy of international coinvention} = \begin{cases} 1 & \text{if international coinvention} \\ 0 & \text{if domestic coinvention}\end{cases}\end{aligned}$$

We also use the cross terms between the dummy variables of application year and those of the technology area to control for the variations of technological or demand characteristics over time.

The estimated coefficients of number of inventors are significantly positive in Korea and Taiwan. Thus, in a situation where a firm has to find a collaboration partner, as the project size proxied by number of inventors becomes larger, it is more likely that the project involves foreign inventors. The coefficient of international co-ownership indicates the effects of international co-ownership relative to single ownership. It is significantly positive in all three countries. It shows that a patent internationally co-owned is positively associated with a research team consisting of both domestic and foreign inventors, while a patent co-owned domestically is not. These results imply that when a project is large and might be technically complex, the firm tends to seek foreign inventors as the research partners, and collaboration with a foreign firm facilitates the hiring of foreign inventors.

Table 7. Results of Probit Estimation (Sample: Number of inventors >= 2)

	Dummy: 1 if international co-invention, 0 if domestic co-invention					
	Korea		China		Taiwan	
	Probit	Marginal Effect	Probit	Marginal Effect	Probit	Marginal Effect
ln(Num. of Inventors)	0.513***	0.020***	0.027	0.005	0.339***	0.026***
	(0.053)	(0.002)	(0.151)	(0.027)	(0.072)	(0.006)
Dummy for International co-ownership	3.560***	0.901***	1.533***	0.387***	2.103***	0.572***
	(0.202)	(0.031)	(0.165)	(0.048)	(0.142)	(0.054)
Dummy for Domestic co-ownership	-0.146	-0.005	-0.250	-0.040	-0.777**	-0.031***
	(0.140)	(0.004)	(0.270)	(0.038)	(0.370)	(0.006)
Constant	-2.311***		-1.626***		-1.549**	
	(0.365)		(0.506)		(0.638)	
Observations	17073		859		7236	
Pseudo R-Squared	0.23		0.33		0.14	
Log Likelihood	-1581.88		-263.98		-1196.58	

Standard errors in parentheses.
*significant at 10%; ** significant at 5%; *** significant at 1%.
Dummy variables of application year and technology are included, but not reported.
Source: Authors.

Next, Table 8 provides the results of estimation, explaining the number of inventors, based on the following model:

$$\ln(\text{inventors}) = f(\text{Dummies of Num. applicants, Dummy for international coownership}), \quad (2)$$

We introduce again the technology by time dummies to control for the variations of technological or demand characteristics over time in each technology area.

The estimated coefficients for the dummy of international co-ownership indicate the average additional effect of international co-ownership on the size of inventors for all levels of the number of owners or applicants (both single ownership and 4 categories of co-ownership). The dummy variables of number of applicants have significantly positive coefficients in the samples of all three countries and the coefficient size increases with the number of applicants monotonically, with the marginal effect being less than 1 (for example, the increase of the number of applicants from 2 to 3 is associated with 0.17), implying that the number of inventors increases but significantly less than proportionately with the number of co-owners. The dummy for international co-ownership has a significantly positive coefficient in Korea, implying that the inventions with international co-ownership, relative to domestic co-ownerships, are associated with a significantly larger number of inventors than purely domestic owned patents (around 20 %). On the other hand, international co-ownership, relative to domestic ownership, is not associated with a larger team size in Taiwan and China. In China, it has a significantly negative coefficient. That is, the patents of pure domestic ownership involve a larger sized research team than the patents of international co-ownership (such relationship between domestic and foreign co-ownership is clear in Figure 6 too).

Table 8. Estimation Results (1)

	ln(Num inventors)		
	Korea	**China**	**Taiwan**
Dummy for num. applicant == 2	0.327***	0.655***	0.164***
	(0.029)	(0.066)	(0.049)
Dummy for num. applicant == 3	0.237***	0.563***	0.362***
	(0.084)	(0.189)	(0.120)
Dummy for num. applicant == 4	0.413***	0.990**	0.724***
	(0.154)	(0.465)	(0.239)
Dummy for num. applicant >= 5	0.834***	0.821**	0.669***
	(0.144)	(0.377)	(0.177)
Dummy for International co-ownership	0.179***	-0.268***	0.033
	(0.064)	(0.081)	(0.072)
Constant	0.740***	0.930***	0.231
	(0.144)	(0.250)	(0.328)
Observations	29750	1483	11744
R-squared	0.11	0.44	0.10

Standard errors in parentheses.
*significant at 10%; ** significant at 5%; *** significant at 1%.
Dummy variables of application year and technology are included, but not reported.
Source: Authors.

4. Use of Prior Knowledge as Measured by US Patent References

An important reason for international research collaboration might be to gain access to the knowledge base of foreign inventors, in addition to using their inventive expertise and efforts. If international collaborations expand the scope of knowledge exploited, we would observe that the patents from international research collaborations are associated with a larger scope of knowledge used for the research, controlling for the number of inventors.

We use the following indicators as the extent of the knowledge used: the amount of prior non-patent literature cited (mainly science literature), the amount of prior US patent literature cited, and the median citation lag to the prior US patent literature (citation lag) as the indicators of how quickly the knowledge disclosed in the patent literature is used in the invention process. The econometric model we estimate has the following structure, with the dependent variable indicating the scope of the use of knowledge by an invention resulting in the patent in the technology area granted in year:

$$\begin{aligned}\text{Use of prior knowledge}_{i,k,t} \\ &= f(\text{Number of applicants, Number of inventors,} \\ &\quad \text{Dummies for international collaborations (co-applicants, co-inventors),} \\ &\quad \text{Dummies for technology by time)}\end{aligned} \tag{3}$$

US patent law imposes strong disclosure requirements in patent applications with respect to prior literature, although the examiners are mainly responsible for identifying the relevant prior art in Japan and EPO. This is the reason why we use the US patent references as the index of knowledge exploitations, although it is a very noisy measure of knowledge flow, because it includes references by patent examiners, not by inventors themselves (Thomson (2006) and Thomson and Fox-Kean (2005)). A recent study based on an inventor survey indicates that the number of references to non-patent literature ("science linkage") is a good measure of knowledge flow (Nagaoka, Motohashi and Goto (2010)).

Table 9 shows the estimation results for each variable: science linkage (the number of non-patent literature references), backward patent citation (the number of patent literature references) and citation lag (median citation lag to the prior US patent literatures). For each dependent variable, we use two international collaboration dummies (one for international co-ownership and the other for international co-invention), measuring the extent of international research collaboration, relative to domestic collaborations. The estimation method is negative binomial regression for the former two dependent variables, and ordinary least square for citation lag.

Table 9. Estimation Results of Negative Binomial Regressions

	Num. citations to non-patent literature			Num. citations to patent literatures		
	Korea	**China**	**Taiwan**	**Korea**	**China**	**Taiwan**
ln(Num. of Inventors)	0.456***	0.401***	0.436***	0.070***	-0.001	0.042***
	(0.022)	(0.104)	(0.066)	(0.008)	(0.037)	(0.014)
ln(Num. of Applicant)	0.358***	-0.406	-0.423	-0.188***	-0.076	0.034
	(0.120)	(0.287)	(0.335)	(0.043)	(0.106)	(0.073)
Dummy for International co-inventions	0.510***	0.076	1.935***	0.072	0.306***	1.003***
	(0.117)	(0.245)	(0.221)	(0.044)	(0.085)	(0.047)
Dummy for International co-ownership	-0.237	-0.668**	-1.040**	0.562***	-0.198**	-0.468***
	(0.240)	(0.265)	(0.484)	(0.087)	(0.099)	(0.099)
Constant	1.114***	1.104***	1.268	1.948***	1.690***	2.888***
	(0.276)	(0.408)	(0.811)	(0.110)	(0.178)	(0.186)
Observations	29750	1483	11744	29750	1483	11744
Pseudo R-Squared	0.04	0.11	0.05	0.01	0.04	0.02
Log Likelihood	-35495.22	-1863.27	-7823.91	-92417.43	-4585.75	-36064.31

Table 9 (continued). Estimation Results of Negative Binomial Regressions

	ln(Citation Lag)		
	Korea	China	Taiwan
ln(Num. of Inventors)	0.005	-0.059***	-0.034***
	(0.004)	(0.023)	(0.008)
ln(Num. of Applicant)	0.042*	0.066	0.112**
	(0.024)	(0.064)	(0.044)
Dummy for International co-inventions	0.013	0.039	0.010
	(0.025)	(0.054)	(0.030)
Dummy for International co-ownership	0.014	-0.181***	-0.121**
	(0.050)	(0.060)	(0.060)
Constant	2.147***	2.618***	2.293***
	(0.062)	(0.106)	(0.118)
Observations	29750	1483	11744
R-squared	0.16	0.28	0.12

Standard errors in parentheses.
*significant at 10%; ** significant at 5%; *** significant at 1%.
Dummy variables of application year and technology are included, but not reported.
Source: Authors.

As shown in Table 9, the number of inventors is highly significant when accounting for the variation of the number of non-patent literature citations (science linkage) for the sample of all three countries, controlling for the changes over time in each technology sector. It is also significant for backward citation of prior patent literature, except for China. It is significantly negative for the citation lag in China and Taiwan. A larger number of inventors are highly associated with more extensive use of the knowledge embodied in non-patent literature (in the three countries), exploitation of a greater amount of patent literature (in Korea and Taiwan) and utilization of more recent knowledge (in China and Taiwan). On the other hand, the number of applicants has a less significant coefficient or a coefficient with an opposite sign, although it is significantly positive for science linkage in Korea. The coefficient is significantly negative for backward citation of patent literature in Korea and significantly positive for citation lag in Korea and Taiwan. Thus, the increase of co-ownership apparently is not strongly associated with more use of prior knowledge for research, unless it is accompanied with a significant increase of the number of inventors. This may be because co-ownership may create a free-rider problem in terms of ex-post incentive for invention or an ex-ante adverse selection problem for a project. That is, there are possibilities that some firms try to use the output of a collaborative research project without contributing it, since each firm can freely use the co-owned invention. And, a firm may not propose a high-quality research project as a collaboration target, if it is able to conduct research by itself even if inefficiently. As a result, only firms with a lesser ability to conduct research might participate in the collaborative research project.

Our main concern is whether the international co-invention or co-ownership has a significant relationship with the additional use of prior knowledge. As Table 9 shows, international co-invention has a positive and highly significant coefficient for science linkage in Korea and Taiwan. The coefficients imply that the participation of one or more foreign inventors is associated with significantly greater use of scientific literature in both samples, after controlling for the number of inventors. Thus, international co-invention significantly enhances the absorption of scientific knowledge in Korea and Taiwan. As for the model for backward citations to patent literature, the international co-invention has a positive significant coefficient in China and Taiwan. Participation of foreign inventors significantly promotes more use of prior knowledge disclosed in patent literatures. On the other hand, international co-ownership is significantly less associated with science linkage in the three countries, and also less associated with backward patent citations in China and Taiwan.

5. Quality of Patents

International research collaborations may improve the quality of inventions, controlling for the number of inventors as well as the scope of prior knowledge used. It may create a synergy between domestic and foreign inventors and may facilitate the exploitation of tacit knowhow, not captured by the number of inventors or the use of literature. We use the quality of patented inventions as a performance measure of an invention: the number of forward citations received from subsequent US patents per patent family. When the number of patents in a family is more than two, there are cases that the two (or more) patents in the family receive references from the same subsequent patent. In such a case, we counted the number of forward citations to the patent family from the subsequent patent as one. That is, we excluded the duplication of citations in constructing the number of forward citations per family. And we also excluded self-citations in a family. For example, when a family includes two US patents and one of the patents cites the other US patent in the family, we do not count it as forward citation, since it is a citation from the same invention.

We postulate the following estimation equation for the invention quality:

$$\begin{aligned}\text{Invention Quality}_{i,k,t} = f(&\text{Number of prior US patent literature cited},\\ &\text{Science linkage, Citation lag},\\ &\text{Number of applicants, Number of inventors},\\ &\text{Dummies for international collaborations},\\ &\text{Dummies for technology by time})\end{aligned} \tag{4}$$

If international co-invention or co-ownership are significant even if we control for its effects of the prior public knowledge used for invention and of the number of inventors and applicants, we can conclude that international collaborations matter for invention performance.

Table 10 shows the estimation results for the forward citations as the dependent variable. Models use two international collaboration dummies (one for international co-invention and the other for international co-ownership) measuring the effect of international research collaboration, relative to domestic projects. As shown in this Table, the estimated coefficients for backward patent citation, science linkage and citation lag have highly significant coefficients for the patent quality variables in Korea and Taiwan. An invention with more reference to prior patent literature, science literature and shorter citation lag tends to have significantly higher values proxied by forward citation, consistent with our expectation and with prior research at firm level (Nagaoka, 2007) and research at patent family level focusing on Japan, US, and three European countries (Naogaka and Tsukada, 2010). In China, although coefficients for backward patent citation and citation lag are significant, science linkage is not significant. Thus, science literature does not play a significant role in enhancing research productivity in China.

Let us turn to the effects of the number of inventors and that of applicants. Patent quality increases highly significantly with the number of inventors in Korea. However, international collaboration in terms of either co-inventions or co-ownership does not have significant coefficients in Korea. That is, there does not seem to exist any additional effects other than the effects on the number of inventors and the use of knowledge embodied in literature already identified for Korea. On the other hand, the dummy of international co-invention has a significant positive coefficient in China and Taiwan. Thus, in these two countries, there seem to be additional effects, after controlling for the effects of the number of inventors.

Table 10. Estimation Results of Negative Binomial Regressions

	Num. forward citations					
	Korea	Korea	China	China	Taiwan	Taiwan
ln(Num. of Inventors)	0.143***	0.124***	0.193**	0.160*	0.050*	0.021
	(0.014)	(0.014)	(0.085)	(0.083)	(0.026)	(0.025)
ln(Num. of Applicant)	-0.225***	-0.155**	0.126	0.096	-0.026	0.077
	(0.079)	(0.077)	(0.238)	(0.229)	(0.142)	(0.135)
Dummy for International co-inventions	0.107	0.055	0.416**	0.375**	0.548***	0.427***
	(0.078)	(0.076)	(0.186)	(0.181)	(0.084)	(0.081)
Dummy for International co-ownership	0.602***	0.369**	0.067	0.034	-0.162	-0.268
	(0.160)	(0.157)	(0.223)	(0.218)	(0.187)	(0.179)
ln(Num.citations to non-patent literatures)		0.035***		0.017		0.242***
		(0.013)		(0.062)		(0.026)
ln(Num. citations to patent literatures)		0.318***		0.382***		0.332***
		(0.012)		(0.065)		(0.020)
ln(Lag of citations to patent literatures)		-0.605***		-0.648***		-0.473***
		(0.019)		(0.099)		(0.028)
Constant	-0.059	0.580**	-0.679	0.299	0.966***	1.064***
	(0.247)	(0.247)	(0.435)	(0.513)	(0.356)	(0.352)
Observations	29750	29750	1483	1483	11744	11744
Pseudo R-Squared	0.08	0.09	0.09	0.11	0.08	0.10
Log Likelihood	-49109.89	-48307.00	-1722.97	-1687.99	-18934.37	-18534.77

Standard errors in parentheses.
*significant at 10%; ** significant at 5%; *** significant at 1%.
Dummy variables of application year and technology are included, but not reported.
Source: Authors.

6. Conclusions and Implications

This paper has analyzed whether and how international research collaboration in terms of co-inventions and co-ownership may affect invention performance in three Asian countries: Korea, China, and Taiwan. We have distinguished its potential effects on the number of inventors used for the invention, on the scope and the speed of using the prior knowledge as measured by the US patent references and the other effects (productivity effect). We focused on the patents which have been applied to the patent offices of a focused country (Korea / China / Taiwan) and also applied to the US Patent Office.

Our major findings are the following. First, foreign firms owned the majority of these patents in each of the three countries: 67% of patents in Korea, 98% of patents in China, 70% of patents in Taiwan. On the other hand, international collaboration is rare both in terms of co-invention (around 1% or less) and also co-application (less than 1%) in the three countries. Focusing on the patents involving at least one inventor of each of the three countries, we have found that there is a large share of patents invented only by a single person; especially in China, 63% of the patents are invented by single person. The share is also higher in Korea and Taiwan than that of Japan, US, and European countries. These findings indicate that the domestic firms in these countries engage in relatively simple inventive tasks during this period.

Second, internationally co-owned patents tend to be more associated with international co-inventions in all three countries. And internationally co-owned patents are associated with a significantly larger size of inventor team than purely domestically-owned patents, controlling for the number of applicants, only in Korea, confirming our earlier study based on the largest OECD countries. This seems to indicate that capabilities or opportunities for engaging foreign inventors enable a domestic firm to undertake a larger scale R&D project. This effect, however, is weak for inventions in China and Taiwan. In addition, more international co-inventions are realized under pure foreign ownership than international co-ownership in China and Taiwan, indicating that international investment plays a more important role in initiating international co-inventions in these countries than international alliance.

Third, international co-inventions are strongly associated with more science linkage, that is, more references to scientific literature in Korea and Taiwan. A research project with a high degree of science linkage is often based on basic research. Absorptive capability may be important for using the scientific knowledge, where international collaboration among inventors matters. This may indicate that Korea and Taiwan have stronger absorptive capabilities to exploit scientific knowledge than China for this period. Moreover, international co-invention is associated with more backward patent citation in China and Taiwan. Knowledge embodied in patent literature may be relatively well-known among the inventors of developed economies, since patent documents are completely disclosed. However, in these economies, collaboration with foreign investors may help local inventors exploit that knowledge too.

Fourth, international research collaborations are associated with higher patent quality, in term of forward citation, in China and Taiwan, even after we control for the number of inventors and the literature cited. Thus, the benefits of international research collaboration in terms of creating a synergy or exploitation of knowhow may be significant for these economies.

Although our study is still at an early stage, we can point out several policy implications of our study. First, it would seem important to enhance international collaborations in research by reducing the barriers to the collaboration. Our study shows that an international co-invention helps domestic inventors to undertake large and science-intensive research projects. Mobility of professionals and students across borders would be very instrumental in this regard. While the Internet provides very effective communication channels across borders, direct contact among persons would be critical in identifying and designing a collaborative research project. International R&D collaboration among firms is also important, since sharing co-ownership can be an important mechanism to allow both the domestic and foreign firm to join their inventive forces, although co-ownership may have some inherent inefficiency due to divided-ownership. International investment plays a more important role for initiating international co-inventions (more than international alliance in China and Taiwan). Direct foreign investment thus plays an even more important role for organizing international collaborative research in less developed economies.

Our study also indicates that the effectiveness of international co-inventions depends on capability of domestic inventors. International co-inventions result in more exploitation of scientific findings in Korea and Taiwan, but not in China during our sample period. International co-inventions did not result in larger inventor teams in China either. These differences seem to be due to the differences of the capability of domestic inventors. Developing the capability of domestic inventors will not only enhance their direct inventive power but it also enhances their absorptive power and spillover from international co-inventions.

There are reservations and further issues to be addressed. First, our study does not distinguish between co-ownership by independent firms and that between related firms. Co-ownership between related firms may have less serious governance problems. Second, there is an endogeneity issue, even though we introduce technology by time dummies to control for the variations of technological or market opportunities in each technology area. Another potential source of endogeneity is the capability of firms. That is, a firm with strong capability in research management may make more use of an international research team and also have high R&D performance. Introducing firm-fixed effects is effective to control for such endogeneity. However, the results of estimation with and without fixed effects using Japanese/European sample restricted to patents owned by single firm are almost the esame in Nagaoka and Tsukada (2011).

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Appendix

Table A1. Example of Relations of Patent Documents and the Priority Documents

Document D1	Priority P1		
Document D2	Priority P1	Priority P2	
Document D3	Priority P1	Priority P2	
Document D4		Priority P2	Priority P3
Document D5			Priority P3

Note: Document D1 claims the priority document P1. D2 claims P1 and P2.

Source: OECD (2009)

Table A2. Basic Statistics

Korea

Variable	Obs	Mean	Std. Dev.	Min	Max
Num. Inventors	29,750	2.517	1.820	1	27
Num. Applicants	29,750	1.030	0.233	1	10
Num. citations of non-patent literatures	29,750	1.089	4.449	0	266
Num. citations of patent literatures	29,750	8.460	13.124	0	820
Citation lag of patent literatures	29,750	6.926	5.133	0	80
Num. forward citations	29,750	1.917	4.073	0	120
Dummy: International co-invention	29,750	0.015	0.121	0	1
Dummy: International co-application	29,750	0.004	0.064	0	1

China

Variable	Obs	Mean	Std. Dev.	Min	Max
Num. Inventors	1,483	2.953	2.370	1	20
Num. Applicants	1,483	1.335	0.539	1	6
Num. citations of non-patent literatures	1,483	1.715	5.936	0	103
Num. citations of patent literatures	1,483	8.837	12.894	0	189
Citation lag of patent literatures	1,483	9.168	7.529	0.5	74
Num. forward citations	1,483	0.967	2.165	0	24
Dummy: International co-invention	1,483	0.102	0.303	0	1
Dummy: International co-application	1,483	0.200	0.400	0	1

Table A2. Basic Statistics

Taiwan

Variable	Obs	Mean	Std. Dev.	Min	Max
Num. Inventors	11,744	2.342	1.468	1	13
Num. Applicants	11,744	1.032	0.251	1	8
Num. citations of non-patent literatures	11,744	0.649	9.363	0	931
Num. citations of patent literatures	11,744	8.259	46.020	0	4,847
Citation lag of patent literatures	11,744	6.089	5.019	0	84
Num. forward citations	11,744	1.877	4.601	0	117
Dummy: International co-invention	11,744	0.029	0.169	0	1
Dummy: International co-application	11,744	0.009	0.097	0	1

Source: Authors.

Table A3. Correlation Coefficient Matrix

Korea

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) **Num. Inventors**	1							
(2) **Num. Applicants**	0.1058	1						
(3) **Num. citations of non-patent literatures**	0.1141	0.0451	1					
(4) **Num. citations of patent literatures**	0.0166	-0.0034	0.2581	1				
(5) **Citation lag of patent literatures**	0.0157	0.0373	0.0155	0.0548	1			
(6) **Num. forward citations**	0.0043	-0.0068	0.0587	0.1625	-0.1172	1		
(7) **Dummy: International co-invention**	0.1345	0.1348	0.0589	0.0156	0.0076	0.0057	1	
(8) **Dummy: International co-application**	0.0556	0.3181	0.0194	0.0263	0.015	0.0038	0.4209	1

China

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) **Num. Inventors**	1							
(2) **Num. Applicants**	0.3149	1						
(3) **Num. citations of non-patent literatures**	0.0597	-0.038	1					
(4) **Num. citations of patent literatures**	-0.042	-0.0444	0.1615	1				
(5) **Citation lag of patent literatures**	-0.0208	-0.0636	-0.0247	0.0329	1			
(6) **Num. forward citations**	0.0422	-0.0136	0.1504	0.2444	-0.0738	1		
(7) **Dummy: International co-invention**	0.0723	0.3098	-0.0115	0.0241	-0.0974	0.0298	1	
(8) **Dummy: International co-application**	0.0539	0.627	-0.0955	-0.0142	-0.1849	-0.0227	0.492	1

Table A3 (continued). Correlation Coefficient Matrix

Taiwan

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) **Num. Inventors**	1							
(2) **Num. Applicants**	0.0735	1						
(3) **Num. citations of non-patent literatures**	0.0223	0.0045	1					
(4) **Num. citations of patent literatures**	0.0039	-0.0004	0.9351	1				
(5) **Citation lag of patent literatures**	-0.041	0.0279	0.0086	0.0144	1			
(6) **Num. forward citations**	0.0145	-0.0015	0.2598	0.2538	-0.1028	1		
(7) **Dummy: International co-invention**	0.1241	0.1123	0.0634	0.055	-0.0088	0.0386	1	
(8) **Dummy: International co-application**	0.0324	0.4188	-0.0023	-0.001	-0.0083	-0.0002	0.2848	1

Source: Authors.