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

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**Abstract:** 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.[1] 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, however, we follow Hahn (2010)[2] to

[1] Theoretical background behind innovation-export linkage will be discussed below in some more detail.
[2] Hahn (2010) shows that exporting plants in Korean manufacturing sector are more likely 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.[3] 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.

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

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introduce new products from the viewpoint of the aggregate economy, utilizing propensity score matching technique.

3 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.

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 the 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.[4] These studies all found a strong positive effect of innovation on exporting. While these studies tend to treat firms' innovation as a exogenous process,[5] 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

[4] 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.

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

participate in the export market, using plant-level data on the Taiwanese 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.[6] 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.[7] 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

[6] 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.

[7] 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.

showed that multi-product firms are more likely to add or 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.[8]

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.[9] So, the bi-directional relationship between innovation and exporting in

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[8] 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.

[9] 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.

these models include the following two step mechanism: exporting (or innovation) improves firm productivity, which subsequently makes that firm more likely 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.a. - Table 1.c. 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.a 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.b.). 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.a: 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.b: 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.c.: 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 2.a.- Table 2.c. show various plant characteristics (mean values) according to the exporting and innovation status of plants. Generally speaking, exporters are larger, more productive[10], 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 4). 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 more capital- and skill-intensive than the other

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

categories of plants by substantive margins.[11]

**Table 2.a: 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 |
| | Shipments(Won) | 965.02 | 6821.52 | 6718 | 41447 |
| | Worker(person) | 22 | 74 | 89 | 379 |
| | Value added Per Worker | 14 | 20 | 18 | 27 |
| **1991** | 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 |
| | Shipment(Won) | 1255 | 5797 | 10077 | 71902 |
| | Worker(person) | 18 | 52 | 71 | 328 |
| | Value added Per Worker | 23 | 33 | 34 | 44 |
| **1995** | 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 |
| | Shipment(Won) | 1597 | 5492 | 12742 | 70791 |
| | Worker(person) | 16 | 40 | 57 | 222 |
| | Value added Per Worker | 29 | 39 | 48 | 59 |
| **1998** | 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 |

[11] 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.b: 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.c: 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.a - Table 5.b, 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.a. and Table 5.b.). 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.a: Transition Matrix Conditional on $Exp_{t-1}$=0: R&D Expenditure, 1991-1992**

| | $Exp_t$\|$Exp_{t-1}$=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.b: Transition Matrix Conditional on $R\&D_{t-1}$=0: 1991-1992**

| | $R\&D_t$\|$R\&D_{t-1}$=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.a: Transition Matrix Conditional on $Exp_{t-1}$=0: Product Adding, 1991-1992**

| | $Exp_t$\|$Exp_{t-1}$=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.b: Transition Matrix Conditional on $Adding_{t-1}$=0: 1991-1992**

| | $Adding_t$\|$Adding_{t-1}$=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.a: Transition Matrix Conditional on $Exp_{t-1}$=0: Product Creation, 1991-1992**

| | $Exp_t$\|$Exp_{t-1}$=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.b: Transition Matrix Conditional on $Creation_{t-1}$=0: 1991-1992**

| | $Creation_t$\|$Creation_{t-1}$=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:

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

Exporting Probability

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

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[12], 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

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

creation. Similarly, Hahn and Park (2009) shows that the average productivity gains of 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;

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

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

(2)

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

(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;

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

(4)

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

(5)

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

(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 1 illustrates the estimated impulse-response functions along with 95 percent confidence bands calculated by a bootstrapping method[13]. 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.

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

**Figure 1: Impulse Response Functions**

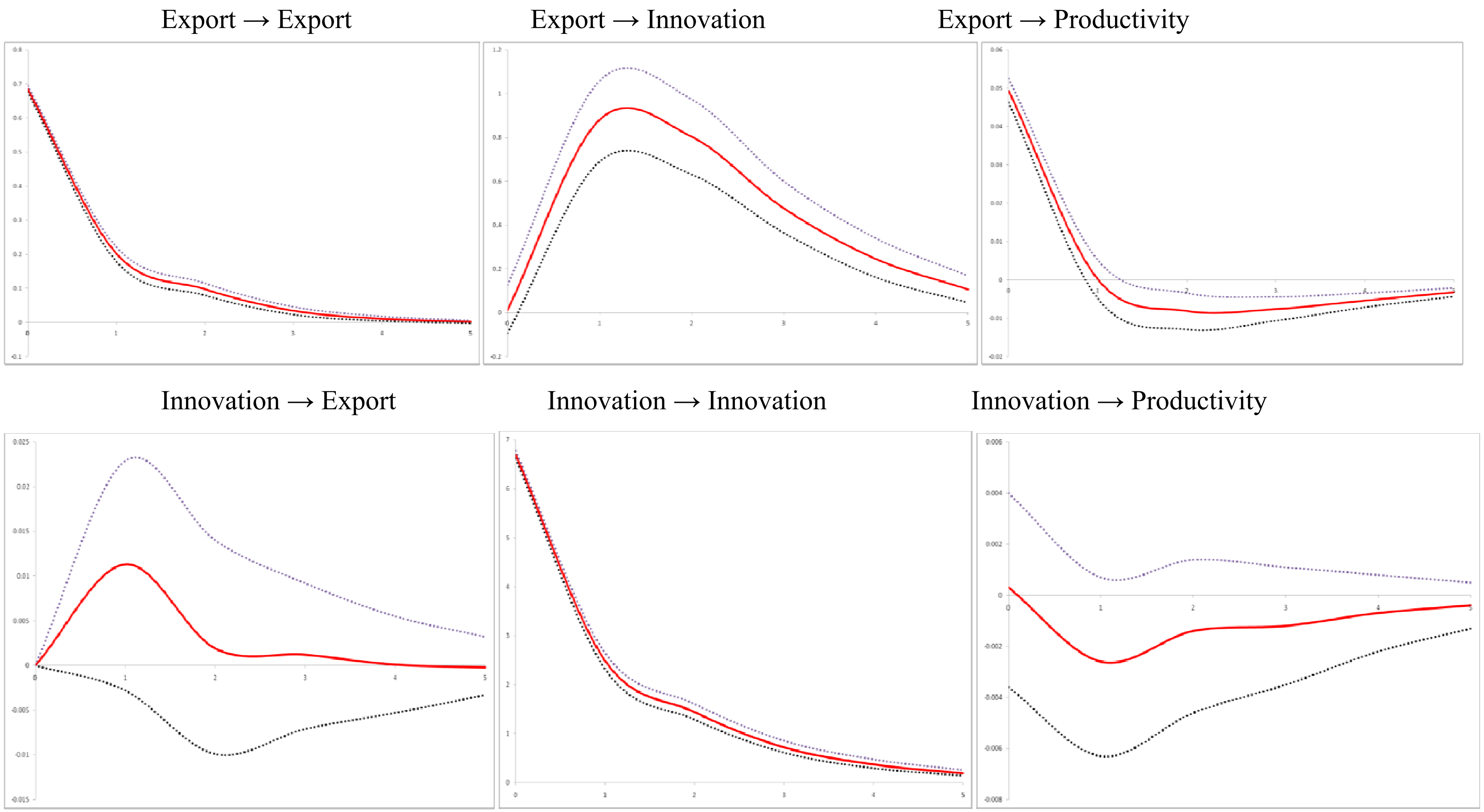
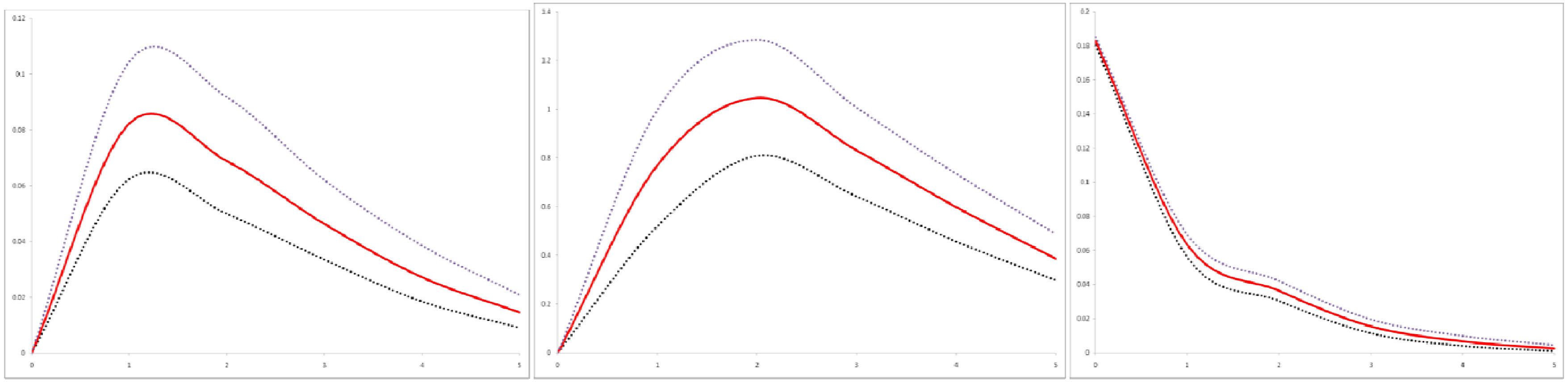


**Figure 1: Impulse Response Functions (Continued)**

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) |

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