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

[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:

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

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

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

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.

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

$$\left.\begin{aligned} Z_i &= 0 \quad if \quad Z_i^* \leq 0 \\ Z_i &= 1 \quad if \quad Z_i^* > 0 \end{aligned}\right\} \tag{8}$$

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

$$\left.\begin{aligned} &Y_i = Y_i^* \quad if \quad \text{Z}_i = 1 \\ &Y_i \ \text{ not observed} \quad if \ \ \text{Z}_i = 0 \end{aligned}\right\} \tag{9}$$

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).

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

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}^2	-	-	-	-
$PROD_{ij}$	-0.09	-4.10*	0.06	0.86
$Size_{ij}$	1	8.04*	0.25	0.81
$Size_{ij}$^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	Column A		Column B		Column B	
to invest in R&D	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.