Thailand and The World Economy
P-ISSN : 2630-0931
E-ISSN : 2651-0529
Homepage : https://www.tci-thaijo.org/index.php/TER
Vol. 33, No. 2, May-August 2015 Page [1-35]

Multinational Enterprises, Exporting and R&D Activities in the South

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Abstract

This paper examines the role of MNEs and exporting on R&D activities by using detailed data from Thai manufacturing. Three types of R&D investment are considered here, namely R&D leading to improved production technology; R&D product development and R&D process innovation. The results show that most MNEs, except those in automotive and hard disk drive industries, use technology transmission, instead of technology generation, i.e. setting up R&D, in the host country. However, MNEs generate the positive spillovers to indigenous firms to invest more in R&Ds, especially in terms of product development and process innovation. The results also show that exporting promote R&D product development, but not for the other two.

Keywords: Multinational Enterprises, Exporting and R&D activity
JEL Classifications: F23, F10, O30 and O5

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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. Government in most developing Asian countries, including Thailand, began to place policy emphasis on R&D activity in order to upgrade the level of technological capabilities in their manufacturing sector, especially since competitiveness emerged 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 over technology transmission, in the hope that the former will help to lay the foundation of national scientific and technology activity in the country.

In relating to R&D activity, recent interest has been paid on the role of trade and investment in promoting R&D activity in the host country. In terms of investment, firm-specific advantages of multinational enterprises (MNEs), which take place in the form of knowledge-based assets, managerial know-how, quality of the workforce, marketing and branding, are expected to generate/promote R&D activity in the host countries. Therefore, there has been a 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 trade, recent literature points to the link from exporting to innovation and productivity (Damijan et.al., 2010 and Cassiman et.al., 2010).

However, the relationship between MNEs, exporting and R&D activity is not straight forward. Some studies (e.g. Daft et.al., 1987) argue that involvement of MNEs may not generate R&D activity in the host country. Instead of decentralizing R&D activity, they may keep R&D activity at headquarter and 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 some types of 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; Salomon and Shaver, 2005; Cassiman et.al., 2010) found that exporting would help only some certain types of R&D activity, i.e. exporting would not help firms to learn much about improving production technologies but would help firms to learn more about product development. By contrast, Damijan et.al (2010) using Slovernian firm-level data show that exporting promote process innovation of medium and large firms, but it does not affect product innovation.

Therefore, to date, the relationship between MNEs, exporting and R&D activity are not yet clear. Identifying such relationship is not without challenges, given the fact that heterogeneity of firms, country characteristics, as well as types of R&D activities influence the relationship. However, attempting to address these challenges is important to gain a better understanding of the role of MNEs and exporting in affecting R&D activities. This will help government design more effective measures in promoting firms' technology upgrading in a country. Thus, this paper aims to examine the relationship between MNEs; exporting and R&D activity by using plant-level data of Thai manufacturing as a case study. Thailand is chosen here as the case study because of three reasons. First, over the past few years, government has emphasized on technological upgrading and placed attention on R&D investment. A number of policy measures have been introduced, especially through Board of Investment (BOI), to stimulate the 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 the key strategy since the late 1980s. Third, however, so far, there has no evidence whether MNE involvement and exporting strategy would help firms, both foreign and domestically-owned firms, to set up R&D activity in the country.

This study is distinct from other empirical studies in three ways. Firstly, 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, while most previous empirical studies use total R&Ds to examine R&D determinants. As mentioned earlier, MNE involvement and exporting could possibly have a different impact on different R&D activities. 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 three types of R&D and their R&D intensity. Examining in both aspects would help us to clearly understand the role of MNEs and exporting activity in influencing these three types of R&Ds. The selection model and instrument variables are applied here to guard against the 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 in the host country, but also their indirect effect, called here as R&D spillovers. It is possible that MNEs may import technology from headquarter, instead of decentralizing R&D activity to the host country, but entering of MNEs helps to stimulate indigenous firms to set up more R&D activity (i.e. R&D spillovers) by reinforcing the imitation and/or demonstration effects as well as by increasing competition in domestic market (Blomström and Kokko, 1998; Kokko et.al., 2001; Kohpaiboon, 2006, Jongwanich and Kohpaiboon, 2008). Thus, it is plausible to examine both the direct and indirect effects of MNEs on R&D activity.

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 literature survey on MNEs, exporting and R&D investment.

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. The 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 US, Japan and Euro 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 noticeable increase.

Table 1: R&D expenditure (% of GDP)

	1996-00	**2001-05**	**2006-07**
World	2.08	2.10	2.16
United States	2.63	2.65	2.66
Euro area	1.81	1.85	1.95
Japan	2.95	3.20	3.42
Lower middle income	0.61	0.90	1.19
Asia			
- China	0.71	1.14	1.45
- Indonesia	0.07	0.05	
- India	0.71	0.74	0.80
- 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: Authors' calculations

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

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

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

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: Authors' calculations

Table 3 presents the R&D investment in Thailand, disaggregated according to four-digit industries of 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). For R&D leading to improved production technology, firms in four industry areas, namely beverage, petroleum and chemical products, textile and electronics, dominate R&D activity. For example, in 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 bearing, 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 manufacture of malt liquors and malt than that for 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, namely manufacture of bicycles and invalid carriages; that of man-made fibers; that of dressing and leather and that of sugar, where there is no participation from foreign investors but have a high percentage of firm participation in R&D activity (20% of total firms, compared to average of 9%). This pattern is also found in exporting. For example, for both manufacture of malt liquors and malt, and that of 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	1326.0	2.0	0.53	18.0
2320	Manufacture of refined petroleum products	61	41.0	4.0	5	16.0	13170.0	2.1	0.62	5.2
2913	Manufacture of bearings, gears, gearing and driving elements	31	35.5	2.3	2	16.0	1526.0	61.4	0.50	10.0
2423	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	210	25.2	4.3	3	32.1	190.5	10.0	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	0.39	34.9
2930	Manufacture of domestic appliances n.e.c.	98	22.4	2.4	11	21.1	1307.0	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	0.52	8.5
3592	Manufacture of bicycles and invalid carriages	23	21.7	2.0	0	16.8	593.1	20.2	0.63	0.0
1532	Manufacture of starches and starch products	67	20.9	4.0	1	18.3	315.4	20.7	0.60	3.5
2430	Manufacture of man-made fibres	29	20.7	2.8	0	17.8	257.9	14.3	0.44	0.0
1911	Tanning and dressing of leather	51	19.6	1.2	0	13.7	192.3	51.9	0.46	0.0

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 participa-tion
1542	Manufacture of sugar	68	19.1	4.8	1	35.4	1512.0	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	0.60	3.4
3210	Manufacture of electronic valves and tubes and other electronic components	277	17.3	2.8	27	11.8	1309.0	44.9	0.39	41.5
	Average		9.0	3.5	2.8	17.6	1052.9	22.7	0.50	13.6
	Max		71.4	13.5	27	38.0	14940.0	99.3	0.65	100.0
	Min		0.0	1.0	0	5.0	0.0	0.0	0.32	0.0

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 participa-tion
1553	Manufacture of malt liquors and malt	7	42.9	2.3	1	11.0	534.5	3.3	0.53	30.0
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	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	2490.0	1.5	0.62	2.5
1820	Dressing and dyeing of fur; manufacture of articles of fur	7	28.6	1.5	1	25.0	1224.0	32.5	0.50	20.0
3592	Manufacture of bicycles and invalid carriages	23	26.1	2.3	0	16.8	495.3	16.8	0.63	0.0
2930	Manufacture of domestic appliances n.e.c.	98	25.5	2.4	8	22.4	2027.0	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	4.0	13	17.6	554.6	11.4	0.52	15.0
2429	Manufacture of other chemical products n.e.c.	121	24.0	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	22.0	1887.0	99.5	0.58	25.0

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 participa-tion
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	11550.0	27.5	0.57	37.8
2511	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres	90	20.0	2.4	8	24.8	1159.0	43.4	0.52	35.7
3190	Manufacture of other electrical equipment n.e.c.	60	18.3	15.4	3	7.6	140.0	33.6	0.45	15.2
	Average		9.3	5.0	3.1	18.2	889.9	22.4	0.50	14.2
	Max		42.9	31.0	26	38.5	11550.0	99.5	0.65	100.0
	Min		0.0	1.0	0	7.6	0.0	0.0	0.32	0.0

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 participa-tion
1553	Manufacture of malt liquors and malt	7	42.9	2.3	1	11.0	534.5	3.3	0.53	30.0
1911	Tanning and dressing of leather	51	27.5	1.4	0	15.2	250.9	18.6	0.46	0.0
3592	Manufacture of bicycles and invalid carriages	23	21.7	1.4	0	14.0	571.0	20.0	0.63	0.0
2320	Manufacture of refined petroleum products	61	21.3	1.2	0	9.3	3506.0	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

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 participa-tion
3330	Manufacture of watches and clocks	19	15.8	5.7	2	24.3	2330.0	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	3356.0	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	1134.0	43.2	0.39	43.5
1820	Dressing and dyeing of fur; manufacture of articles of fur	7	14.3	1.0	0	18.0	388.1	30.0	0.50	0.0
2930	Manufacture of domestic appliances n.e.c.	98	13.3	2.2	6	23.4	1701.0	21.5	0.54	24.7
2422	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	153	13.1	1.9	2	17.0	257.2	3.4	0.39	5.6
2109	Manufacture of other articles of paper and paperboard	133	12.0	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	0.50	14.3
	Max		42.9	25.0	25	55.0	24750.0	99.3	0.69	79.7
	Min		0.0	1.0	0	5.5	0	0	0.32	0.0

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.

Source: Authors' calculations

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 manufacture of malt liquors, while the 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 covered in product development are more diversified than the other two types of R&D. Electrical equipments and appliances; watch and clocks; rubber tyres and tubes; paints and printing inks are industries that have a high percentage of firm participation. Note that for both product development and process innovation, there is also no clear pattern of MNEs and exports in determining R&D investment.

Government Policy in Promoting R&D in Thailand

Government policy to promote R&D activity in Thailand is mostly implemented through Broad of Investment (BOI). BOI classifies R&D activity into three broad areas, namely basic research; applied research and experimental development. Basic research means new and original study, either theoretical or empirical, from which there has not been a specific target group to use the results. Applied research means new and original study, from which there has been a target group to apply the result. Experimental research means using the existing knowledge to improve product and production process.

To get benefit from BOI, R&D investment must exceed 1 million baht, not including costs of land. The investment is, then, categorized as the "special investment" that will bring the special benefit to the country. Under this category, the company will (1) receive tariff exemption for imported machines, regardless company location; (2) receive tax exemption for corporate income for 8 years, regardless company location; (3) get income tax reduction by 50% for another 5 years after 8 years of income tax exemption when the company is located in "Thailand Science Park"[1]; (4) be allowed to deduct transportation and utility costs by two times of actual expense from its profit for 10 years; (5) be 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 any years, within 10 years; (6) receive other benefits proposed by BOI, varying from location to location.

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

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

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

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

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 place in a form of knowledge-based assets, including proprietary information assets relating to product or process technology, managerial know-how, quality of the workforce, marketing and branding. However, there is not always that multination firms will establish R&D activity in an investment-receiving country (Lall, 1979; Daft et.al.., 1987). In fact, the R&D activity of MNEs could take place either at a company's headquarter or be decentralized to the host country, or both.

There are three key reasons why MNEs keep R&D activity as a headquarter function (Daft et.al., 1987 and Athokorala and Kohpaiboon, 2010). First, the establishment of R&D activity involves high (fixed) costs and uncertainties, given the fact that transportation costs have noticeable declined overtime, MNE affiliates can easily import technology (or the so called "technology transmission"), which is developed and produced from their headquarters, instead of establishing R&D activity in the host country. Second, innovatory process essentially involves rich communication and cooperation within a firm, from product design; production team, marketing and other related key functions. A face-to-face communication, interdepartmental relationships and highly networked teams in transmitting high equivocal and uncertainty information are highly needed for the development of innovation. Thus, decentralization of R&D activity may be wasteful and reduce productivity of R&D effort. Third, the decentralization of R&D also has a risk of leakage of proprietary technology, which is the assets created by the R&D process and determines ownership advantage in international operation, to foreign competitors. 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, MNE decides to keep R&D activity as a headquarter function.

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

Some previous empirical literature (e.g. Lall, 1979; Athokorala and Kohpaiboon, 2010) argues that setting up of R&D research support by MNE affiliates in the host country are 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 sale prospects are promising, the subsidiary begins to set up local R&D research support activity. In addition, investment promotion campaigns, e.g. generous R&D related tax concession and high quality infrastructure at subsidy prices may help to encourage the subsidiary to establish R&D activity in the host country.

In addition to the direct potential of MNE affiliates in establishing R&D activity in the host country, the indirect effect, in which entering of MNE affiliates stimulates domestically-owned firms to set up R&D activity, could occur (Blomström and Kokko, 1998; Sjöholm, 1999; Kokko et.al., 2001; Kohpaiboon, 2006, Jongwanich and Kohpaiboon, 2008). The indirect effect of multinational firms to indigenous firms is referred here as "R&D spillovers". There are two key channels that R&D spillovers could take place. First, MNEs can be a source of information, i.e. technologies and management techniques, from which domestically-owned firms can benefit through processes of demonstration and imitation. This includes providing new technologies and management techniques. Subsidiaries tend to have more advanced production technology than local firms. While such technology associated with foreign firm has also certain public good qualities, the localization of the foreign firm could potentially generate 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 set up R&D activity.[3]

Second, 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 become more productive and competitive. 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) points 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.

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 (e.g. Grossman and Helpman, 1991; Melitz, 2008; Aw et.al., 2009;

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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.

Damijan, 2010 and Cassiman et.al., 2010). In fact, the recent theoretical literature suggests bi-directional relationship between innovation and exports. Aw et.al (2008) develop the theoretical model, which can be viewed as the dynamic innovation-based endogenous growth theories. Specifically, the model is a dynamic structural model of a producer's decision to invest in R&D and participate in the export market. The investment decisions of investing in R&D and participating in export market depend on the expected future profitability and the fixed and sunk costs[4] incurred with each activity. The model has linked the innovation-export nexus with the role of firm-level productivity. While involving in R&D and export activities requires entry costs, this generates the feature of productivity-based self-selection into both activities. Meanwhile, the model suggests that a firm that involves with R&D and/or exporting will be able to improve its productivity. Subsequently, this process helps to reinforce a firm to involve more into innovation and/or export activities.

All in all, the model points out that the bi-directional relationship between innovation and export could be occurred 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 be the other way round, which is a firm that involves in innovation activity results in productivity improvement and subsequently, makes the firm more likely to self-select into export market. Aw et.al (2009) apply this model to Taiwanese electronics industry and find that the self-selection of high productivity plants is the dominant channel driving participation in the export market and R&D investment.

"Learning by exporting", which refers to engaging in exporting that would allow a firm to enhance its productivity and overall competitive position, would be a key link between export 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 in productivity could help a firm to involve more 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 market 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 the intense global competition, the firm must keep improving product and/or process innovation, stimulating the firm to set up more R&D activity.

Note that there is no clear evidence what types of innovation that are promoted by exporting. On the one hand, Vernon (1979); Salomon and Shaver (2005); Hahn (2010)

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

found exporting would help firms to learn more about product development, but not much for improving production technologies. By contrast, Damijan et.al (2010) using Slovernian firm-level data show that exporting promote process innovation of medium and large firms, but it does not affect product innovation.

However, the bi-directional relationship between innovation and exports is not always supported by empirical studies. Most of the studies find only the impact of 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 market, 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 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 of learning by exporting could be because of using 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 the statistical relationship between exports and productivity. Salomon and Shaver (2005), who proxy learning by patent application (instead of productivity) and use number of new product launched to proxy product innovation, find the positive relationship between these two variables. They conclude that exporting is associated with innovation.

4. Empirical Model

The empirical model 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 alternatives 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 wasting management system (process innovation) (RDProcess). As argued in the previous section, MNEs and exporting tend to have different impacts on different types of R&D, so that separating R&D investment into these three alternatives allows us to clearly examine a possibly different impact of MNEs and exporting on R&D investment.

In this study, we examine the impacts of MNEs and exporting on each type of R&D in three stages. The first stage examines the impacts of MNE involvement and exporting on a firm's decision to participate in R&D investment. In this stage, R&D activity is measured in terms of binary dummy variable, where '0' refers to a firm that is not involved in R&D activity and '1' refers to a firm that involves in R&D activity (RDTech, RDProduct, RDProces).[5]

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

The second stage is to examine the impacts of MNEs and exporting on each R&D expenditure (i.e. R&D intensity) (RDTechEx; RDProductEx; RDProcessEx). R&D investment is measured here in terms of percentage of sales. In this stage, the sample selection bias, which refers to problems where the dependent variable is observed only for a restricted, nonrandom sample, i.e. we can observe R&D expenditure only if the firm decides to invest in R&D, could occur. Thus, the sample-selection model is applied to redress the possible bias that could 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, MNEs variable (MNE) is measured by proportion of foreign share holding 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 FDI (regardless of the magnitude of the foreign share in capital stock) are considered to be foreign plants. The cutting point (i.e. zero percent) 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 percent. However, the choice is dictated by data availability since information of 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-own firms. As mentioned in the previous section, MNE affiliates can stimulate indigenous firms to invest in R&D activity through the processes of both demonstration and imitation as well as through more intense competition. To examine such impacts, the data used for R&D investment and MNEs in the first and second stages are modified. In the first and second stages, dependent variable (i.e. all three types of R&D investment) includes both multinational firms and domestically-owned firms, but in the third stage (i.e. to examine spillovers), only R&D activities of domestically-owned firms are included as dependent variable in the model. In addition, instead of using firm level information of 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 indigenous firms to invest in R&D investment.

In addition to MNEs and exporting, firm and industry specific variables are included in these three stages to reduce the possible estimation bias that could arise from correlation between an error term and independent variables. The firm and industry specific variables are based on the previous literature on R&D determinants.

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 done by small firms, which have no formal R&D unit, 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 the positive relationship between firm size and innovation. Such positive relationship could arise from two key reasons. First, due to the imperfection in capital market, large firms, which have stability and internally generated funds, can afford to invest in (risky) R&D. Second, under the large sales, the returns of R&D are higher, i.e. the fixed costs arising from investing in R&D can be recovered faster under the large sale volume. However, there are some studies (e.g. Aces 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 condition and market structure seem to be more crucial than firm size while the non-linear relationship between firm size and R&D investment is possible.[6]

In this study, firm size (size) is measured by 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 be larger firms than non-exporters and non-MNE firm, by omitting this variable (size), an 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) as 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 process and adopting new technologies. The need to adopt new technology may be higher than younger firms since their technologies are outdated so the likelihood that they will have to involve in R&D investment is higher. In addition, firms would accumulate knowledge through experience (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.

[6] 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 (the results are upon the request). However, Jongwanich and Kohpaiboon (2008) found that market concentration has the negative and significant effect on exports. Thus, 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).

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 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 of this variable.

The government policy to promote R&D investment is included in the empirical model. The sign of government policy is ambiguous. Some studies find the positive relationship between government policy and R&D investment. Yoon (2000) found the government subsidy program in Korea helps to stimulate the R&D activity in IT industry; Lee and Hwang (2003) showed that the government subsidy helps to promote R&D activity only for 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 of the subsidy. This could disincentive a company to conduct R&D. To capture the government policy, we include the binary dummy variable, which take value '1' for a plant that receives investment (R&D) promotion from Board of Investment (BOI) and '0' otherwise.

To capture a possible effect of both regional-specific factor and infrastructure, the model includes location of plant (region) as another explanatory variable. Infrastructure could influence a firm's R&D decision and facilitate the R&D intensity. Since infrastructure tends to be well developed in a central part of a country, including Bangkok, Vicinity and Central regions, we include the binary dummy variable, which take value of '1' for a plant that is established in Bangkok; vicinity and central regions and '0' otherwise.

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

Finally, the model also includes a proxy of 'international production network' (Network) in the model. 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 product 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 production network tends to be more dynamic such as electronic and electrical appliance industry. Thus, the need to invest in R&D activity is expected to be higher than other industries.

We use trade data to capture the aspect of international production network (Network), It is measured by the ratio of parts and components (P&C) trade (the sum of imports and exports) to total goods trade. List of P&Cs is from a careful disaggregation of trade data based on the Revision 3 of the Standard International Trade Classification (SITC, Rev 3) extracted from the United Nations trade data reporting system (UN Comtrade database) (Kohpaiboon, 2010; Jongwanich, 2011). There are 319 items classified as parts and components in which 256 products are in SITC7 and 63 products are in SITC8.[7]

Note that industry dummy variables are included in the model to control for different characteristics of each industry. In addition, while MNEs play a key role in some certain industries in Thailand, including the automotive and hard disk drive industries, and products from these industries has been truly success in the global economy, it could be possible that the role of MNEs in R&D activities of these industries differ from other industries. The interaction terms between MNEs and industry dummy variables are tested in the model, e.g. MNEs × automotive industry dummy; MNEs × hard disk drive industry dummy.[8]

All in all, the empirical model to determine a firm's decision to invest in R&D activity and a firm's R&D expenditure can be summarized as follows :[9]

1. $$RDTech_{ij} = f\begin{pmatrix} MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij},\ Network_j, \\ D_j,\ MNE \times D_j \end{pmatrix} \quad (1.1)$$

$$RDTechEx_{ij} = f\begin{pmatrix} MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij},\ KL_{ij},\ region_{ij},\ Network_j, \\ D_j,\ MNE \times D_j \end{pmatrix} \quad (1.2)$$

2. $$RDProduct_{ij} = f\begin{pmatrix} MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij},\ Network_j, \\ D_j,\ MNE \times D_j \end{pmatrix} \quad (2.1)$$

$$RDProductEx_{ij} = f\begin{pmatrix} MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij},\ KL_{ij},\ region_{ij},\ Network_j, \\ D_j,\ MNE \times D_j \end{pmatrix} \quad (2.2)$$

3. $$RDProcess_{ij} = f\begin{pmatrix} MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij},\ Network_j, \\ D_j,\ MNE \times D_j \end{pmatrix} \quad (3.1)$$

$$RDProcessEx_{ij} = f\begin{pmatrix} MNE_{ij},\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij},\ KL_{ij},\ region_{ij},\ Network_j, \\ D_j,\ MNE \times D_j \end{pmatrix} \quad (3.2)$$

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[7] Note that the Comtrade database does not provide for the construction of data series covering the entire range of fragmentation-based trade.

[8] ISIC for automotive industry is ISIC3000 while hard disk drive industry is ISIC 3410. Thus, the dummy variable for automotive industry is equal to "1" when a firm is classified as ISIC3000 and "0" otherwise. Likewise, the dummy variable for hard disk srive industry is equal to "1" when a firm is classified as ISIC3410 and "0" otherwise.

[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 in different ages, but the results are statistically insignificant.

Where

$RDTech_{ij}$ = Decision of firm i in industry j to invest in R&D improved technology

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

$RDProduct_{ij}$ = Decision of firm i in industry j to invest in R&D product development

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

$RDProcess_{ij}$ = Decision of firm i in industry j to invest in R&D (process innovation)

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

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

Ex_{ij} = Propensity to exports of firm i in industry j

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

BOI_{ij} = Investment (R&D) promotion from Board of Investment (BOI) of firm i in industry j

$region_{ij}$ = Location of plant of firm i in industry j

$Network_j$ = Proportion of parts and components exports in industry j

D_j = Duummy variable for industry j

$MNE_{ij} \times D_j$ = Interaction term between MNE and industry dummy variable

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

$$RDTech_{ij,d} = f\begin{pmatrix} FOR_j,\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij},\ KL_{ij},\ BOI_{ij},\ region_{ij}, Network_j, \\ D_j,\ FOR_j \times D_j \end{pmatrix} \quad (4)$$

$$RDProduct_{ij,d} = f\begin{pmatrix} FOR_j,\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij}, KL_{ij},\ BOI_{ij}, region_{ij}, Network_j, \\ D_j,\ FOR_j \times D_j \end{pmatrix} (5)$$

$$RDProcess_{ij,d} = f\begin{pmatrix} FOR_j,\ Ex_{ij},\ Size_{ij},\ Size_{ij}^2,\ Age_{ij},\ Age_{ij}^2,\ PROD_{ij}, KL_{ij},\ BOI_{ij}, region_{ij}, Network_j, \\ D_j,\ FOR_j \times D_j \end{pmatrix} \quad (6)$$

where

$RDTech_{ij,d}$; $RDProduct_{ij,d}$; $RDProcess_{ij,d}$ = Decision of firm i (which is only indigenous firm) in industry j to invest in R&D improved technology, product development and process innovation

FOR_j = the presence of multinational firms in industry j

Note that for the spillover model, the interaction term between FOR and automotive industry dummy is not applicable because all auto makers (ISIC 3000) are all multinational firms.

Note that for the spillover model, the interaction term between FOR and automotive industry dummy is not applicable because all auto makers (ISIC 3000) are all multinational firms.

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 the cross-sectional data set with each industry representing a single data point is that they make it 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 the panel data set compiled by pooling cross-industry and time-series data. Particularly, in the nature of technology spillover that involves a time-consuming process, panel data is 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 establishment identification number, the number is not assigned systematically. 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 four-digit industries of International Standard of Industrial Classification (ISIC). The census was cleaned up by firstly checking duplicated samples. As occurred in the 1996 industrial census, there are some duplicated records in survey return, presumably because plants belonging to the same firm filled the questionnaire using the same records. The procedure followed in dealing with this problem was to treat the records that report the same value of the eight key variables of interest in this study, are counted 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 delete establishments which had not responded to one or more the key questions such as sale value, output and which had provided seemingly unrealistic information such as negative output value or the initial capital stock of less than 5,000 baht (less than $200).[10]

The 2006 census contains a large number of micro-enterprises defined as the plants with less than 10 workers. There are 37,042 samples which employ less than 10 workers, out of which 52 per cent 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 samples with more than 10 workers net of self-employed firms. 7 industries that are either to serve

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

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 explicitly preserved for local enterprises (e.g. manufacture of ovens, furnaces and furnace burners, manufacture of coke oven products) are excluded. All in all, these remained establishment plants accounted for 75% of the 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 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) to guard 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 high level of disaggregation.[11]

Econometric Procedure

To examine 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 binary dependent variable, i.e. 1 for firms that export and 0 otherwise. Firstly, predicted value of dependent variable under OLS could be higher than 1 or become negative. Secondly, the linear relationship between dependent and independent variables are generally assumed. However, the relationship between probability to invest in R&D and explanatory variables could be non-linear. To limit predicted value of dependent variable to lie between 0 and 1, the Probit models 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 endogeneity issue, especially for exports, the instrumental variable method is applied with the probit model (IV probit) (Criscuolo et.al., 2005). Instrument variables are the one those statistically affect/determine exports but are not statistically significant in determining R&D. Effective rate of protection (ERP) and concentration ratio (CR4) are used as instrumental variables.[12] For both of them, based on diagnostic tests, we found that concentration ratio performs well as an instrument variable than effective rate of protection. Thus, we use concentration as a key instrument variable in this study.

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[11] Effective rate of protection is also used as alternative instrument variables for exports. It is calculated based on official data provided by Custom Duty, Ministry of Finance (see Jongwanich and Kohpaiboon,, 2007). However, concentration ratio provides better results, especially in terms of diagnostic tests.

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

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 a firm makes a decision to invest in R&D (i.e. could be observed only for a restricted, non-random 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 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.

$$\begin{aligned} &Z_i^* = w_i^* \alpha + e_i \\ &\left.\begin{aligned} &Z_i = 0 \quad if \quad Z_i^* \le 0 \\ &Z_i = 1 \quad if \quad Z_i^* > 0 \end{aligned}\right\} \end{aligned} \tag{8}$$

$$\begin{aligned} &Y_i^* = x_i' \beta + \mu_i \\ &\left.\begin{aligned} &Y_i = Y_i^* \quad if \quad Z_i = 1 \\ &Y_i \text{ not observed} \quad if \quad Z_i = 0 \end{aligned}\right\} \end{aligned} \tag{9}$$

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 uncorrelated, the simple OLS approach is efficient and unbiased to explain Y, and we can apply either Maximum Likelihood (simultaneously estimating equation (8) and (9)) or Heckman two-step estimation.

In this study, we apply the two-step estimation since the model need to take into account the possible endogeneity problem that could arise, especially for export variable. The estimation procedure is as follows. First, we construct the inverse Mills' ratio from the probit model (IVprobit model) in each type of R&D (equation 7) and then estimate equations 1.2; 2.2; 3.2, using 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

Table 4, 5 and 6 report the results of a firm's R&D investment for improved production technology, product development, and process innovation, respectively. In each table, there are two columns. Columns A presents the determinants of a firm's R&D decision, which take a value of '1' for a firm involving with R&D activity and '0' otherwise, and column B shows a determinants of a firm's R&D intensity. Table 7 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 statistical significant relationship between multinational firms (MNE) and a firm's decision to invest in R&D leading to improved production technology and leading to product development, but statistical insignificant in R&D leading to process innovation (Column A of Tables 4, 5 and 6). This 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 while transportation costs become cheaper so that it tends to be more efficient to invest 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 keep the firm ownership advantage in international operation.

Table 4: Estimation Results of R&D 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	-9.80*	-3.16	-1.32
MNE_{ij}	-11.13	-1.60**	-4.15	-0.24
Ex_{ij}	0.90	1.36	0.08	0.10
Age_{ij}	0.07	2.72*	0.07	1.14
$Age_{ij}^{\wedge 2}$	-	-	-	-
$PROD_{ij}$	-0.08	-3.53*	0.003	0.07
Sizeij	0.99	7.51*	0.43	1.79**
$Size_{ij}^{\wedge 2}$	-0.02	-5.90*	-0.01	-1.99*
KL_{ij}	0.07	4.67*	-0.006	-0.12
BOI_{ij}	-0.09	-0.31	-	-
$region_{ij}$	0.02	0.41	0.14	1.62**
$Network_j$	0.43	2.30*	1.14	2.78*
MNE_{ij}×Auto dummy	12.76	0.80	31.09	1.60**
MNE_{ij}×Hard disk dummy	1.96	0.09	92.38	2.63*
Inversed mill ratio	-	-	-0.40	-0.30
Dj	Included		Included	
No. of obs	17,427		1018	
Log likelihood	5316.07		Root MSE = 0.89	
Wald chi2	1254.87 (Prob>chi2 = 0.00)			
Wald-test for exogeneity	1.32 (Prob>chi2 = 0.25)			

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 significant 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

In terms of product development, the innovatory process involves rich communication and cooperation within a firm, from product design; production team; and marketing etc, and a face to face communication; 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. However, MNEs still listen and gather information from their affiliates to ensure that the innovated products could 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" but the proportion of firms who invest in such activities are still low.

Table 5: 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	-11.53	-9.34*	-2.43	-1.12
MNE_{ij}	-16.44	-2.57*	7.44	0.52
Ex_{ij}	1.90	3.35*	-0.55	-0.79
Age_{ij}	0.12	4.87*	-0.02	-0.33
$Age_{ij}^{\wedge 2}$	-	-	-	-
$PROD_{ij}$	-0.09	-4.10*	0.08	2.11*
Sizeij	0.99	7.89*	0.39	1.64**
$Size_{ij}^{\wedge 2}$	-0.02	-6.37	-0.01	-1.88**
KL_{ij}	0.04	3.21*	0.05	2.01*
BOI_{ij}	-0.60	-2.29*	-	-
$region_{ij}$	0.26	5.22	0.41	3.50*
$Network_j$	0.52	2.92*	0.52	1.54***
MNE_{ij}×Auto dummy	-8.84	-0.53	53.59	2.12*
MNE_{ij}×Hard disk dummy	9.96	0.49	94.67	2.40*
Inversed mill ratio	-	-	0.14	0.52
Dj	Included		Included	
No. of obs	17,427		1191	

Log likelihood	5058.57	Root MSE = 0.98
Wald chi2	1643.85 (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 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 significant 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

Table 6: 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	-11.54	-8.35*	-0.30	-0.11
MNE_{ij}	-9.69	-1.25	11.89	0.83
Ex_{ij}	0.34	0.47	-0.56	-1.00
Age_{ij}	0.35	2.47*	0.10	0.37
$Age_{ij}^{\wedge 2}$	-0.04	-1.52***	-0.03	-0.52
$PROD_{ij}$	-0.12	-4.40*	0.07	1.46***
Sizeij	0.88	6.03*	0.12	0.43
$Size_{ij}^{\wedge 2}$	-0.02	-4.38*	-0.008	-1.01
KL_{ij}	0.05	3.04*	-0.04	-1.14
BOI_{ij}	-0.009	-0.03	-	-
$region_{ij}$	0.13	2.25*	0.26	2.05*
$Network_{j}$	0.04	0.17	0.63	1.77**
MNE_{ij}×Auto dummy	16.65	0.96	57.39	2.52*
MNE_{ij}×Hard disk dummy	-36.99	-1.29	-1.00	-0.02
Inversed mill ratio	-	-	1.82	2.20*
Dj	Included		Included	
No. of obs	17,473		748	
Log likelihood	5893.83		Root MSE = 0.88	
Wald chi2	917.03 (Prob>chi2 = 0.00)			
Wald-test for exogeneity	0.36 (Prob>chi2 = 0.55)			

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 significant 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

Interestingly, when R&D intensity is considered (Column B of Tables 4, 5 and 6), the positive relationship is found for the interaction term between MNEs and automotive industry dummy variable for all three types of R&D activities. For the hard disk drive industry, such positive relationship is found for R&D improved production technology and R&D product development. This result shows that MNE affiliates in both industries set up R&D activities in Thailand, confirming the world-class production bases of the country in these two industries.[13] Meanwhile, the expenditure of R&D activities in these two industries tends to be far higher than the other, leading to a significant coefficient corresponding to such interaction terms.

In contrast to MNEs, the positive sign is found for 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 4 and 6). The statistical insignificance implies that the probability of firms to invest in R&D for improving production technology and for process innovation is not affected by market destination, i.e. either domestic or export markets.

This study finds the *positive* and *statistically significant* relationship between exports and a firm's decision to invest in R&D product development (Table 5). The statistical significance for R&D product development, but not for production technology and process innovation, could reflect that exporters tend to learn more about competing products and customer preference in international market, but the ability to access information relating to improving production technology and process innovation is still limited. The information on competing products and customer preference could come from customer feedback; export intermediaries and other foreign agents. Thus, information passed from foreign customer help firms innovate/tailor product to meet the specific needs of international market. 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 intense global competition that would begin to stimulate firms to invest in R&D leading to improved production technology and process innovation.

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 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 have more experience in changing production process and adopting new technologies than younger firms. Interestingly, for R&D process innovation, we find that ($Age^{\wedge 2}$) is negative and statistical significance along with a significantly positive sign of *Age*. This implies that the incentive of firms to invest in process innovation would become negative when the firms are getting too old. In this study, we find that when firm age is over 70 years, the probability of firms to invest in

[13] While (real) wages in Thailand have continued to grow, albeit on a lower growth path since the 1997–1998 crisis, the global export shares of both industries have shown an upward trend for a decade.

R&D process innovation would become negative. Note that the negative sign of $Age^{\wedge 2}$ is also found in R&D improved production technology and R&D product development but statistical insignificance.

The non-linear relationship between firm size ($Size_{ij}$) and a decision of firm to invest in R&D activity is also found in this study. The positive sign of firm size reflects the fact that R&D activity involves with high fixed costs. Meanwhile capital market is imperfect so that larger firms, which likely to have stability of funds, can afford to invest more in R&D than smaller firms. However, the negative sign of $Size^{\wedge 2}$ 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 some certain level. In other word, after the firm can reach a break-even point, other factors would become more important for the firm decision making. In this study, such level of firm size, measured by sales, would be around 126 billion baht. Firm size is also statistically significant in R&D intensity for both improved production technology and product development.

In addition to firm age and firm size, our study finds the negative and statistically significant relationship between a firm's productivity ($PROD_{ij}$) and a firm's decision to invest in all three types of R&Ds. 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 who has lower productivity would be higher than a firm who has high productivity. This tends to reflect the possible catching up behavior at the firm level, not only to improve its own productivity, but also to survive in intense competition environment. The coefficient corresponding to this variable is the highest for R&D process innovation, followed by R&D product development and improved production technology. This may reflect the fact that to improve a firm's productivity, (smaller) firms tend to use process innovation mode before improving production technology, which is relatively higher fixed costs. Interestingly, once firms already made a decision to invest in R&D, a firm that has higher productivity tends to invest more in R&D, especially in product development. This is shown by the positive sign of a firm's productivity ($PROD_{ij}$) in determining R&D intensity. As productivity could affect the prospects of the firm's future profit, firms with higher productivity are likely to spend more for R&D investment (Lazonick, 2006).

The model also shows that firms that produce more capital-intensive industry have a higher probability to involve in all three types of R&D activities, confirming the nature of industry could influence a firm's decision to invest in R&D. 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 coefficient corresponding to "region" in both a firm's decision to invest in R&Ds and R&D intensity (Column A and B of Table 4, 5, 6).

The 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.[14] This result could, to some extent, reflect that the government policy so far is not effective enough to influence a firm's decision to set up R&D activity. By contrast, other fundamental variables, such as firm age, firm size, firm productivity, and other industrial characteristics, play more crucial role in influencing the firm's decision making. However, when we consider only domestically-owned firm in R&D spillover (Table 7), government policy (BOI) positively increase the probability of a firm to invest 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, which most of their decisions are influenced by their parent company (firm specific factors) while government policy is less relevant. Government policy, by contrast, tends to affect more on the decision of domestically-owned firms in setting up R&D since most of them are disadvantage in terms of proprietary assets and need more support from government.

Meanwhile, the positive relationship of "network" and a firm's decision to invest in R&D, supports the role of international production network in promoting a firm's R&D decision. The dynamism of industries involving in production network is likely to require more R&D investment to keep the industry upbeat and competitive in the international market. Not only a firm's decision, "network" is also statistically significant and positive for R&D intensity for all three types. This implies that the higher the degree of international production network, the greater the R&D expenditure is expected.

Note that some fundamental variables such as firm age are statistically insignificant in R&D intensity equations (equations 1.2; 2.2 and 3.2). The inability to capture well their relationship could result from the smaller sample size of firms who involve in R&D activity. In addition, the variation of R&D expenditure is limited among these firms. For example, in R&D improved production technology, there are only 1,018 firms who decide to set up R&D activity and the R&D expenditures are mostly set by less than (or equal) 10 percent. The low variation of R&D expenditure may make it rather difficult to reveal the relationship, statistically.

R&D spillovers

Interestingly, although there is evident that most of multinational firms tend to import technology, instead of establish R&D activity in the host country (except some industries such as automotive and hard disk drive industries), multinational firms tend to stimulate indigenous firms to invest more in R&D activity (i.e. spillovers). Such evidence is supported by the positive 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 7). Among three types of R&D activities, the spillover tends to be strong in the product development, followed by process innovation. The strong spillovers in product development

[14] 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. The disaggregated details of government policy in each industry, which so far are not available, may help to improve accuracy of our model.

and process innovation support the important process of demonstration and imitation in generating R&D spillovers. Intense competition from entering of MNEs might play some role in generating spillover and encouraging domestic firms to invest in R&D and reduce costs. However, the relatively weak significance of FOR in R&D improved production technology may arise because of the relatively high fixed costs of such investment so that it limits the possible positive effect that could arise from demonstration and imitation effects. Note that there is no industry outliner in stimulating spillovers as coefficients corresponding to interaction terms between FOR and industry dummy variables, including hard disk drive industry are statistically insignificant and excluded from the reported results.

Table 7: 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	-14.06	-10.91*	-12.23	-8.90*	-12.78	-11.03*
FOR_j	0.004	1.50***	0.004	1.70**	0.003	1.76**
Ex_{ij}	-1.30	-1.27	1.34	1.45***	-2.02	-1.20
Age_{ij}	0.05	1.62**	0.10	3.64*	0.17	1.56**
$Age_{ij}^{\wedge 2}$	-	-	-	-	-0.02	-0.81
$PROD_{ij}$	-0.14	-5.67*	-0.14	-5.48*	-0.14	-6.59*
$Size_{ij}$	1.06	7.21*	1.02	7.29*	0.92	6.51*
$Size_{ij}^{\wedge 2}$	-0.02	-5.40*	-0.02	-5.64*	-0.02	-4.60*
KL_{ij}	0.10	5.88*	0.06	4.24*	0.07	4.71*
BOI_{ij}	0.92	2.08*	-0.29	-0.70	1.08	1.49***
$region_{ij}$	-0.02	-0.43	0.22	4.24*	0.06	1.19
$Network_j$	0.45	1.84**	0.64	2.92*	-	-
D_j	Included		Included		Included	
No. of obs	16,221		16,245		16,289	
Log likelihood	7347.51		7095.7		10290.9	
Wald chi2	1167.4 (prob>chi2 = 0.00)		1370.4 (prob>chi2 = 0.00)		1 (prob>chi2 = 0.00)	
Wald-test for exogeneity	1.88 (prob>chi2 = 0.17)		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 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 significant level at 5, 10 and 15%, respectively,
(3) Interaction terms between FOR and industry dummy variables are all insignificant,
(4) Industrial dummy variables are included (according to ISIC) in included in the estimation.
Source: Authors' estimations

The model shows the mild significance of exporting and a 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 decision to invest in R&D leading to production technology and process innovation. This is consistent with the above finding when we include both domestic and foreign firms, i.e. entering in export market tends to help firms get/learn more information about products and consumer preference than production technology and process innovation. However, the smaller coefficient of this variable, compared to a situation that we consider both foreign and domestic firms, reflects the fact that domestic firms still have limited knowledge in world market, especially in terms of networking, compared to foreign firms. In addition, the negative relationship between exporting and a firm's decision to invest in R&D production technology also reflects the fact that indigenous firms, who export, could access/update new production technology easier than other domestic firms so that they are likely to import production technology, instead of involving in 'technology generation'.

Firm age, firm size, capital intensity matters in affecting the decision of domestically-owned firms in investing in all types of R&D activity (Table 7). The positive relationship of these variables and the firm's R&D decision is found. In particular, the non-linear relationship between firm size and the firm's R&D decision is revealed in all these three types of R&D activities. The catching up behavior at the firm level is still found in a case of domestically-owned firms as suggested by the negative and statistical significance of coefficients corresponding to a firm's productivity variable. The production network (network) tends to positively and significantly affect the probability of a domestic firm to invest in R&D 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 by using plant-level data in Thai manufacturing. Three types of R&D investment are considered in this study, namely R&D leading to improved production technology; R&D leading to product development and R&D leading to process innovation. The paper shows that firm-specific factors, including firm age; firm size; firm productivity, and capital-labor ratio are very crucial in determining R&D activities. Government policy could help to stimulate R&D activities, mostly for indigenous firms in the areas of production technology and process innovation while infrastructure is very crucial in promoting all types of R&D activities.

MNEs do not have a significant positive direct impact to influence a firm's decision to invest in all types of R&D. This implies that most of MNE affiliates still import technology from their parent companies. The negative and significant impact of MNEs on R&D leading to product development also confirms that almost R&D activity to innovate new products is still within the parent company.

However, automotive and hard disk drive industries are two exceptional cases where MNE affiliates in these industries have a significant and positive impact on R&D activities in Thailand. Particularly for the automotive industries, entering of MNEs generates all three types of R&D activities in Thailand while in hard disk drive industry, the role of MNEs is found more in product development and production technology. The results confirm the world-class production bases of the country in these two industries.

Though most MNEs could not generate positive and direct impact on R&D activity in the host country, they could generate the spillover effect by stimulating indigenous firms to invest in R&D activity, especially for product development and process innovation. This is done mainly through demonstration and imitation processes.

Exporting tends to have a positive and significant impact only on a firm's decision to invest in R&D leading to product development, but not for the other two. This implies entering in export market tends to help firms to learn more about competing products and customer preference, but the ability to access the information relating to improving production technology and process innovation is limited from exporting channel.

Our study highlights another potential gains from MNEs on R&D activities of indigenous firms. This happens even when MNE affiliates rely heavily on technology transmission instead of technology generation at the host country. Although providing specific recommendation to entice MNEs into the host country is far beyond the scope of the current study, our finding raise awareness of the host country policymakers in designing policy toward MNEs. Putting too much emphasis and effort to promote MNE technology generation activities in the host country cannot be ensured the benefit but could jeopardize the overall investment climate.

Our findings suggest the passive role of government in promoting firms to commit R&D investment. It is likely that firms' decision to commit such investment largely depends on firm-specific factors as well as overall competitive environment. Improving infrastructure truly matters in promoting all types of R&D activities. This could eventually attract more foreign direct investment into the host country, generating spillover impacts to indigenous firms. In-depth and firm-level case studies are needed to provide in detail types of infrastructure services that yield the highest outcome in terms of R&D development. Government promotion policy, through Broad of investment such as tax exemption, could be done to spur R&D activity but from our study, its effectiveness is likely to be limited only for certain types of R&Ds and mostly for domestically owned-firms.

Acknowledgement

This paper received financial support from Economic Research Institute for ASEAN and East Asia. The authors would like to thanks participants in workshop "Globalization and Innovation in Asia", organized by Economic Research Institute for ASEAN and East Asia, during 19-20 December 2010, Bali, Indonesia and 25-26 February 2011, Bangkok, Thailand.

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