THE ROLE OF RESEARCH AND DEVELOPMENT (R&D) ON EXPORT PERFORMANCE: A STUDY OF MANUFACTURING FIRMS IN THAILAND

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by

Panisa Vishuphong

A Thesis submitted in partial fulfillment of
the requirements for the degree of

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ABSTRACT

After the economic crisis in 1997, R&D began to play an important role on Thailand. In the public sector, the Thai government implemented R&D incentives including tax allowances and soft loans. In the private sector, the amount of R&D expenditure considerably increased from 512 million baht in 1997 to 4,094 million baht in 2001. One of the firm's objectives to implement R&D is to recover competitiveness and export performance which decreased during the economic crisis.

However, the benefits of R&D on export performance to firms in Thailand remain ambiguous. A number of studies propose that R&D can improve the export performance of those firms only in the developed countries but not beneficially to those in the developing countries. On the contrary, some studies argue that the advantage of R&D on export performance should not overlook those firms in the developing countries.

To manifest the role of R&D on the export performance of manufacturing firms in Thailand, this study comprises two objectives. The first objective is to estimate the effect of R&D intensity on the firm's export performance. The second objective is to discriminate the R&D behavior of the exporting firms from the R&D behavior of the non-exporting firms.

For the first objective, there are two alternative models; the single censored tobit model and the Cragg's two stage specification. In this study, the log-likelihood ratio test (LR-test) suggests that the tobit model is more appropriate for our analysis, thus the tobit model is applied to all of the estimations. For the second objective, the analysis of variance (ANOVA) is employed to compare the mean differences. The data used in this study is secondary firm-level data, "The Thailand R&D/Innovation Survey 2003", which is collected by The National Science and Technology Development Agency (NSTDA)

The estimated results of the first objective found that the R&D intensity and firm's size determine export performance of Thai firms, while skilled labor has no influence on export performance. On the contrary, R&D intensity does not determine export performance of non-Thai firms.

For Thai firms, R&D intensity affects export performance in positive way. An increasing in R&D intensity increases firm's export intensity. R&D improves productivity, and consequently increases export performance. For firm's size, this study found the inverted U-shaped relationship between firm's size and export. This indicates that the large Thai firms have superior export performance than the small Thai firms do. However, very large firms tend to sell their products on the domestic markets rather than export them.

For non-Thai firms, R&D intensity does not have an impact on the export performance. The export performance of non-Thai firms is determined by firm's size. This finding implies that export performance of non-Thai firms is not derived from R&D. Non-Thai firms may perform R&D in their countries and export R&D output to affiliate in Thailand. This finding indicates that the behavior of MNEs in Thailand corresponding to the concept of multiplant economy of scale.

Additionally, the result of this study suggests that R&D intensity affects export performance of firms in supplier dominated industries and scale intensive industries, but no influence on export performance of firms in specialized supplier and science based industries. This concludes that, for Thai manufacturing firms, R&D can improve export performance of firms in low and medium technology industries.

For the second objective, this study finds that, among firms perform R&D, R&D intensity and the share of own design products in total sale of Thai exporting firms are higher than that of Thai non-exporting firms. This outcome suggests that carrying out R&D activity and having R&D intensity and its own design product are the important distinguish for the exportation of Thai firms.

The finding of this study proposes three important issues. Firstly, MNEs behave in R&D different from local firms. MNEs behavior in R&D does not link with their export. R&D may determine export performance of only local firms. Secondly, with the specific characteristics of developing countries, although R&D intensity determine export performance of local firms, its may have effect on the local firms in low and medium technology industries. Finally, to enhance export performance of the local firms in developing countries, which are technology-followers, non-R&D activities such as design activity should be considered.

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I solely take full responsibility for any deficiencies and shortcoming in this thesis. Any criticisms from the readers are welcomed.

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CHAPTER 1

INTRODUCTION

"All is transient, nothing is permanent"

- Buddha Shakyamuni[1]

1.1 Statement of the Problem

The export has been the basic engine of Thailand's economic growth over the past three decades. Before the 1970s, due to the import substitution policies, Thai manufacturing centered on a domestic market. However, the small domestic market combined with an increase in trade deficits in the early 1970s pressured Thailand's policy makers to draw attention to an export strategy. Export promotion policies were implemented and had been in effect for Thai industries, especially in labor-intensive industries. During the period of the export promotion policy, Thai GDP dramatically increased. The export accounted for a large share of GDP and was considered to be a principal source of economic growth (Kohpaiboon, 2006). A rapidly rising growth rate reflected the success of the export-led growth strategy in Thailand.

The export-led-growth strategy is widely accepted as a beneficial strategy for developing countries with the small domestic market. The export enables firms to increase their profits with high returns in the international markets, to enlarge market share, and to have economies of scale, for instance. The export-led-growth strategy also establishes a link between the economy of a developing country and the world. Similarly, the export brings the Thai economy into contact with the world economy. This link has been considered as an important factor of Thailand's structural transformation from primary to secondary economic activities. An economy in transition is widely recognized through the pace of its economic development.

For countries following the export-led-growth strategy, it is crucial to have a continual growth of export in order to sustain long-term economic growth. By doing so, Thailand is obliged to be competitive in the world markets. A historical

[1] Cited in Kiatipong, Cheerapan, and Chatsurank (2006)

background of Thai export identifies that the competitiveness of Thai manufacturing has derived from relatively low wages, and in turn, cost advantages. The cost advantages contribute to a superior performance in export, particularly for resource-based and light manufacturing goods.

In the late 1995, the level of exports began to decline, particularly in labor-intensive industries (Kohpaiboon, 2006). The decreasing in the labor intensive exports was a sign of a vanishing of the cost advantages of Thai manufacturing and a shifting of the world demand from labor-intensive to technology-intensive goods. Primary, resource-based and light manufacturing goods are not very dynamic in the world trade nowadays (Lall, 2000). Changes in the world trade pattern from cost competition to technological competition alter the rules of the game. Thai manufacturing cannot escape today's technology-oriented competition. The Thai exporting firms that desire to survive in the world market have to adjust their production to correspond with world demand. All industrial activities need to constantly upgrade their technologies to retain international competitiveness.

In order to have competitiveness in the world of technology, research and development (R&D) is widely accepted as the way of technological improvement. It has been proposed by many preceding studies that R&D can improve export performance. Performing R&D makes firms benefit from productivity improvements (Crepon, Duguet, and Mairesse; 1998), cost reductions (Johnston, 1966; Blind, 2001; Rodriguez and Rodriguez, 2005; and DiPietro and Anoruo, 2006), and new product developments (Krugman, 1979; Grossman and Helpman, 1990). The benefits of R&D enhance firms' performance and competitiveness. Consequently, in the context of international trade, the export performance is improved.

In Thailand, R&D expenditures in the private sector dramatically increased after the economic crisis in 1997. The largest part of them is in the manufacturing sector. In the public sector, the Thai government introduced a series of measures to enlarge private R&D expenditures. R&D is anticipated to be a new strategy in helping manufacturing firms to recover the export performance and the competitiveness. The statistical evidence indicates that the both the private and public sectors in Thailand underscore the worth of R&D and look forward to exploit the benefits derived from it.

However, the benefits of R&D on the export performance of manufacturing firms in Thailand remain ambiguous. One important notification is that Thailand is developing countries. There are the number of theories mentioned that R&D improves export performance of developed countries, but not developing countries[2]. Developed countries have superior technology to developing countries, thus firms in developed countries create new products (and/or production processes) and then trade on the world market. Meanwhile, firms in developing countries attempted to imitate those new products (Walker, 1979). According to the theories above, R&D directly involves the export performance of developed countries because it increases probability of success in new product expansions. Conversely, it seems that R&D does not involve the export performance of developing countries.

However, many studies argued that the suggestion that R&D plays no role in the export performance of developing countries is too restricted. The imitation and technology acquisition have some costs and risks. Consequently, firms in developing countries have incentive to carry out R&D as well.

In addition, although the exporting firms in developing countries produce their export products by imitating new products established by developed countries, they also have the incentives to perform R&D in order to successfully compete with the exporting firms in other developing countries. Moreover, as mention earlier, the exporting firms in developing countries are pressured by the continued increasing in the world demand for high quality and high technology products. From these reasons, there are several studies argued that R&D is important for firms in developing countries, and are related to export performance. The conclusion of this question remains under discussion.

In light of these concerns, this study, therefore, tries to analyze the role of R&D on export performance of manufacturing firms in Thailand. The analysis aims to acquire accurate results regarding the role of R&D on the export performance in the case of Thailand. Results should be completed regarding the aspect of developing countries.

Furthermore, the development of Thai manufacturing closely involves with the presence of multinational enterprises (MNEs). MNEs and Thai owned firms may

[2] See Posner (1961), Hirsch (1965), Vernon (1966).

have differences in both R&D and export behavior[3]. Hence, regarding the importance of MNEs, the outcome of the analysis may differ from other developing countries.

In short, this study analyzes the role of R&D on the export performance of manufacturing firms in Thailand with two objectives. The first objective is to estimate the effect of R&D intensity on the export performance. The second objective is to investigate the differences in the R&D behavior between the exporting and non-exporting firms. The second objective is beneficial for studying the role of R&D in the developing countries. In developing countries, the benefits of R&D are not only the results from R&D intensity but also R&D behavior (Forbes and Wield, 2000).

An analysis of the role of R&D on the export performance of manufacturing firms in Thailand will be fruitful in twofold. Firstly, it provides an understanding of Thai export performance and its determinants, regarding the context of technology. It is beneficial for firms and policy makers to successfully establish relevant strategies of R&D to enhance export performance, which respectively associates with competitiveness, and the long-term economic growth.

As discussed previously, the role of R&D on the export of developing countries remains unclear. Secondly, understanding the effect of R&D on export performance of Thai manufacturing allows us to have a clearer picture of the effect of R&D on the export performance of developing countries. In addition, examining the role of R&D on export performance regarding the presence of MNEs will be useful for further studies of the countries in which the economy is being driven by MNEs.

1.2 Objectives of the Study

This thesis aims to study the two following objectives:

1. To estimate the effect of R&D intensity on the export performance of manufacturing firms in Thailand.

2. To investigate the differences in R&D behavior between exporting firms and firms without export (non-exporting firms).

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[3] See Markusen (1984).

1.3 Scope of the Study

This study estimates the impact of R&D on export performance by using a cross-section of firm-level data of Thai manufacturing firms collected in 2003 by The National Science & Technology Development Agency (NSTDA). The definitions of R&D in this study follow the NSTDA survey[4]. This study focuses on the following industries; food and beverage, textiles, wearing apparel, leather, wood products, paper products, chemical, rubber and plastic, glass and non-metallic mineral products, metal products, machinery and equipment, electrical machinery and products, motor vehicle and parts, and transport equipment.

1.4 Organization of the Study

This study is organized as follows. Chapter 1 presents an introduction of the study. Chapter 2 provides overviews of export and R&D in Thailand. In chapter 3, the study discusses the theory involving R&D and export performance. Previous related literature and researches are also reviewed. A theoretical framework is provided in chapter 4. In chapter 5, data description and methodology employed for the analysis are outlined. Chapter 6 presents empirical results and discussions of the finding. Finally, conclusions and implications are discussed in chapter 7.

1.5 Glossary

Thai firms - Firms where 100% of its capital is held by Thai people.

Non-Thai firms - Firms report any share of foreign capital.

Exporting firms[5]- Firms report the share of exports of total sales is greater than zero (not sold 100% on the domestic market).

Non-exporting firms - Firms that not export at all (sold 100% on the domestic market).

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[4] See Appendix A.

[5] In a part of the analysis of variance, exporting and non-exporting firms refer to Thai firms with R&D, which is our sample of analysis.

CHAPTER 2

AN OVERVIEW OF THE EXPORT AND RESEARCH AND DEVELOPMENT (R&D) IN THAILAND

2.1 Historical Background of Thai Export

Thai manufacturing has been developing for three decades. At the start, due to the import substitution policies (ISI) of 1970s, Thai manufacturing centered on the domestic markets. Thai manufacturing was not concentrated on serving the export market. During this period, the exports of Thailand relied heavily on primary and resourced-based products such as traditional agricultural and mineral products.

At the same time as maintaining protection for ISI sectors, the government implemented export promotion policies in 1972. They introduced a series of measures to promote the manufacturing export through tax, tariff rebates, and preferential interest rates on short-term loans. During the period of export promotion policies, a number of industries which was established under the ISI promotion policies, such as a textile industry, began to export. Primary product exports as a percentage of the total exports started to fall, while manufacturing exports started to rise. Export promotion policies were significant internal factors for the rapid growth of Thai manufacturing exports in the period that followed (Anukoonwattana, 1999).

Table 2.1 illustrates the composition of Thai exports during 1976-2005. Thai exports grew rapidly in the period 1976-1980. The average growth rate was 21.68%. The major exports were primary goods such as food products (51.05%). The share of manufacturing exports overall was 28.99%, but its growth rate was impressive. While the average annual growth of primary products was approximately 10.58%, manufacturing exports grew by 36.67%. The export growth of footwear products was approximately 145.1%. Textile and garments became important Thai exports. Their export share accounted for 9.04% of total exports. The export composition and the export growth rate during this period reflected the expansion of food products and traditional light manufacturing goods in Thai exports.

Due to the collapse of world trade and commodity prices, the export growth rate slowed in the early 1980s (Anukoonwattana, 1999). The Thai government implemented a second round of export promotions, including tax incentives and two devaluations in 1981 and 1984. Despite these policies, the overall export growth rate during 1981-1985 was much lower than the growth in the 1970s. It is interesting that the share of manufacturing exports as part overall exports increased from 28.99% in preceding period to 35.35% in this period, whereas the share of primary exports decreased from 67.69% to 62.69%. It indicated that Thai exports began to transform from being primary and resourced-based to manufacturing-based exports.

The appreciation of Japan's and the East Asian Newly industrializing countries (NICs) currencies and the weakening US dollar after the 1985 Plaza Accord led Thai export growth to recover after 1986, because firms in those countries moved their investments to other countries. With the foreign direct investment (FDI) oriented policies and relatively low wages, Thailand was appreciated by foreign firms to invest in. The amount of FDI in Thailand dramatically increased in the late 1980s, in particular labor-intensive industries (Kohpaiboon, 2006). The presence of FDI gave substantial benefits to the textiles, garments, and electronics industries. During 1986-1990, textiles and garments accounted for 16.55% of manufacturing exports. The electronics industry, which had negative growth in the previous period, had a growth rate of 49.35%. FDI inflows also conduced the growth in other manufacturing exports such as machinery, automotive, and chemical industries.

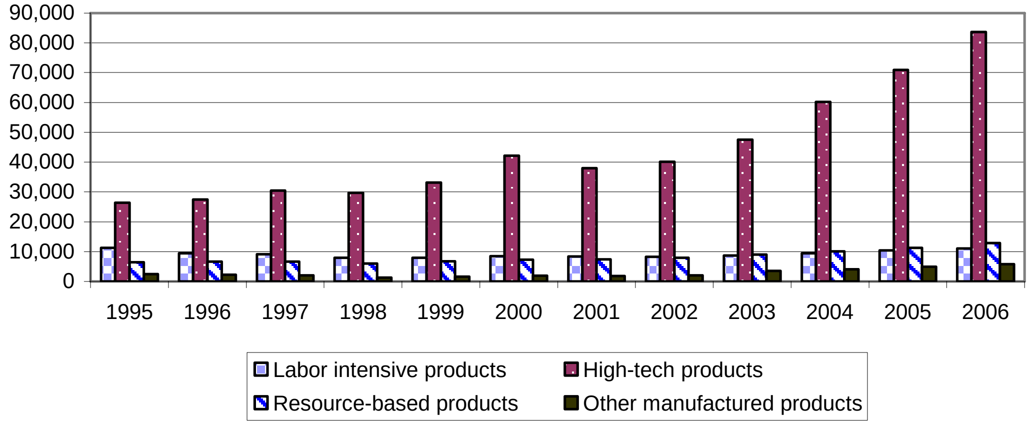
The transformation of Thai exports was considerable in the early of 1990s. During 1991-1995, the share of manufacturing exports as a total exports was 70.3%, while the share of primary exports was 28.85%. In addition, a growth rate of primary exports was lower than the growth of exports as a whole. In this period, the major export products of Thailand were still labor-intensive products. Textiles and garments remained important for Thai export. Electronics, automotive, machinery, transport equipment, and chemical industries began to play an important role in the exports of Thailand. Their annual growth rates were approximately 30%.

The impressive growth rate of Thai export began to be slow in late 1995, and was then followed by the economic crisis in 1997. The growth rate of total exports dropped from 19.68% in the preceding period to 4.42% in this period. The growth rate of primary exports was 0.84%, while the export growth of manufacturing product was 5.08%. The growth rates of textiles and garments, and footwear exports were -3.44% and -16.61% respectively. This reflects that the export products that relied on simple cost advantage were more affected by the economic crisis. After the crisis, the majority of Thai exports changed from labor-intensive products to mixed export products. The automotive industry started to play a significant role in Thai export. The share of automotive exports as a total exports increased from 1.39% in 1991-1995 to 2.55% in 1996-2000 and 5.41% in 2001-2005. The continued growth originated from the reason that Thailand became the production base of the automobile industry for this region.

During 2001-2005, the primary products accounted for 21.63% of overall exports, while manufacturing exports comprised 61.03%. The share of light manufacturing exports, such as textiles, garments, and footwear products, as a total of exports decreased. Conversely, the share of high technology exports such as chemical, machinery and transport equipment, and automotive products as a total of exports increased. This evidence reflected that Thai export started to change from exporting light-manufacturing products to high-technology products. Figure 2.1 illustrates the importance of manufacturing exports during 1995-2006. The export of manufacturing products has continually increased.

Figure 2.1

Exports Classified by Product Group (million US$)



Source: Bank of Thailand

Table 2.1

Thai Export Performance by Commodity Category 1976-2005*

	1976-1980			1981-1985			1986-1990**		
	Export values ($)	Composition (%)	Growth rate (%)	Export values ($)	Composition (%)	Growth rate (%)	Export values ($)	Composition (%)	Growth rate (%)
Total exports	4,471,302,758	100.00	21.68	6,978,875,085	100.00	2.21	15,905,446,031	100.00	35.77
Primary products	2,970,961,104	67.95	10.58	4,372,624,279	62.69	13.02	6,661,975,507	44.28	13.68
Food products	2,217,934,506	51.05	14.01	3,506,827,239	50.28	3.04	5,339,005,263	35.45	21.68
Manufacturing products	1,354,775,035	28.99	36.67	2,470,137,883	35.35	5.56	9,068,132,097	54.67	39.60
Plastics and Rubber	21,049,382	0.42	28.63	50,912,143	0.72	10.40	198,538,017	1.23	7.26
Paper	6,258,135	0.13	39.09	11,633,938	0.17	18.54	46,459,585	0.33	29.35
Textile and Garment	412,335,336	9.04	27.08	814,038,624	11.64	11.22	2,629,945,961	16.55	40.74
Footwear	6,455,744	0.12	145.10	68,907,152	0.99	45.07	393,054,647	2.22	75.85
Furniture	13,771,461	0.27	70.72	40,641,945	0.58	10.95	194,861,912	1.16	61.86
Machinery and Transport equipment	176,908,758	3.60	55.69	465,132,941	6.63	12.55	2,733,002,547	15.57	53.99
Electrical Machinery and appliances	29,658,925	0.64	36.99	46,915,575	0.67	-4.15	170,050,719	0.99	49.35
Automotive	7,938,948	0.17	44.20	12,161,681	0.17	-0.27	112,292,814	0.59	84.84
Chemical	21,462,642	0.46	32.41	49,473,395	0.71	13.90	197,089,139	1.20	40.54
others	145,566,620	3.07	18.09	136,112,922	1.95	-20.63	175,338,427	1.05	35.77

Source: Compiled from the UN COMTRADE database.

Note: * All figures in the Table are five years average of the value of export, export composition, and annual export growth rate.

** The data of year 1998 was not available.

	1991-1995			1996-2000			2001-2005		
	Export values ($)	Composition (%)	Growth rate (%)	Export values ($)	Composition (%)	Growth rate (%)	Export values ($)	Composition (%)	Growth rate (%)
Total exports	39,947,387,272	100.00	19.68	58,957,231,514	100.00	4.42	83,941,660,167	100.00	10.28
Primary Products	11,268,572,149	28.85	3.09	14,057,468,444	23.95	0.84	18,121,685,810	21.63	4.37
Food products	8,808,939,369	22.71	10.91	10,152,882,354	17.36	-1.79	11,203,446,034	13.61	5.46
Manufacturing Products	28,242,511,096	70.03	23.07	43,295,978,958	73.35	5.08	63,729,003,670	75.73	10.83
Plastics and Rubber	692,959,648	1.68	9.24	1,870,671,117	3.13	14.84	4,114,782,473	4.76	7.93
Paper	145,529,106	0.33	52.31	477,558,540	0.80	22.24	815,498,157	0.98	9.68
Textile and Garment	5,764,866,338	14.81	13.62	5,591,060,221	9.54	-3.44	6,073,923,359	7.39	3.93
Footwear	1,289,378,290	3.16	23.88	937,148,045	1.61	-16.61	786,533,420	0.97	2.74
Furniture	590,403,273	1.49	19.75	759,730,399	1.29	4.77	1,071,309,919	1.29	7.29
Machinery and Transport equipment	12,096,456,563	29.41	30.32	23,949,867,731	40.49	9.86	36,656,397,296	43.47	11.03
Electrical Machinery and appliances	550,317,196	1.37	21.61	875,925,481	1.48	6.97	1,501,608,797	1.75	16.62
Automotive	569,173,319	1.39	31.27	1,534,210,848	2.55	29.29	4,738,766,167	5.41	27.44
Chemical	818,206,281	1.99	35.96	1,452,228,423	2.44	8.48	2,819,639,640	3.30	17.09
others	436,304,027	1.12	1.86	1,603,784,112	2.70	40.70	2,090,970,687	2.64	-8.02

Source: Compiled from the UN COMTRADE database.

Note: * All figures in the Table are five years average of the value of export, export composition, and annual export growth rate.

In order to recover economic growth from the economic crisis in 1997, the Thai government attempted to regain Thailand's economic growth by implementing of export promotions and FDI-oriented policies (Intarakumnerd, 2004), but several Thai major exports currently confront a competitiveness drawback. For instance, the market share of processed food, textiles and garments, chemical, and leather products as total of world exports have declined overtime (Athukorala and Suphachalasai, 2004). The revealed comparative advantage index (RCA) showed that wood products, chemicals, basic manufacturing, and textiles are the incompetitive products in the world market (see Khoman, 2006).

The collapse of competitiveness in several exports was due to two causes. On the one hand, the cost advantages eroded from the rising relative real wage. On the other hand, the diminishing of competitiveness came from the weak technological capability of Thai manufacturing firms, which was the result of the lack of R&D investments (Lall, 1992), and shortage of skilled labors (Reinhardt, 2000). Thai manufacturing firms have grown without deepening their technological capability. Their learning capabilities were low and passive (Intarakumnerd, 2004). In addition, the competitiveness of Thai manufacturing industries was also moderated by the emergence of China in world export markets. Some FDI in labor-intensive industries moved from Thailand to China or "footloose" (Pananond, 2006).

The deficient technological capability of Thai manufacturing firms pointed to two important facts. First of all, FDI may not improve the technological development of Thai manufacturing as much as expected (Pananond, 2006). One reason is that many local firms had low absorptive capacity to receive advanced technological from foreign partners, and their technology efforts of local firms were near ground level (Lall, 2000). The level of R&D investment is low. Second of all, lacking technological capability may be due to the deficiency in science and technology at the national level. The next section is the discussion of this issue.

2.2 <u>An overview of Research and Development (R&D) in Thailand</u>

Research and development (R&D) in Thailand has been neglected for a long period. Over the past four decades, Thailand's economic development still mostly relies on natural resources and cheap labor, with less emphasis on technological activities. Manufacturing firms in Thailand have built up their technological capabilities by technology acquisition. As mentioned in the Ninth National Economic and Social Development Plan (2002-2006),

"A major portion of the industrial sector relies heavily on imported capital goods and fails to adapt and apply foreign advanced technologies effectively, raising total production cost. Furthermore, domestic science and technology development has not supported production sectors. Science and technology human resources are insufficient both in terms of quantity and quality. Research work is not oriented toward producing practical knowledge and applied technologies consistent with the needs of production sectors. As a result, Thai production sectors have been forced to continuously rely on foreign technologies."

Table 2.2 presents the total R&D expenditures (GERD) of Thailand and the proportion of R&D expenditures in Thailand per gross domestic product (GDP). During 1987-1999, R&D expenditures of Thailand were approximately 2,500-5,000 million baht. However, R&D expenditures have increased considerably in 2001. R&D expenditures increase from 5,021 million baht in 1999 to 11,056 million baht in 2001. In the year 2003, R&D expenditures of Thailand were approximately 15,449 million baht.

Table 2.2

R&D expenditures/GDP

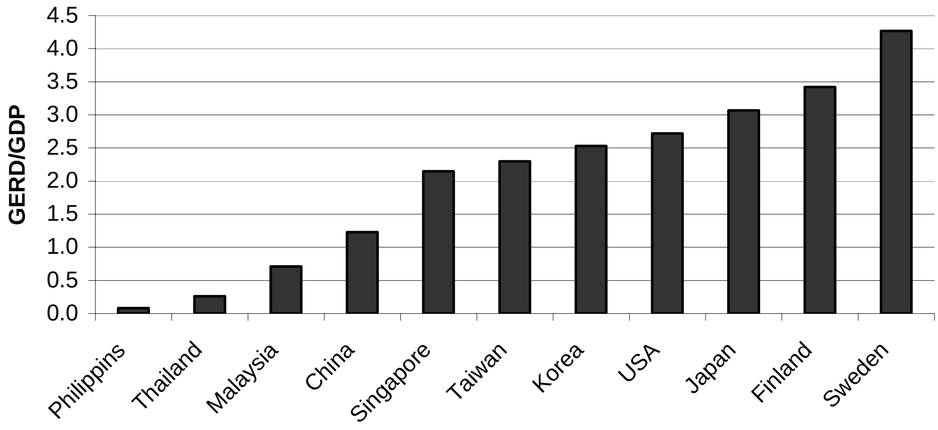
Year	R&D expenditures (million baht)	R&D expenditures/ GDP
1987	2,664	0.21
1989	2,908	0.15
1991	3,928	0.16
1993	4,473	0.14
1995	5,174	0.13
1996	5,528	0.12
1997	4,811	0.10
1999	5,021	0.11
2001	11,056	0.22
2003	15,449	0.26

Source: Office of the National Research Council of Thailand

Although R&D expenditures have increased, the proportion of R&D expenditures per GDP remained small. It reflects the slow progress in R&D over the past 15 years. Actual R&D expenditures have not risen but stayed at merely 0.2 percent of GDP, which is very small compare to other countries.

Figure 2.2

R&D Expenditures /GDP across Countries



Source: Office of the National Research Council of Thailand (data in 2003)

Figure 2.2 compares a share of R&D expenditures in GDP across countries. It seems obvious that the ratio of R&D expenditures over GDP is high in developed countries. In Sweden, The share of R&D expenditures as a proportion of GDP is 4.2. The share of R&D expenditures as a proportion of GDP of Finland, Japan, USA, Korea, Taiwan, and Singapore are greater than 2.0. In the developing countries, the share of R&D expenditures as a proportion of GDP is less than 2.0. For Thailand, the share of R&D expenditure in GDP is 0.2 which is lower than that for China and Malaysia. In China, the share of R&D expenditures in GDP is 1.23. The share of R&D expenditures in GDP is 0.71 in Malaysia.

Regarding the financial sources of R&D expenditures of Thailand, the public sector plays a more important role than the private sector. R&D expenditures from the public sector accounted for 63% of total R&D expenditures in 2001 (see Table 2.3).

Table 2.3

R&D Expenditures Classified by Sector

	1996	1997	1999	2001
Total R&D expenditures (million baht)	5,528	4,811	5,021	11,064
Government sector (million baht)	2,708	2,666	1,833	5,019
High education sector (million baht)	1,219	1,631	2,570	1,950
Business enterprise sector (million baht)	1,243	466	587	4,009
Private non-profit sector (million baht)	357	46	30	85

Source: Office of the National Research Council of Thailand

Table 2.3 presents R&D spending of Thailand classified by sector. The main sector being provided R&D expenditures was the government sector.

The Thai government not only provided a large amount of R&D spending but also exercised the Thailand Science and Technology (S&T) policies. However, the S&T policies neglected to stimulate R&D in the private sector. The policies were based on the view that private firms were science and technology passive and had no need of creating science and technology knowledge (Intarakumnerd, 2004).

Apart from the S&T policies, other policies were ineffective to stimulate R&D in private sector as well. The investment policies, particularly the promotion of foreign direct investment (FDI), were aimed primarily at generating capital inflow and employment, not at enhancing technology spillover from MNEs.

Nearly all of the trade policies were also operated for macroeconomic objectives. For instance, increasing tariffs was applied to reduce domestic demand for imported goods at the time of deficit in balance of a payments, rather than to promote the technological learning by Thai manufacturing (Intarakumnerd, 2004).

After the economic crisis in 1997, R&D and innovation strategies were reconsidered with a high priority. The Thai government sets of related policies and strategies have been adopted in building up indigenous technological capabilities in order to enhance competitiveness (Intarakumnerd, 2004). The Thai government introduced a new ten year Science and Technology Action Plan (2003-2013) which focuses on national innovation and clustered in selected industries. The project seeks to make the sector competitive, to increase the local content of assembled products, and to promote design and product development capability (UNCTAD, 2005). Private R&D has also been stimulated. There are two channels for stimulating private R&D, one by the Board of Investment, and the other by the Ministry of Finance. The Board of Investment (BOI) applied an investment package promoting “Skill, Technology and Innovation” or STI. This policy allows firms to benefit from one or two years extra tax incentives when they conduct the following activities in the first three years; spending on R&D or design at least 1-2 percent of their sales, employing scientists or engineers with at least a bachelors degree comprising at least 5% of their workforce, spending on training of their employees at least 1% of their total payroll, and spending on training the personnel of their local suppliers at least 1% of their total payroll (Intarakumnerd, 2004). The Ministry of Finance offered special accelerated depreciation for machinery and equipment purchased for R&D purposes, plus a combined 200 per cent tax credit for R&D expenditures. However, a success of R&D incentives remains blurred. Tax schemes may have a limited impact on technological activities of firms as the lack of confidence in the ability of tax auditors (Dhanani and Scholtes, 2002).

Although the government policy has not succeeded in stimulating the private investment in R&D, the diminishing of the export during the economic crisis and the high competition in the global market have led firms in manufacturing sector to recognize the importance of R&D and then carry out R&D automatically. The level of R&D performed in manufacturing sector after the economic crisis increases as shown in Table 2.3. R&D expenditures of the private sector (business enterprise sector and private non-profit sector) increased from 466 million baht in 1997 to 4,009 million baht in 2001. In addition, new firms emerging at this time were usually operated by managers with a strong R&D or engineering background (Intarakumnerd, 2004). These evidences indicate that the manufacturing firms in Thailand have realized the importance of R&D activity.

2.3 Conclusion

The export structure of Thailand has transformed from exporting primary products to manufacturing products. Manufacturing exports approximately account for 70% of total exports.

The impressive growth rate of manufacturing exports was sluggish during the Thailand economic crisis. In addition, some major export products tend to loose competitiveness. One important reason is weaken in technological capability of Thai manufacturing.

After the economic crisis in 1997, the importance of R&D was realized. The Thai government implemented the sets of policies and strategies related to science and technology improvement. In private sector, the level of R&D expenditures happened to increase considerably.

CHAPTER 3

REVIEW OF RELATED LITERATURES

As mentioned earlier, the role of R&D on export performance remains under discussion both from the theoretical and the empirical viewpoints. In order to have an overall picture of this topic, it is important to review the related works in both aspects.

This chapter reviews related theories and previous empirical studies on R&D and exports. At first, this study discussed the conceptions of R&D and exports in a section 3.1. This section includes the firms' benefits regarding R&D, R&D and trade behavior, and the nature of R&D in developing countries. A section 3.2 reviews previous empirical works involving R&D and export performance. At last, conclusion and remark for the study of Thailand are discussed in a section 3.3.

3.1 Reviews of the Conceptual Discussion

Theoretical discussions on R&D and export performance have many aspects. This study begins with the benefits of R&D to firms, and their export performance. Since the role of R&D in developing and developed countries is different, discussions about the nature of R&D in developing countries are also considered.

3.1.1 Firms' Benefits of R&D

At first, the benefits of R&D on firms are discussed. It is important to note that the benefits of R&D are not directly derived from R&D inputs (R&D expenditures, R&D personnel), but from R&D outputs (Science and technology, innovations) (Crepon, Dugest, and Mairesse, 1998). Outputs of R&D depend on the objective of conducting R&D. Firms may perhaps carry out R&D in order to develop production processes, improve the quality of existing products, and expand into new products and processes.

Basically, R&D contributes benefits to firms in two forms; cost reduction and product development. Johnston (1966), Crepon, Dugest, and Mairesse (1998) pointed out that R&D reduces the production cost by productivity increase (Crepon, Dugest, and Mairesse, 1998), labor saving (Johnston, 1966), and increasing returns to scale technology (IRTS) (Romer, 2001). Because of increasing in productivity, labor saving and an increasing return to scale technology, firms can reduce the average cost of production. Firms with R&D can produce at the lower cost than other firms.

Besides, R&D induces the product development. R&D pushes technology frontier and increases firms' capability to produce new products (or improve existing products). New products can replace firms' existing products that are already out-of-date and then allows firms to maintain their profits and competitiveness. In addition, if new products are very different from existing products in the market, firms will be able to gain some monopolistic power and to charge a price above marginal cost, and then obtain excess profits (Grossman and Helpman, 1990).

Up to now, it is obvious that R&D improves firms' performance. With such a superior performance, firms have a higher competitiveness over competitors. From this reason, it seems that firms with R&D should have higher export performance. However, in the context of international trade, the discussion over the benefits of R&D on exports is complicated. Export performance is influenced by several factors. R&D may or may not enhance firms' export. This issue will be discussed on the next section.

3.1.2 R&D and Trade Behavior

Many previous studies on R&D and export performance frequently draw on the technology-gap[1] theory. The technology-gap theory attempts to explain trade patterns between developed and developing countries by assuming that the level of technology of developed and developing countries are different. In this theory, the difference in technology or "technology gap" determines trade pattern among countries (Kumar and Siddharthan, 1994). Developed countries originate new

[1] See Posner (1961), Hirsch (1965), and Vernon (1966) for more detail.

products (or new production processes) and sell them to the world markets. Developing countries attempt to imitate the products. However, the imitation of new products takes time. During this time, developed countries are the major exporters. After developing countries succeed in imitating new products, and with the advantage of labor cost, they become the major exporters taking places of those in developed countries. Developed countries have to develop new products by conducting R&D in order to maintain export performance. In this theory, it seems obvious that R&D determines export performance of developed countries. For developing countries, export performance is not influenced by R&D.

The technology-gap theory considers developing countries like the "South" and developed countries like the "North" in the North-South international trade model[2]. In this framework, developed countries or "North" perform R&D and obtain new technologies (or R&D outputs), and then transfer[3] them to developing countries or "South". For the South, using new technologies developed by the North are cost-free, easy, and incur no risks. Under this assumption, firms in the South have no incentive (and may no potential) to perform R&D by themselves.

Nonetheless, many economists argued that the model of a technology gap may not appropriate to explain the export performance of developing countries (Kumar and Siddharthan, 1994). Lall (2000) proposed that importing technologies from developed countries is often costly, risky, and unpredictable for developing countries. Firms in developing countries run with an imperfect knowledge in finding and learning to master new technology. Lots of technologies have an important tacit component which is difficult to be codified (Rodriquez and Rodriquez, 2005). Firms may possibly have success or failure in applying new imported technologies. With the presence of organising cost on imported technologies, firms in developing countries have incentives to create own technologies, and carry out R&D by themselves.

Besides, using the technology-gap theory to explain the role of R&D on export of developing countries is restricted by an assumption that technological capability of each developing country is equal. Actually, the technology level among

[2] See Krugman (1979), Grossman and Helpman (1992) for more detail.

[3] The transfer of technology between north and south countries may be both intentional (technology transfer) and unintentional transfers (such as imitation).

developing countries is asymmetric. When firms in developing countries carry out R&D, they can improve the technological capability and have the superior export performance over competitors (other exporters in developing countries). Expected benefits from an increasing in export performance induce firms to carry out R&D. In conclusion, firms in developing countries also have the incentive to undertake R&D with the intention of improving export performance.

Additionally, the dramatically increase in world demand for quality and high technology products indicates that developing countries cannot merely rely on the cost advantages from lower labor cost forever. Firms who would like to survive in the world markets must produce the products which correspond to the world demand. Alternative speaking, firms in developing countries are obliged to carry out R&D in order to export success. It leads to the similar conclusion like other above discussions. R&D determines export success of firms in developing countries as well.

From the above discussions, we observed that the role of R&D in developing countries differs from developed countries, and requires further discussion. Section 3.1.3 discusses the nature of R&D in developing countries including a) the role and organisation of R&D in a technology follower and b) Industrial structure and the role of R&D.

3.1.3 The Nature of R&D in Developing Countries

As discussed before, the role of R&D on export performance of developing countries differs from developed countries. Since this study analyzes the role of R&D on export performance of firms in Thailand, which is a developing country, the nature of R&D in developing countries will be taken into account.

There are two central aspects on the nature of R&D in developing countries. Firstly, since developing countries are technology-followers[4] by nature, the role and organisation of R&D in technology-followers will be discussed. Secondly, according

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[4] Forbes and Wield (2000) define technology-follower as countries (and firms within them) which their technology levels can be far, near, or at the technology frontier, but not involved in pushing it forward. The technology-leaders countries (or firms) are those who move technology frontier forward.

to Kumar and Siddharthan (1994), the benefits of R&D on export performance of developing countries vary across industries and should also be considered.

a) The Role and Organisation of R&D in Technology-Followers

Based on Forbes and Wield (2000), the role and organisation of R&D in technology-followers are different from technology-leaders. They stated the functions of R&D in technology-follower as follows,

- *R&D as a complement to shop-floor innovations.*

In technology-followers, many production problems arise at shop-floor[5] level. Doing R&D led firms solving the problems effectively and systematically. A bulk of benefits from R&D as a means of shop-floor problem solving depend on whether or not R&D is performed closely and permanently connected to the firms. Alternative speaking, an in-house R&D[6] is required.

Having the in-house R&D allows R&D personnel to observe routine problems taking place at shop-floor level, and then efficiently removed. It is also more convenient to solve bigger and longer term shop-floor problems. The benefits of R&D on shop-floor problem solving are one of the keys to success in R&D for technology-follower firms.

- *R&D as the formal learning unit of the firms*

In technology-leaders, R&D acts like the formal innovating unit of firms. In technology-followers, R&D acts like the formal learning unit. Therefore, a successful R&D activity in technology-followers should be carried out to improve firm's learning capability. In other word, R&D activity

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[5] The part of a factory or workshop where machinery is operated.

[6] Carry out R&D activity within firms.

should be performed with the intention of building firms’ absorptive capacity[7] in order to exploit and utilize knowledge and technology created by other firms (such as making use of new technologies created by technology-leader firms).

A key factor of firms’ learning capability is the role of “gatekeeper”. The gatekeeper is the qualified staff member searching for knowledge and technologies from external sources and then incorporating them into the firms’ internal stock of knowledge. According to the fact that an R&D department generally contains a high concentration of qualified people, R&D plays an important role in the firms’ learning capability.

- *R&D as a measure to build an independent product design capability*

In technology-followers, the development of new products is not derived from new technology, but from new designs. Design capability induces firms to increase value-added features to products. Since technology-follower firms cannot move the technological frontier forward, building design capability is an alternative manner to capture higher value-added features to products. In other words, technology-follower firms can push out the design frontier; even though their technology-frontier is unchanged.

- *R&D as a source of intangible spin-off benefits for the firm*

Finally, R&D provides intangible benefits for technology-follower firms. The intangible benefits can take place in several ways. For instance, R&D can set the tone for a discourse on technology. Conducting R&D attracts qualified people to join the firms. (See Forbes and Wield (2000) for more details)

[7] Cohen and Levinthal (1990) explained absorptive capacity as “firms’ ability to recognize the value of new information, assimilate it, and apply it to commercial ends.”

Based on Forbes and Wield (2000), the four criterions discussed above pertain to the role of R&D that effectively supports technology-follower firms to have long-term competitiveness. In other words, with the same level of R&D intensity, firms that perform R&D activity that corresponds to those criterions will have a higher export performance.

b) Industrial Structure and the Role of R&D

Kumar and Siddharthan (1994) proposed that, in developing countries, R&D determines the export performance of firms in low-technology and medium-technology industries, but does not affect export performance of firms in the high-technology industry. This section provides a clearer picture of this issue.

First of all, in developing countries, exporters rarely have competitiveness in technology-intensive products. In high-technology industries, the competitiveness is determined by product innovations. But there are only a few firms in developing countries that have the ability to compete through product innovation.

Furthermore, the markets of high-technology products have many barriers to entry, for instance, vertical integration and geographical diversification. Firms are required to provide product specific services such as instruction, installation, repairs, and maintenance. From all above reasons, it is difficult for firms in developing countries to compete in high-technology industries.

The suggestions of Kumar and Siddharthan (1994) are supported by Dijk (2002). He applied Pavitt's taxonomy[8], the well-known industrial classification, to categorize Indonesia manufacturing in order to control the effects of industrial variation on the exports of Indonesia. He found that the benefits of R&D on export performance in science based and specialized supplier industries, which are high-technology industries, are small.

In addition, since Thai economy, as mentioned earlier, closely involves with the foreign direct investment. The behavior of MNEs should also be considered. The

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[8] See appendix B.

concept of multiplant economy of scale and R&D behavior of MNEs is discussed in a section 3.1.4.

3.1.4 The Multiplant Economy of Scale and R&D Behavior of MNEs

Markusen (1984) introduced a concept of "economies of multiplant operation" which explains MNEs behavior in host countries. He proposed that the behavior of MNEs and locally-owned firms in economic activity is different. This theory also encompasses the R&D behavior of MNEs, which are different from the R&D behavior of local firms.

Based on this theory, MNEs firms may be composed of many plants. One plant (or more) carries out non-production activities such as operation, research, and service.

The outputs of the non-production plant are the "joint inputs" of all plant productions. In particular, outputs of the non-production plant are typically intangible assets that can be jointly used by other production plants. The intangible assets, for example, consist of R&D, advertising, marketing, and distribution.

Regarding R&D activity, based on the multiplant economy of scale, the cost of doing R&D by MNEs is independent of the number of plants. After the non-production plant of MNEs succeed in R&D, all plants of MNEs can exploit R&D outputs. The average cost of R&D is reduced in proportion to the number of plants. For this reason, MNEs do not have the incentive to carry out R&D in their affiliates in host countries. Although the affiliates of MNEs in host countries do not perform R&D by themselves, they are able to make use of R&D outputs (produced by another plant in MNEs) to improve export performance. Therefore, the level of export performance of MNEs does not match with the level of R&D intensity. Overall, it can be stated that R&D behaviors of MNEs are different from local firms and should be separately analyzed.

3.2 Empirical Studies of R&D and export performance

At the start, studies on export performance did not draw much attention on R&D. They often concerned macroeconomic factors and a country's resources as determinants of export performance. However, under the edge of technology, several following studies emphasized the role of R&D on export performance.

There were a lot of following studies regarding the role of R&D on export performance. The majority of the studies with respect to the export performance and R&D mainly employed in developed countries, for example, Japan (Ito and Pucik, 1993), UK (Wakelin, 1998), UK and Germany (Roper and Love, 2002), Italian (Becchetti and Rossi, 2000), Ireland (Roper et.al, 2006). In the studies of R&D and export performance in developed countries, most of the studies found that R&D positively determines export performance.

However, there were a number of studies examined the relationship between R&D and export performance of developing countries such as Brazil (Willmore, 1992), India (Kumar and Siddharthan, 1994), Turkey (Qzcelik and Taymaz, 2004), Indonesia (Dijk, 2002), Spain (Rodriquez and Rodriquez, 2005). Some of them are revealed below.

Hirsch and Bijaoui (1985) considered the relationship between R&D and export performance of Israel; a small country which experienced a rapid rise in exports in the 1970s. They studied on 111 Israeli firms which undertake R&D expenditure. Initially, they contrasted the propensity to export of firms with R&D with the average propensity to export in each sector, and found that the firms with R&D, grouped into sectors, had a higher propensity to export than the sector average. In the model which followed, they found lagged R&D expenditure to be significant in explaining the rate of change of exports in a cross-section. The size of the firm, measured by sales, and the change in firm sales, taken as an indicator of firms' characteristics were also noted that while a minimum size is probably required to export, beyond that firm size is not a major factor.

Willmore (1992) concentrated on the role of transnationals in Brazil's trade, estimating both the determinants of exports and those of imports. He found no significant role for R&D expenditures as a determinant of exports. However, R&D

appeared to play a small negative role with respect to imports. This result indicated that the technological effort through R&D led to increased domestic inputs and less reliance on imports.

Kumar and Siddharthan (1994) analyzed the relationship between R&D expenditure and exports of 640 Indian firms from 1988-1990 grouped according to industry. They found R&D expenditure to be an important factor in low and medium technology industries, and concluded that India does not have a competitive advantage in high technology sector, but R&D expenditure influences export performance in other sectors.

Liu and Shu (2001) investigated the determinants of China's export performance using cross-section data at the industry level. They found that R&D had no influenced export performance and explained that China's export products contain fewer R&D components. The export performance of China was influenced by labor costs, the level of FDI, and firms' size. They concluded that China's industries have not established technological competitiveness, and thus R&D intensity appeared less important than other factors in explaining China's exports. For policy implication, they suggested that it is appropriate for Chinese firms to compete in the world markets based on the competitive advantage of low labor costs at their current stage of development. But the government should also design policy toward supporting R&D activities to enhance technological competitiveness in order to sustain export growth in the long-run. Nevertheless, the study of China's export performance at firm-level provided different result. *Guan and Ma (2003)* argued that if firms conduct R&D with other supplementary technology factors (i.e. skilled labor); they will obtain the have positive benefits from R&D which can improve their export performance.

Similar results were proposed by *Dijk (2002).* He examined the effect of R&D on export performance of Indonesian firms. The results claimed that R&D determines export performance only low and medium technology industries. The results are similar to *Kumar and Siddharthan (1994).*

From the review of the literatures, the effect of R&D on export performance is varies across industries. It seems to suggest that the role of R&D on export performance involves with country's specific characteristics. The following section summarizes the important issues for the study of R&D and export in the case of Thailand.

3.3 Conclusion and Remark for the Study of Thailand

To study the role of R&D on the export performance of manufacturing firms in Thailand, there are three issues which should be considered.

- Thailand is a developing country. By nature, most of the manufacturing firms in Thailand are technology-followers. Hence, this study analyzes the effects of R&D under the scheme of a technology follower, which differs from a technology leader.
- Similar to other developing countries, Thailand has been successful in exporting light manufactured goods for a long time. It indicates that, like other developing countries, Thai manufacturing exports do not have any export performance in high-technology products. Therefore, investigating the export performance of Thai manufacturing should deal with industrial structure.
- MNEs play a significant role in Thai manufacturing. R&D activity of MNEs in Thailand is generally low. Several MNEs conduct R&D only in the parent office and export them to Thailand (Brimble and Urata, 2006). Thus, the R&D behavior of MNEs should also be considered.

CHAPTER 4

THEORETICAL FRAMEWORK

4.1 Theoretical Model

To estimate an effect of R&D intensity on export performance, this study develops a short run microeconomic model introduced by Basile (2001). A representative firm in the model is able to sell its product on the domestic market or export it to the foreign market[1], or sell it in both markets. Thus, a firm's revenue consists of two separable components; the revenue from the export market and the revenue from the domestic market. The revenue function of the representative firm *j* is written as shown in equation (4.1).

$$R_j = p^d q_j^d + p^f q_j^f \tag{4.1}$$

where p^d and p^f are domestic and foreign prices respectively. q_j^d is the outputs of firm *j* sold on the domestic market and q_j^f is the outputs of firm *j* sold on the export market. The total outputs of firm *j* is $q_j = q_j^d + q_j^f$

The total cost function of firm *j* can be presented as:

$$C_j = h(q_j^d + q_j^f) + v^d(q_j^d) + v^f(q_j^f) \tag{4.2}$$

where $h(q_j^d + q_j^f)$ is the production cost function, $v^d(q_j^d)$ is the distribution cost function for the domestic market, and $v^f(q_j^f)$ is the distribution cost function for the foreign market. The distribution cost function associates with the specific cost such as the cost of penetrating market, advertising, design, and transportation. All cost functions are assumed to be the increasing function and convex.

For practical analysis, the cost functions are assumed to have simple functional forms.

$$h(q_j^d + q_j^f) = \frac{a}{2}(q_j^d + q_j^f)^2 + g(q_j^d + q_j^f) \tag{4.3}$$

---

[1] The model treats the foreign market as a single entity.

$$v^d(q_j^d) = \frac{1}{2}b(q_j^d)^2 + c^d q_j^d \tag{4.4}$$

$$v^f(q_j^f) = \frac{1}{2}b(q_j^f)^2 + c^f q_j^f \tag{4.5}$$

where *a*, *b* are scalar parameters. g , c^d and c^f are the functions of cost variables for the production , and the distribution cost functions of the domestic market and the foreign market respectively. In particular, g , c^d and c^f can be defined as,

$$g = g(x, z_j) \tag{4.6}$$

$$c^d = c^d(x, z_j, m^d) \tag{4.7}$$

$$c^f = c^f(x, z_j, m^f) \tag{4.8}$$

where *x* is the cost variable that is common to production for both markets. m^d is the specific cost variables of the domestic market. m^f is the specific cost variable of the foreign market. z_j denotes a vector of the specific factors of firm *j*, such as the productivity, size, and ownership.

Now, the representative firm is assumed to produce at the profit-maximizing level. So, the firm's maximization problem is

$$\underset{q_j^d, q_j^f}{Max}\ p^d q_j^d + p^f q_j^f - h(q_j^d + q_j^f) - v^d(q_j^d) - v^f(q_j^f)$$

Subject to $q_j^d, q_j^f \geq 0$

Applying first-order condition, the optimal levels of the products sole on the domestic market and the foreign market are q^{d*} and q^{f*}.

$$q_j^{f*} = \frac{1}{2ab + b^2}\left[(a+b)p^f - (a+b)c^f - ap^d + ac^d - bg\right] \tag{4.9}$$

$$q_j^{d*} = \frac{1}{2ab + b^2}\left[(a+b)p^d - (a+b)c^d - ap^f + ac^f - bg\right] \tag{4.10}$$

Equation (4.9) and (4.10) show that, if the common production cost (*g*) decreases, the overall level of firm's output will increase. If the specific cost of the domestic market (c^d) increases, or the prices of the products in the domestic market

(p^d) decreases, the firm will produce more products for exporting and produce fewer products for serving the domestic market. Conversely, if the price of the product sold abroad (p^f) increases, or the specific cost of the foreign market (c^f) decreases, the firm has intention to rather sell the products abroad than in the domestic market.

In short, firm's optimal product is

$$q_j^* \in Arg \max_{q_j} \left\{ \pi_j = pq_j - C(x, m^k, z_j \left| q_j \right.) \right\} \quad (4.11)$$

$$q_j^* = \begin{bmatrix} q_j^{f*} \\ q_j^{d*} \end{bmatrix} = \begin{bmatrix} q_j^{f*}(p^f, x, m^k, z_j) \\ q_j^{d*}(p^d, x, m^k, z_j) \end{bmatrix} \quad (4.12)$$

where q_j^* is the optimal level of the firm's total output. q_j^* is a vector of the optimal level of output sold in the domestic market (q_j^{d*}) and the output sold in the foreign market or the level of the firm's export product (q_j^{f*}). m^k is the specific cost of each market ($k = d, f$).

In this study, we focus on the firm's export. Therefore, the only optimal level of the firm's export product is taken into account. We can state that

$$q_j^{f*} = q_j^{f*}(p^f, x, m^k, z_j) \quad (4.13)$$

From the optimal exports in equation (4.13), the level of firm's export depend on x, m^k and z_j. In particular, there are two main variables; the dependent variable and the independent variable. The dependent variable is the quantity of firm's export product. The independent variable consists of three main factors; price, cost, and firm's characteristics.

The relationship between R&D and export performance can be explained by the equation (4.13) through the cost variables. Firstly, we define all cost variables in equation (4.13) as the exporting cost. Following with Crepon, Duguet, and Mairesse (1998), R&D can improve productivity, then reduce the exporting cost, and increase export level.

It can be noted further that R&D can also ease firms to develop new products. In practice, the preference of the consumer in both the foreign and the domestic markets is frequently different. If the new products match with the preference of those consumers in the foreign market, they would be relatively sold on the foreign market rather than the domestic market. Share of firm's export product in total products will increase.

Applying equation (4.13) in practice, it can be inferred that firm's export performance is influenced by the exporting cost and firm's characteristics. Price of the exports, in several studies of R&D and export performance, is not the issue since it is determined by the market. As mentioned earlier, R&D indirectly determines export performance through the exporting cost. However, it is difficult to estimate the effect of R&D on the exporting cost; we use the proxy variable as an alternative way to represent it. To detect the proxy variables, we study related literatures (see table 4.1) and obtain the knowledge as follows:

R&D intensity

Based on the theoretical viewpoint, R&D reduces the exporting cost and then the export performance of firms increases. As stated above, to analyze the effect of R&D on export performance, the effect of R&D on the exporting cost should be considered first, and then we can use its outcome to estimate the effect upon the export performance. Since it is difficult to measure the consequence obtained from R&D on the exporting cost, many studies alternatively use the R&D intensity. The R&D intensity can be regarded as the firm's effort to reduce the exporting cost. For that reason, R&D intensity has been a well-known proxy of cost reduction from R&D. It is anticipated to have a positive relationship with firm's export performance.

R&D intensity is generally computed by R&D expenditure over the total sales (or the total products/ the total employees). The relative term is applied in order to eliminate a scale effect.

Skilled labor

Skilled labor is an alternative proxy of the effect of R&D on the exporting cost. In many preceding studies, skilled labor is a classical proxy of the R&D effort of the developing countries. Skilled labor, on the one hand, acts as the informal R&D and a complementary factor of the formal R&D activity. The number of skilled labor also indicates the quality of firm's R&D. Hence, skilled labor enhances the firm's exports.

Nevertheless, the large number of skilled labors can raise the exporting cost at the same time, and moderate firm's cost advantage respectively. For that reason, skilled labor can either contribute positive or negative benefits on firm's export performance. In case that the benefits obtained from skilled labor offset the cost of skilled labor employment, skilled labor will has positive impact on firm's export performance. If the benefits from skilled labor are less than the increasing in the exporting cost from hiring them, skilled labor will has the negative impact on firm's export performance.

Apart from the exporting cost, another set of factors determining firm's export performance is those factors involving the firm's characteristics. In this study the firm's characteristic refers to firm's size and ownership.

Firm's size

The traditional variable representing firm's characteristics in the studies of export performance is firm's size. To enter the export market, the firm might face the extra costs of expanding their business overseas such as; the cost of collecting information on the export market (Smith et al., 2002), launching overseas sale-promotion campaign, and adapting product to foreign market demand (Liu and Shu, 2001). These costs can be concerned as the sunk cost in penetrating the export market. In general, the sunk cost affects the firm's export decision. If the sunk cost is large, the small firm ceased the export due to the lack of resources for the export. The large firm can potentially enter the export market.

Besides, when the firm starts to export, it is to confront other costs as well. For instance, it must face the financial cost such as the cost for covering risks in the foreign market (Wakelin, 1998) and the document fees. The large firm, which has a bargaining power with financial institutions, tends to get lower financial cost than a small firm. As a matter of fact, the cost per units of exports of the large firm is lower than those of the small firm. Therefore, it is logical to expect a positive relationship between firm's size and export performance.

However, several studies pointed out that the relationship between firm's size and export performance is represented by an inverted U-shaped. The minimum size is required to overcome the exporting cost. Size of firms is positively correlated with export performance until it reaches an efficiency size (critical size, threshold size). Above the critical size, firm's size has negative relationship with export performance. One possible explanation is that the very large firm prefers to sell their products on the domestic market due to its monopoly power (Kumar and Siddharthan, 1994; Wakelin, 1998).

Ownership

Another variable generally used for representing the firm's characteristics in the studies of R&D and export performance is the ownership. It is believed that the foreign affiliate is more likely to have higher export performance than the local firm since it has superior knowledge on business opportunity and experience in export market (Rodriquez and Rodriquez, 2005). Besides, it can access to the advanced technology and know-how which are not available for the local firm (Dijk, 2002). Firm's ownership is frequently observed by the share of foreign capital in the total capital. The firm with large share of foreign capital in the total capital is expected to have high export performance.

In conclusion, a model of export performance is constructed as follows;

EXP = f (R&D intensity, Skilled labor, Size, Size2, Ownership)

where *R&D intensity*, *Size*, and *Ownership* are expected to positively affect firm's export performance (*EXP*). The Quadratic term of size variable (*Size2*) is expected to have negative relationship. *Skilled labor* can have either negative or positive sign.

4.2 An Analytical Framework for the Comparative Study on R&D Behavior between Exporting firms and Non-Exporting firms

The theoretical model of export performance in section 4.1 can only be use to explain the effect of R&D intensity on firm's export performance. However, excepting R&D intensity, many previous studies proposed that the different types of R&D cause the different performances of the export (see table 4.1 for the results of the previous studies). This implies that exporting firms and non-exporting firms carry out the R&D in different ways. Thus leading to the questions "What kinds of R&D performed by exporting firms?" and "Do they difference from R&D activities performed by non-exporting firms?"

To answer those questions, this study applies a comparative study to compare the R&D behavior between exporting firms and non-exporting firms. The measure of R&D behavior is derived from the study of Forbes and Wield (2000) and some factors regarded in previous studies.

In Forbes and Wield (2000), technology-follower firms will succeed in R&D and have the competitiveness if they maximize benefits from R&D intensity. By doing so, R&D activities in the technology-follower firms should meet four conditions. Firstly, R&D should be a complement activity of shop-floor activity. Secondly, R&D should be formal learning unit of firms. Thirdly, R&D in technology-follower firms should be carried out by concentrated in design. Finally, R&D should contribute other intangible benefits. According to this framework, we propose three criterions related to firm's export.

A presence of the in-house R&D

Firms with the in-house R&D are likely to effectively remove problems during shop-floor operation, and in turn improve production process. Based on Forbes and Wield (2000), having the in-house R&D enhances firms to have higher competitiveness. Applying this concept to our study, with the idea that the export refers to firm's competitiveness, exporting firms and non-exporting firms may have different levels of the in-house R&D. In particular, exporting firms tend to have higher level of the in-house R&D than non-exporting firms.

Learning capability

Learning capability is an ability to exploit outside knowledge and incorporate them to internal firm's knowledge stocks. Forbes and Wield (2000) suggested that firms that have higher learning capability are likely to have technology advantage, and in turn higher competitiveness. Likewise, since the firm's competitiveness refers to export, it can be proposed that learning capability of exporting firms should be higher than non-exporting firms.

Product design

For technology-follower firms, new product development should be based on the new design, not on the new technology. A large amount of products designed by firms reflects the firm's performance. The product design provides the competitiveness. Thus, the number of the own designed products of the exporting firms are likely excess those of the non-exporting firms.

Apart from Forbes and Wield (2000), this study comprises three additional criterions; the types of R&D, the objectives of R&D, and the external collaboration in R&D. These criterions are derived from the preceding studies. The detail of each criterion is discussed below.

Types of R&D

Frascati manual (2002) classified the R&D activities into three types; the basic research, the applied research, and the experimental development. Different types of the R&D activities trigger different forms of the R&D outputs. According to Lefebvre et al. (1998)[2], firms that sell their products on the different markets should perform different types of R&D. Applying this concept to our study; we proposed that the exporting firms, selling the products in the export market, and the non-exporting

[2] Lefebvre et al. (1998) investigated effects of R&D strategies on Canadian firms' export performance. They found that firms carried out basic R&D can improve their export performance in North America but not global market. On the contrary, firms designed their R&D strategy toward applied research can achieved in export performance in global market.

firms, who sell products in the domestic market, should carry out different types of R&D.

The objectives of R&D

Likewise, the difference in the objectives of R&D may lead firms to have difference in the level of export. Lefebvre et al. (1998) considered three R&D objectives; the new product development, the new process development, and the existing product improvement. They stated that the new product improvement and the new product development were necessary for the firms that desire to export. The importance of the new product development on export is affirmed by Roper and Love (2002).

Qzcelik and Taymaz (2004), and Rodriquez and Rodriquez (2005) found that firms successful in the process development can reduce the production cost and consequently get higher export performance. In Basile (2001), both the product and the process improvement had positive influences on firm's export. Accordingly, based on the previous studies, we proposed that exporting firms and non-exporting firms have differences in the objectives of carrying out R&D. Exporting firms are expected to have much more success in both the product and the production process improvement.

The external collaboration in R&D

The external collaboration in R&D releases resources and technology constraints of the firms. The external linkages also stimulate the creativity, reduce the risk, and upgrade the quality of R&D (Roper and Love, 2002). Firms that collaborate with other agents tend to succeed in R&D; consequently, they are capable of exploiting the most benefits from them. Thus, it can be proposed that the external collaboration enhances the firm's competitiveness and improves the firm's export performance. Exporting firms are inclined to have more collaboration with the external agents than non-exporting firms are.

4.3 Conclusion

To estimate the effect of R&D intensity on export performance, the theoretical model of export performance is introduced. The model is short-run microeconomic model developed from Basile (2001). According to this model, the level of firms' exports relies on exporting cost and firms' specific characteristics.

R&D can increase the productivity and reduce the exporting cost, which consequently increase the firm's export intensity. However, it is difficult to estimate the magnitude of the cost reduction from R&D; we use the R&D intensity as an alternative. As well, skilled labor is introduced to the model because it is a well-known proxy of R&D in the developing countries.

Finally, firm's size and ownership are included in the model to represent firm's specific characteristics.

To analyze the difference in R&D behavior between exporting firms and non-exporting firms, this study constructs analytical framework based on the studied of Forbes and Wild (2002) as well as some proceeding studies discussed in literature review. We proposed six criterions for analysis; a presence of in-house R&D, learning capability, product design, the types of R&D, the objectives of R&D, and the external collaboration in R&D.

Table 4.1

Summary of the studies on R&D and export performance

			Dependent = Export intensity		Dependent = Probability of exporting	
Categories	Independent variables	Measurement	Impacts on exports	Authors	Impacts on exports	Authors
R&D	R&D intensities	R&D expenditure over total sale/ total employee	+ / - / No	Schlegelmilch and Crook (1988), Ito and Pucik (1993), Kumar and Siddharthan (1994), Lefebvre et al.(1998)**, Liu and Shu (2001) , Dijk (2002), Becchetti and Rossi (2000), Yang, Chen, and Chuang (2004), Qzcelik and Taymaz (2004), Rodriquez and Rodriquez (2005)	+ / No	Becchetti and Rossi (2000), Rodriquez and Rodriquez (2005)

			Dependent = Export intensity		Dependent = Probability of exporting	
Categories	Independent variables	Measurement	Impacts on exports	Authors	Impacts on exports	Authors
Skilled labor	Skilled labor	Share of technician	+ / -	Kumar and Siddharthan (1994), Wakelin (1998), Roper and Love (2002), Dijk (2002), Smith et al. (2002), Guan and Ma (2003), Qzcelik and Taymaz (2004), Yang, Chen, and Chuang (2004)	+ / -	Wakelin (1998), Roper and Love (2002), Yang, Chen, and Chuang (2004)
		Expenditures on engineer, design, trail production	+	Sterlacchini (1999)	+	Sterlacchini (1999)
		Training expenditure	No	Dijk (2002), Yang, Chen, and Chuang (2004)		
Ownership	Ownership	Share of foreign ownership	+	Liu and Shu (2001), Dijk (2002), Qzcelik and Taymaz (2004), Rodriquez and Rodriquez (2005)	+	Rodriquez and Rodriquez (2005)

			Dependent = Export intensity		Dependent = Probability of exporting	
Categories	Independent variables	Measurement	Impacts on exports	Authors	Impacts on exports	Authors
Size	Size	Number of employees or total sale	+ / No	Kumar and Siddharthan (1994), Wakelin (1998), Lefebvre et al. (1998), Sterlacchini (1999), Becchetti and Rossi (2000), Basile (2001), Liu and Shu (2001), Nassimbeni (2001), Dijk (2002), Roper and Love (2002), Guan and Ma (2003), Lachenmaier and Woessman (2004), Qzcelik and Taymaz (2004), Yang, Chen, and Chuang (2004)	+ / -	Wakelin (1998), Sterlacchini (1999), Becchetti and Rossi (2000), Basile (2001), Nassimbeni (2001), Smith et al. (2002), Roper and Love (2002), Yang, Chen, and Chuang (2004)
Size	(Size)2	(Size)2	-	Kumar and Siddharthan (1994), Wakelin (1998), Sterlacchini (1999), Nassimbeni (2001), Roper and Love (2002), Dijk (2002), Guan and Ma (2003), Yang et al. (2004)	-	Wakelin (1998), Sterlacchini (1999), Nassimbeni (2001), Smith et al. (2002),Roper and Love (2002), Yang, Chen, and Chuang (2004)

			Dependent = Export intensity		Dependent = Probability of exporting	
Categories	Independent variables	Measurement	Impacts on exports	Authors	Impacts on exports	Authors
Types and objectives of conducting R&D	Basic R&D	Dichotomous Var.	+ / No	Lefebvre et al.(1998)		
	Applied R&D	Dichotomous Var.	+ / No	Lefebvre et al.(1998)		
	Number of new product / process development	Dichotomous Var.	+ / No	Lefebvre et al. (1998), Basile (2001), Roper and Love (2002), Rodriquez and Rodriquez (2005)	+	Basile (2001), Roper and Love (2002), Rodriquez and Rodriquez (2005)
External collaboration	Collaborative R&D with external agent	Dichotomous Var.	+ / - / No	Lefebvre et al.(1998), Basile (2001), Qzcelik and Taymaz (2004), Rodriquez and Rodriquez (2005),	+	Basile (2001), Rodriquez and Rodriquez (2005)
		Dichotomous Var.	+	Becchetti and Rossi (2000)	+	Becchetti and Rossi (2000)
	Collaborative R&D with Public	Dichotomous Var.	+ / No	Lefebvre et al.(1998)		
	Collaborative R&D with customers/ subcontractors	Dichotomous Var.	- / No	Lefebvre et al.(1998)		

			Dependent = Export intensity		Dependent = Probability of exporting	
Categories	Independent variables	Measurement	Impacts on exports	Authors	Impacts on exports	Authors
	Collaborative R&D with competitors	Dichotomous Var.	+ / No	Lefebvre et al.(1998)		

* Roper and Love (2002) studied by UK and Germany data, skilled workers had positive impacts for UK, and negative in Germany
** Lefebvre, Lefebvre and Bourgault (1998) compared the export performance on North America Market and World market.

CHAPTER 5

METHODOLOGY

The role of R&D and innovation on export performance is analyzed in two steps. Firstly, we estimate the model of export performance constructed in chapter 4. The model and the method of estimation are discussed in section 5.1 and 5.2. In the section 5.3, we describe the data used in this study. Secondly, the analysis of variance (ANOVA) is introduced to compare R&D behavior between exporting and non-exporting firms. A discussion of the analysis of variance and the factors for means comparison are shown in section 5.4 and 5.5.

5.1 The Studied Model

Based on the discussion in the previous chapter, the model is constructed as equation(5.1). This section gives more detail on each variable and its expected sign.

$$EXP = f(RDINT, SKILL, SIZE, SIZE2, OWN) \qquad (5.1)$$

A dependent variable is export performance (*EXP*) measured by the export intensity (the share of the firm's exports in total sales). The value of this variable lies between zero and one. If firms report this variable as equal to one, firms export all of their products. Conversely, the value zero means firms sell all their products in the domestic market and not export at all. For the value which lies between zero and one, a greater value implies a greater amount of exports.

There are six independent variables in our model; *RDINT, SKILL, SIZE, SIZE2, OWNER, DUM*. The details of each variable are explained below.

RDINT is the R&D intensity measured by a firm's expenditure on R&D (in million baht) over a firm's total employees. The number of employees is introduced to this model in order to eliminate scale effects. From theoretical model, the R&D

intensity can reduce the exporting cost. The R&D intensity is anticipated to positively influence export performance.

SKILL is skilled labor. This variable is measured by the share of graduate workers of total employees. Skilled labor has two impacts on export performance. On the one hand, a great number of skilled labors accomplish R&D efficiencies. On the other hand, hiring skilled labor raises firm's production cost. Therefore, skilled labor can have either a positive or a negative impact on export performance.

SIZE is firm's size. This variable is measured by the number of total employees. Large firms are expected to have a higher export performance than small firms. One explanation is large firms have lower exporting cost. Additionally, when firms face small domestic markets, large firms are forced to export because they are pressured by large production scales. Therefore, firm's size should be positively correlated to export performance.

SIZE2 is computed by the quadratic terms of *SIZE*. This variable is included in the model in order to examine the inverted U-shaped relationship between firm size and exports. An inverted U-shaped relationship is found in many preceding studies. If size has an inverted U-shaped relationship with exports, the coefficient of variable SIZE2 will be negative.

OWN is a firm's ownership. Ownership is indicated by the share of foreign capital in total capital. In this study, this variable is measured by 1-5 Likert scale. Firms are scored one if they are pure Thai firms (100% of capital is held by Thai people), two if 71-99% of capital hold by Thai people, three if a Thai owners have a share between 51-70%, four if 50% or less of capital is held by Thai people, and five if they are a wholly foreign owned company (0% of capital hold by Thai people). As discussed earlier, foreign firms have a higher export performance than local firms, since they can access superior technologies and have previous experience in the export market. This variable is expected to have a positive relationship with export performance.

As stated previously, the effects of R&D on a firm's export performance may vary cross industries. To eliminate sector variation effects, this study include the dummy variables as the control variables. The dummy variables present the group of industry or industrial structure (classified by Pavitt taxonomy) which firms belong to.

The summary of variables is presented in table 5.1.

Table 5.1

Summary of the Variables and the Expected Signs

	Variable	Description	Measurement	Expected sign
Dependent variable				
Export performance	EXP	Share of firm's export in total sale	Proportion	
Independent variables				
R&D intensity	RDINT	R&D expenditure (million baht) over total employees	Proportion	+
Skilled labor	SKILL	Share of graduate workers in total employees	Proportion	+/-
Firm's size	SIZE	Total employees (Hundred persons)	Number	+
	SIZE2	Square of total employees	Number	-
Ownership	OWN	Share of foreign capital in total capital	1-5 Likert scale	+
Industrial structure	DUM	Dummy variables of the group of industries	Binary	

Source: Author

In conclusion, the estimated equation for econometric analysis is

$$EXP^* = \beta_0 + \beta_1 RDINT + \beta_2 SKILL + \beta_3 SIZE + \beta_4 SIZE2 + \beta_5 OWN + \beta_6 DUMi + \varepsilon \quad (5.2)$$

$$EXP = \begin{cases} EXP^* & \text{if } EXP^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

5.2 The Econometrics Procedure

In the equation 5.2, a dependent variable (export performance) is measured by a firm's export intensity. There are two interesting characteristics of the dependent variable which must be of concerned. Firstly, the export ratio (export intensity) can not be negative by nature; its value varies between 0 and 1. Secondly, the whole sample consists of many firms that do not export at all. Therefore, this variable takes the value of zero, which reflects that it has more left censored than right censored observations. From both reasons, using OLS estimation provides downward biased results.

In line with the characteristics of the dependent variable, there are two alternative procedures for estimation, the single censored tobit model (Tobin, 1958) and the Cragg's two stage specification model (Cragg, 1971)[1].

In the censored single tobit model, a changing the expected value of a dependent variable with respect to the regressor has two components. One effect works by changing the conditional mean (intensity) and another by changing a probability that an observation will be positive (participation).

Many preceding studies indicate that the effects of R&D on the export intensity and the export probability are different. For this reason, applying the single censored tobit estimation will not be appropriate. The single censored tobit estimation provides a single parameter which encompasses both effects of changes in the export intensity and the probability. By using the tobit estimation, we cannot observe the effect of export intensity and export probability independently.

Another method is the two-stage estimation presented by Cragg (1971). An assumption underlying the two-stage procedure is that the two stages are independent of each other. Hence, the estimation should be conducted in two stages. The first stage takes into account the whole sample and considers the firm's decision to export (whether or not firms export). To estimate the effect of R&D on the export decision, the probit estimation is introduced. Instead of using the value of the dependent variable, the probit model takes its value equal to 1 (if firms report any export

[1] See Appendix D

products) and 0 (if firms do not export at all). The second stage takes into account export intensity, thus only exporting firms are retained. The data of non-exporting firm is excluded from the estimation. The dependent variable is not restricted by 0 and 1. However, it remains limited by the left censored. In other words, the sample is truncated at zero value. Then the truncated estimation procedure is appropriate for estimating in the second stage.

In order to select between these two procedures, their restrictions must be considered first. Cragg assumes the change in conditional mean and the change in the probability of dependent variables are independent. Thus the disturbances in the latent regression underlying the probit model and the truncated model are independent respectively. If the two stages are not independent, the resulting estimates cannot hold true for the population as a whole. The result of truncated estimation will be biased from the true population (Cragg, 1971).

To find the suitable estimation method, this study applies the chi-squared likelihood ratio test (LR-test) to test the single censored tobit model against Cragg's two stage specification. The single tobit model is regarded as a restricted model where Cragg's two stage specifications is unrestricted model.

In conclusion, the model is estimated in two steps. At first, we estimate the whole sample, Thai firms, and non-Thai firms. By doing this, we can compare the effect of the R&D intensity on the export performance between Thai firms and non-Thai firms. The estimated result also examines the behavior of "economies of multiplant operation" of non-Thai firms.

If the R&D behavior of non-Thai firms harmonizes to the concept of the economies of multiplant operation, the data of non-Thai firms will be excluded from further estimation. With the presence of economies of multiplant operation, the effect of the R&D intensity on the firm's export performance is incomprehensible.

Second, we estimate model across a group of industries to examine whether the effect of the R&D intensity on export performance varies across industries.

5.3 Data Description

The data used in this study is the secondary firm-level data, "The Thailand R&D/Innovation Survey 2003", collected by The National Science and Technology Development Agency (NSTDA)[2]. The data includes 2,051 manufacturing firms and 532 firms in service industries. This study uses data of manufacturing only, including 23 industries classified by TSIC-2001 rev.3. All firms in the survey have turnovers of more than 12 million baht

This study selects 1,695 firms from 18 manufacturing industries[3] as a sample for our quantitative analysis. Some data is dropped due to statistical reasons. For example, firms enclose missing data in some variables are excluded from our analysis. Some industries that do not have any R&D expenditures are also excluded.

Table 5.2

Sample Classified by Ownership

Classification		Total	Firms with R&D	% Firms with R&D
All firms	All	1695	262	15.46
	Exporting firm	840	176	20.95
	Non-exporting firm	855	86	10.06
Non- Thai firms	All	553	98	17.72
	Exporting firm	336	63	18.75
	Non-exporting firm	217	35	16.13
Thai firms	All	1142	164	14.36
	Exporting firm	504	114	22.62
	Non-exporting firm	638	50	7.84

Source: Compiled from NSTDA, *the Thailand R&D/Innovation Survey 2003*

Table 5.2 presents classifications of our samples. Thai firms are defined as firms where 100% of its capital is held by Thai people. If firms report any share of foreign capital, they have to be classified as non-Thai firms. Firms with R&D are

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[2] See appendix of NSTDA Thailand R&D& innovation survey report 2003 for method of collecting data and systematic sampling.

[3] See appendix C for manufacturing categories.

firms that report their R&D expenditures. Exporting firms are firms where their share of exports of total sales is greater than zero (not sold 100% on the domestic markets). Firms that not export at all (sold 100% on the domestic markets) are defined as non-exporting firms.

The sample has 1695 firms. Of this, 840 firms (49.56%) are exporting firms, and 855 firms (50.44%) are non-exporting firms. On average, 15.46% of total firms expend on R&D activities. 20.95% of exporting firms carry out R&D, while only 10.06% of non-exporting firms perform R&D.

In Table 5.2, most of the samples comprise Thai firms (1142 firms or 67%). Of which, 638 firms (59%) are non-exporting firms, and 504 firms (41%) are exporting firms. 22.64% of exporting firms perform R&D while only 7.84% of non-exporting firms perform R&D. For non-Thai firms, 336 firms (60.76%) are exporting firms, and 217 firms (39.24%) are non-exporting firms. The number of exporting firms and non-exporting firms that perform R&D is similar. 18.75% of exporting firms carry out R&D, whereas 16.13% of non-exporting firms perform R&D.

Table 5.3 the samples are classified by industry. Firms are categorized into 4 groups[4]; supplier dominated industries (SDOM), scale intensive industries (SCAI), specialized supplier industries (SPEC), and science-based industries (SDOM). Supplier dominated industries have the smallest number of R&D firms (6.5%). The amount of R&D and innovating firms are largest in scale intensive industries (23.77%). In specialized supplier industries, R&D firms account for 12.18% of total firms. 17.49% science based firms are R&D firms. When comparing exporting firms and non-exporting firms, the number of exporting firms conducting R&D is greater than non-exporting firms in all groups.

R&D in Thailand has some common characteristics with other developing countries such as India (Kumar and Siddharthan, 1994) and Indonesia (Dijk, 2002). A number of R&D firms are concentrated in scale intensive industries, which can be considered as low and medium technology industries). But some distinctive

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[4] See Appendix C.

characteristics were also discovered. The science based industries show a higher proportion of R&D firms, which does not exist in those developing countries.

Table 5.3

Sample Classified by Industries

Classification		Total	Firm's with R&D	% Firms with R&D
All firms	All	1695	262	15.46
	Exporting firms	840	176	20.95
	Non-exporting firms	855	86	10.06
Supplier dominated industries (SDOM)	All	492	32	6.50
	Exporting firms	243	22	9.05
	Non-exporting firms	249	10	4.02
Scale intensive industries (SCAI)	All	547	130	23.77
	Exporting firms	284	88	30.99
	Non-exporting firms	263	42	15.97
Specialize supplier industries (SPEC)	All	271	33	12.18
	Exporting firms	134	20	14.93
	Non-exporting firms	137	13	9.49
Science based industries (SCIB)	All	383	67	17.49
	Exporting firms	178	46	25.84
	Non-exporting firms	205	21	10.24

Source: Compiled from NSTDA, the Thailand R&D/Innovation Survey 2003

Table 5.4 shows the statistical summary of variables in the studied model. The average of the R&D intensity is 0.0047 million baht (4,700 baht). Share of skilled labor in total employee is approximately 0.19. Total employees are about 390 workers per firm.

Table 5.4

Statistical Summary of the Key Variables

	Variable	Mean	S.D.	Max.	Min.
Export intensity	EXP	0.25	0.36	1.00	0.00
R&D intensity	RDINT	0.0047	0.04	0.75	0.00
Skilled labors	SKILL	0.19	0.24	1.00	0.00
Firm's size	SIZE	3.90	12.52	271.09	0.00
Firm's size(2)	SIZE2	129.93	2,646.11	73,489.79	0.00
Ownership	OWN	1.89	1.42	5.00	1.00

Source: Compiled from NSTDA, *the Thailand R&D/Innovation Survey 2003*

Table 5.5 shows correlations among the independent variables in our model. There are no correlations between these variables that are higher than 0.5. At this level of correlation, it can be accepted that there is no multicollinearity problem.

Table 5.5

Correlations between Independent Variables

	RDINT	SKILL	SIZE	OWN
RDINT	1	0.1085	-0.0139	0.0188
SKILL	0.1085	1	-0.0412	0.0582
SIZE	-0.0139	-0.0412	1	0.2342
OWN	0.0188	0.0582	0.2342	1

Source: Calculated from NSTDA, *the Thailand R&D/Innovation Survey 2003*

5.4 <u>Comparison between Exporting firms with R&D and Non-Exporting firms with R&D</u>

Apart from the R&D intensity, the difference in firm's export may also relate to the difference in R&D behaviors (Lefebvre et al., 1998). The next step of this study is to find R&D behavior that may distinguish the firm's export. We apply the analysis of variance to compare R&D behavior of exporting firms and non-exporting firms.

In this analysis, we consider only firms that report R&D expenditures[5] given some criterions, such as the objectives of R&D that requires data that is not available in non-R&D firms. Furthermore, it is important to remember that all samples are Thai firms. Therefore, the definitions presented below (NE, SSE, LSE) refer to Thai-firms that carry out R&D.

Firms that conduct R&D can be exporting firms (export some/all products) and non-exporting firms (not export at all). However, the exporting firms encompass firms that export 1% of the total products and firms that export all of their products (100%). Since both firms are very different in the level of export, it is more appropriate to distinguish these firms. Overall, this study divides the firms into three sub-samples; non-exporting firms or NE (firms with 0% export), small-share exporting firms or SSE (firms with export between 0% and 50% of their total sale), and large-share-exporting firms or LSE (firms with export accounting for more than 50% of the total sale).

Table 5.6

Summary of Firm's Definitions for the Analysis of Variance

	Classification	Notation	Description
Exporting firms	Large-share exporting firms	LSE	Firms with % export in total sale is greater than or equal to 50%
	Small-share exporting firms	SSE	Firms with % export in total sale is larger than 0% but less than 50%
Non-exporting firms	Non-exporting firms	NE	Firms with % export in total sale is zero

Source: Author

Our framework for comparing R&D behavior between exporting firms and non-exporting firms is derived from Forbes and Wield (2000) and reviewed literature.

[5] Although in reality some firms that do not spend on R&D are possibly having activities related to our criterions, for example, firms without R&D expenditures may have high learning capabilities by hiring many scientists and engineers, this study exclude those firms from the analysis.

We use six factors; in-house R&D, numbers of scientists and engineers, own designed products, type of R&D, objective of R&D, and external collaboration in R&D; as representative of firm’s R&D behavior. The detail of each factor is presented below.

The In-house R&D

This factor is measured by % distribution of the in-house R&D in all R&D activities of firms. Based on Forbes and Wield (2000), the in-house R&D refers to firm’s competitiveness. Accordingly, the competitiveness refers to firm’s export performance.

The reason is that the export market, in reality, is generally much more competitive than the domestic market (Qzcelik and Taymaz, 2004). Therefore, exporting firms, which sell some of their products on the export market, are regarded to have higher competitiveness than non-exporting firms.

Hence, from above discussion, we propose two suggestions. First of all, the differences in %distribution of the in-house R&D of firms relate to the differences in firm’s export. Second of all, exporting firms are anticipated to have higher export performance than non-exporting firms.

Numbers of scientists and engineers

This factor is measured by the share of scientists and engineers in total employees. The number of scientists and engineers indicate a firm’s capacity to utilize new knowledge and technology. Exporting firms have more chances to access external knowledge and new technology, both from the export market and the domestic market. In order to succeed in exploiting new knowledge and technology from the external sources, exporting firms have the incentive to employ the large number of scientists and engineers. This study proposes that the differences in the number of scientists and engineers of firms relate to the differences in firm’s export. Exporting firms tend to have greater number of scientists and engineers than non-exporting firms.

The number of own design product

Own designed products are computed in two ways; the share of products designed by firms according to customer requirements in total sales, and the share of products designed and sell under own brand in total sales. As for the reason that to sell the products in the export market, firms are obliged to compete with more competitors than sell the products in the domestic market. Thus exporting firms should reveal higher numbers of own designed products than non-exporting firms.

Types of R&D

Types of R&D consist of the basic R&D, the applied R&D, and the experimental R&D. In this study, the types of R&D activities are measured by % distribution of firm's R&D expenditure on each type of R&D. Exporting firms and non-exporting firms are anticipated to carry out different types of R&D.

The objectives of R&D

As mentioned earlier, the outputs of R&D depend on firm's objectives in conducting R&D. Hence, this study uses the outputs of R&D as the proxies for firm's objectives. There are five outputs from R&D; significantly improved efficiency of the production process, a new production process, significantly improved quality of the existing products, new products which are already commercialized, and granted patents. Exporting firms and non-exporting firms are anticipated to have the different objectives in performing R&D.

Level of external collaboration in R&D.

From the NSTDA survey, firms are requested to assess the level of their external collaboration by 1-5 Likert scales. They have asked to evaluate the level of collaboration with; customers, local and foreign suppliers, parent and associated company overseas, public research institutes, business and technical providers, private non-profit organizations, government agencies, universities, and competition.

A score of "one" denotes firms have less external R&D collaboration; while a score of "five" means they usually conduct R&D with that agent. According to Lefebvre et al. (1998), level of collaboration in R&D refers to competitiveness in the export markets. Thus exporting firms are expected to have higher level of collaborate in R&D with external agents than non-exporting firms.

5.5 <u>The Analysis of Variance (ANOVA) Technique</u>

An analysis of variance (ANOVA), or one-factor analysis of variance, is a procedure to test the hypothesis that several populations have the same mean. There are three assumptions for using this technique. Firstly, the populations from which the samples were obtained should be normally distributed. Secondly, the samples must be independent. Thirdly, the variance of the populations should be equal.

To test whether mean of each population is equal or not, the null hypothesis is all population means are equal, the alternative hypothesis is that at least one mean is different. The hypothesis of testing can be written as follows.

$H_0 : \mu_1 = \mu_2 = \mu_3 = ... = \mu_k$

$H_a :$ One or more of the population means is not equal to the others

To test the hypothesis, calculating the ANOVA *F* statistic by

$$F = \frac{S_B^2}{S_W^2}$$

where S_B^2 is *between-groups variance estimate,* computed by

$$S_B^2 = \frac{n\sum_{j=1}^{k}(\overline{X}_j - \overline{\overline{X}})^2}{k-1}$$

S_W^2 is *within-groups variance estimate,* computed by

$$S_W^2 = \frac{\sum_{j=1}^{k}(n_j - 1)S_j{}^2}{n_T - k}$$

$\overline{\overline{X}}$ is the overall sample mean for all of the observation include in the study.

$\overline{\overline{X}} = \frac{\sum_{i=1}^{n_j}\sum_{j=1}^{k} X_{ij}}{n_T}$ and *k* is the number of populations or groups being tested. n_T is the total number of samples ($n_T = n_1 + n_2 + ... + n_k$). $\bar{X}_j = \frac{\sum_{i=1}^{n_j} X_{ij}}{n_j}$ is the sample mean for the jth group.

The analysis will result in either of two conclusions: If the calculated F ratio is not larger than the table $F_{\alpha,k-1,n_T-k}$ value, then the conclusion is that there is not sufficient evidence to indicate that one or more of the population means is not equal to the others. If the calculated F ratio is larger than the table $F_{\alpha,k-1,n_T-k}$ value, then the conclusion is that one or more of the population means is not equal to the others.

5.6 Conclusion

In conclusion, this study analyzes the role of R&D on export performance in two steps. Firstly, this study estimates the effect of R&D intensity on firm's export intensity. There are two method of estimation. One is the single censored tobit model and another one is Cragg's two stage specification. Both models, the tobit model and Cragg's two stages specification, are tested by using likelihood ratio test (LR-test) to find suitable method of estimation. As proposed by the concept of "multiplant economy of scale", we also test Thai firms and non-Thai firms separately to examine whether non-Thai firms behave differently from Thai firms in doing R&D. If R&D behaviors between Thai firms and non-Thai firms are different and the multiplant economy of scale exists, only Thai firms will be considered in this study.

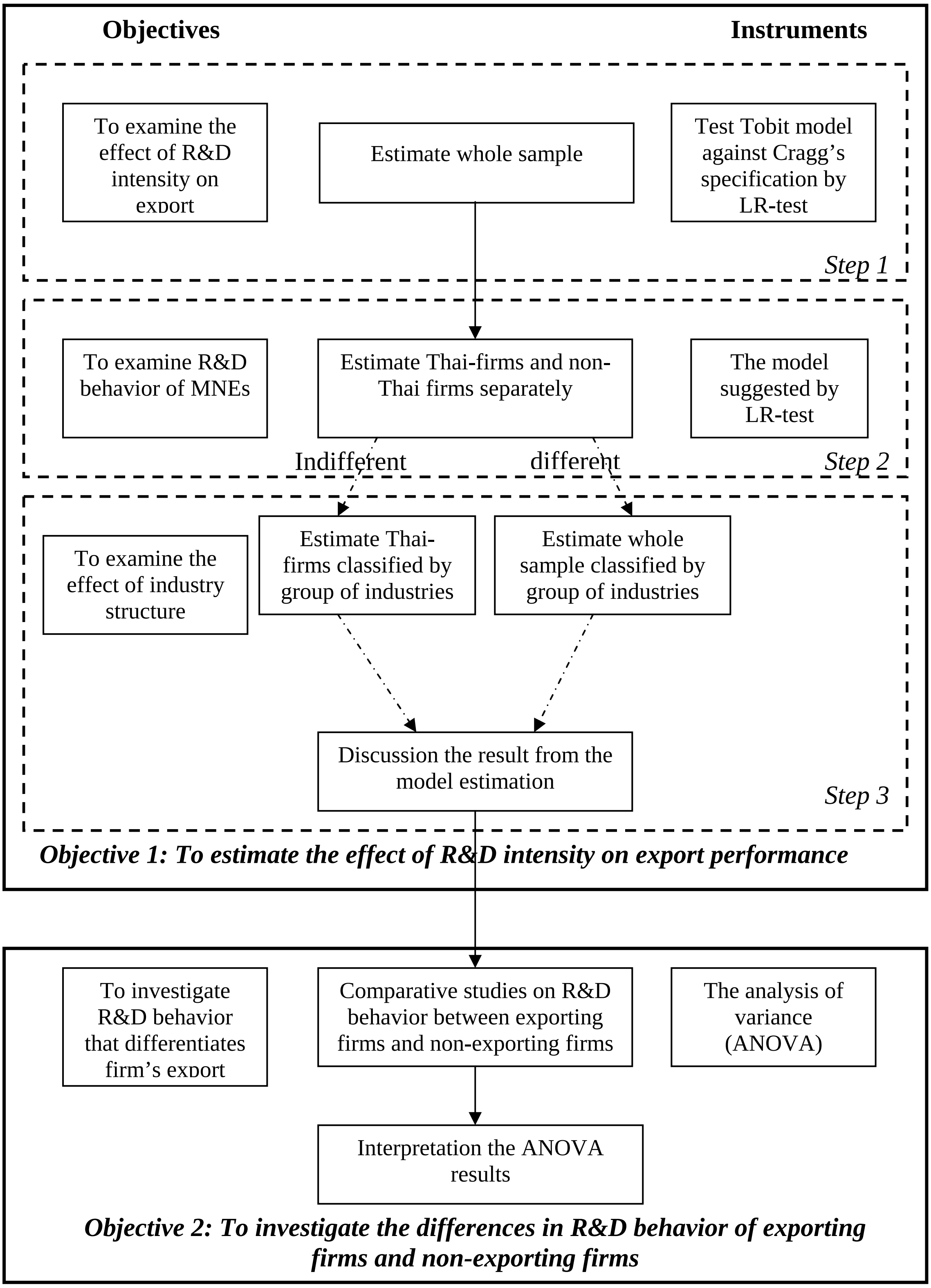
Then we examine whether effect of R&D on export performance varies across industries by classify industries into four groups using Pavitt taxonomy and estimate each group separately.

Finally, we apply the analysis of variance to compare R&D behaviors between exporting firms and non-exporting firms, in order to examine whether exporting firms and non-exporting firms carry out different kinds of R&D.

The summary of thesis framework is presented in Figure 5.1.

Figure 5.1

Thesis Framework



CHAPTER 6

RESULTS OF THE STUDY

This chapter consists of two parts. The first part describes the econometric results, including the choice of specification and discussions of the results. The second part reports the results from the analysis of variance (ANOVA) and statistics interpretations.

6.1 The Econometrics Results

This study estimates the equation 5.1 by the single censored tobit model and Cragg's two-stage specification. The equation 5.1 is tested whole sample and sub-samples include Thai firms and non-Thai firms. The results are presented in Tables 6.1 and 6.2.

6.1.1 The Choice of Specifications

The results of the specification in LR-test are presented in the bottom row of table E-1 and E-2 in appendix E. The single censored Tobit model (restricted model) is tested against Cragg's two-stage specification (unrestricted model). The Likelihood ratio test (LR-test) is implemented on both whole sample and sub-samples that are classified by their ownership. For the whole sample, the LR-test rejects the restricted model (Tobit model), indicating that the effects of the independent variables on the probability of exporting and export propensity are statistically different. The test statistics is equal to 33.66, which is greater than the critical value of the chi-squared distribution with 8 degrees of freedom at 95% confidence level (equal to 15.51). The result of LR-test on the whole sample suggests that the Cragg's two stage specification is more suitable.

On the contrary, for the sub-samples classified by the ownership, the results of LR- test reveals that the single censored Tobit model is more appropriate than the

Cragg's two stage specifications. Calculated test statistics of Thai firms and non-Thai firms are 3.3 and 12.99 respectively. Both test statistics are less than the critical value of the chi-squared distribution with 8 degrees of freedom at a 95% level of confidence. Therefore, estimating both the Thai firms and non-Thai firms by the single censored tobit model is more appropriate than analyzing them by the Cragg's two-stage specification.

The LR chi-square (in the tobit and the probit models) and Wald chi-square (in the truncated model) are both statistically significant at 99% level of confidence, implying that all independent variables jointly influence the dependent variable. Unfortunately, all models report diminutive Pseudo R^2. One possible explanation is that the firm's export performance is determined by several factors, for example, capital-labor ratio (indicating firm's productivity). However, some factors are not included in our model due to the limitation of data. Justification for disregarding the Pseudo R^2 is further asserted by Gujarati (2003). According to Gujarati, the foremost priority is the expected sign of the regression coefficients; the goodness of fit (measured by Pseudo R^2) is of a secondary importance in the binary choice model. Thus this study ignores econometrics limitations and focuses more on the effects of each independent variable on export performances.

Although the LR-test suggests that the Cragg's two stage specification is suitable for the whole sample estimation, this study focuses on the results from the Tobit model because it permit us to compare the results with the results of sub-samples. It is important to note that the results of both the estimations are similar in terms of estimated signs and the statistical significance of the coefficients. Therefore, it is advisable to not adhere to the method of estimation preferred in the study, but to focus on the comparison of the results obtained from the whole sample with the results of sub-samples (Thai firms and non-Thai firms). The study is simplified and comprehendible when the results from the same method of estimation are compared. Hence, Table 6.1 below shows the Tobit estimated results of whole sample, Thai firms, and non-Thai firms. The results of the probit and truncated estimations (Cragg's specification) are shown in appendix E.

Table 6.1

Tobit Estimated Results of the Whole Sample (All firms) and Sub-Sample Classified by Ownership (Thai firms and non-Thai firms)

	Variables	All Firms	Thai firms	Non-Thai firms
R&D intensity	*RDINT*	0.4445*** (2.94)	0.3342*** (3.22)	0.4453 (0.66)
Skilled labor	*SKILL*	0.0684 (0.46)	0.0159 (0.17)	0.0242 (0.24)
Size	*SIZE*	0.0039*** (6.63)	0.0643*** (6.43)	0.0136** (3.26)
Size2	*SIZE2*	-0.0001*** -(4.16)	-0.0013*** -(3.86)	-0.0001** -(2.33)
Ownership	*OWN*	0.0362*** (4.48)		
Constant		-0.1980*** -(4.58)	-0.2354*** -(4.23)	0.0103 (0.16)
Sigma		0.6039	0.6272	0.5573
Log-likelihood		-1338.90	-871.34	-453.05
LR chi2, Wald chi2		114.43	74.79	76.24
Prob > chi2		0.00	0.00	0.00
Pseudo R2		0.041	0.0412	0.0486
Number of Observation		1695	1142	553

Note: Figures in this table are marginal effects calculated at mean; t-statistics are in parenthesis
Dummy variables of industrial structure are not shown
* statistically significant at 10% level of significance
** statistically significant at 5% level of significance
*** statistically significant at 1% level of significance

6.1.2 <u>The Results of the Whole Sample (all firms)</u>

The estimated results of the whole sample have been shown in the third column of table 6.1. This study finds that the expected signs of all variables are correct with the given assumptions. Since the values of coefficients of these models have no meaning, this study reports only the marginal effects in Table 6.1. The marginal effects at mean can be interpreted as the magnitude change in the conditional expected value of the dependent variable given an alteration by one unit of the independent variables. The marginal effects of each independent variable are discussed below.

RDINT positively correlates with the export intensity. The marginal effect of *RDINT* is 0.4445, indicating that if the R&D intensity increases (decreases) by one million baht, the conditional expected export intensity will increases (decreases) by 0.4445 units. The results reflect that R&D intensity improves the export performance of the manufacturing firms in Thailand.

SKILL has a positive influence on the export intensity. The marginal effect of *SKILL* has a positive sign and equals to 0.0684, indicating that if the share of skilled labor in the total number work force increases (decreases) by one unit, the conditional expected export intensity will increase (decreases) by 0.0684 unit. However, this variable is insignificant. Therefore, we conclude that skilled labor does not affect the export performance of manufacturing firms in Thailand.

Firm's characteristics are the important determinants of the export performance. *SIZE* has a positive influence on the export intensity. The marginal effect of *SIZE* is 0.0039 indicating that if the number of employees increase (decreases) by one hundred workers, the conditional expected export intensity increases (decreases) by 0.0039 unit. Thus, it can be concluded that large firms have higher export performance than small firms.

The square of size variable (*SIZE2*) has a negative sign reflecting the inverted U-shaped relationship between a firm's size and export performance.

The marginal effect of *OWN* is positive and significant. It indicates that foreign ownership correlates positively with the export intensity. If the share of foreign capital in the firm's total capital increases (decreases), the conditional expected export intensity increases (decreases).

6.1.3 The Results of Sub-Samples Classified by Ownership (Thai Firms and non-Thai firms)

In order to examine whether MNEs behave differently in R&D activities from local firms, this study divides the whole sample into two sub-samples; Thai firms and non-Thai firms. Both of these sub-samples are estimated separately, and the estimated results are presented in the forth and fifth column of Table 6.1. On comparing them with the whole sample, we observed that the regression results of Thai firms are similar those of the whole sample, but the results of non-Thai firms are different.

For Thai firms, the expected signs of all variables are correct with the assumption. Discussions on the effects of each independent variable are presented below.

RDINT has a positive influence on the export intensity. The marginal effect of *RDINT* is 0.3342, indicating that if R&D intensity increases (decreases) by one million baht, the conditional expected export intensity increases (decreases) by 0.3342 unit. This lends support to the assumption that R&D intensity improves the export performance of Thai firms.

SKILL has a positive influence on the export intensity. The marginal effect of *SKILL* is equal to 0.0159 which indicates that if the share of skilled labor on total work force increases (decreases) by one unit, the conditional expected export intensity increases (decreases) by 0.0159 unit. Similar to the estimated results of the whole sample, this variable is insignificant. Hence, for Thai firms, this study concludes that skilled labor does not affect the export performance.

The estimated marginal effect of *SIZE* is positive and significant. The marginal effect of *SIZE* is 0.0643, which points out that if the number of employees increases (decreases) by one hundred workers, the conditional expected export intensity increases (decreases) by 0.0643 unit. Our finding indicates that large Thai firms have a higher export performance than small Thai firms.

The square of size variable (*SIZE2*) has a negative sign. The positive sign of *SIZE* and the negative sign of *SIZE2* reflect the inverted U-shaped relationship between the size of Thai firms and their export performance.

Regarding non-Thai firms, the expected signs of all variables are correct with the assumption. Nevertheless, several variables are insignificant. A discussion on the effects of each independent variable is presented below.

The marginal effect of *RDINT* is positive but not significant. It indicates that if the R&D intensity increases (decreases) by one million baht, the conditional expected export intensity increases (decreases) by 0.4453 unit. Nevertheless, this variable is insignificant. It reveals that, for non-Thai firms, the R&D intensity does not determine their export performance.

Similar to the estimated results of the whole sample and Thai firms, *SKILL* has a positive influence on the export intensity but is insignificant. Hence, this study concludes that skilled labor does not affect the export performance of non-Thai firms.

The estimated marginal effect of *SIZE* is significantly positive. The marginal effect of *SIZE* is 0.0136. It can be inferred that if the number of employees increase (decrease) by one hundred workers, the conditional expected export intensity increases (decreases) by 0.0136. Thus, similar to previous results, large non-Thai firms have a higher export performance than small non-Thai firms.

For non-Thai firms, the square of size variable (*SIZE2*) has a negative sign and is significant. It reflects the inverted U-shaped relationship between firm's size and export performance.

6.1.4 Interpretation and Discussion on the Results of the Whole sample and Sub-Samples (Classified by Ownership)

From the estimated results of the whole sample, it can be stated that the R&D intensity positively influences the export performance of manufacturing firms in Thailand. We find specifically that the R&D intensity determines the export performance of Thai firms but it is inconclusive for non-Thai firms. For Thai firms, the result is as we expected, the R&D intensity facilitates Thai firm's export performance. As for theoretical suggestions, the R&D intensity improves productivity and then reduces the exporting cost. The R&D intensity may also increase a firm's probability of succeeding to develop new products and production processes. For this reason, an increase in R&D intensity leads a firm to have an advantage over its competitors. In other words, R&D intensity improves the export performance of Thai firms. However, the R&D intensity does not affect the export performance of non-Thai firms. As we mentioned earlier, non-Thai firms possibly carry out R&D in parent offices and then allocate R&D output to their affiliates in Thailand.

Skilled labor, although having positive marginal effects, have no influence on export performance in all estimations (whole sample, Thai firms, and non-Thai firms). From the theoretical viewpoint, skilled labor may contribute either positive or negative effects on export performance. Therefore, skilled labor can be considered as informal R&D element. A large number of skilled labor increases the probability of R&D success, the given level of success in R&D lets firms reduce production costs and develop new products, which consequently induce export performance. In contrast, employing skilled labor simultaneously raises the cost of production and reduces the export performance. In our results, skilled labor positively affects export performance. Thus, employing skilled labor proves to be beneficial for firms. Nevertheless, this variable is insignificant, which indicates that the benefits of skilled labor are small and scarcely improve export performance. Consequently, we conclude that skilled labor does not influence the export performance of manufacturing firms in Thailand.

This study also finds an inverted U-shaped relationship between a firm's size and exports (whole sample, Thai firms, and non-Thai firms). The finding results point out that, in general, large firms have a superior export performance than small firms. One possible reason is that large firms are financial secure than their smaller counterparts allowing them to cover penetration costs in export markets. Large firms also have the advantage from lower financial costs and transportation costs. In addition, large firms have higher bargaining power compared to small firms in dealings with financial institutions, enabling large firms to secure lower financial costs on per exported unit.

The reverse of the effects of firm's size on export, which showed by an inverted U-shaped relationship, need an explanation. Our finding is similar to that of Wakelin (1998). Wakelin proposes that very large firms tend to sell their products to the domestic market more than abroad if they obtain benefits from being large firms in the domestic market. For instance, if the domestic market is not perfectly competitive, large firms possibly obtain monopolistic power, which in turn reduces the incentive to export.

Regarding foreign ownership, generally, the larger the share of foreign capital in the firm's total capital, the higher is the export performance. It indicates that foreign shareholders have positive impacts on firm's export performance for two reasons. Firstly, by the nature of foreign and joint venture firms, they intend to export more than to sell to the domestic market. Foreign firms usually have disadvantages (compared to local firms) in competing in the domestic market (for example, language and cultural differences). Secondly, foreign shareholders have strong export experiences, international background, and management skills. In addition, they usually are the technology owners. International backgrounds and experiences reduce the cost of penetrating in the export market such as information and advertising costs. Being a technology owner also reduces the costs of technology adaptation. To sum it all up, we can conclude that foreign shareholders induce higher export performance in Thai manufacturing firms.

Besides, the results reflect the presence of economies in multiplant operation. According to the whole sample estimation, we observe that foreign ownership positively correlates with export performance. Non-Thai firms have higher export performance than Thai firms. However, when we estimate the sub-samples classified by ownership, R&D intensity does not determine the export performance of the non-Thai firms. These results suggest that the superior export performance of non-Thai firms comes from other factors, not from R&D intensity. According to the concept of economies of multiplant operation, non-Thai firms may exploit R&D output from other plants (within their enterprise) to improve their export performance.

Under the presence of economies of multiplant operation, an analysis of the effect of R&D intensity on the export performance of non-Thai firms by using our framework is ineffective. Thus, non-Thai firms are excluded from our further analysis.

6.1.5 The Estimated Results Classified by Industrial Structure and Interpretation

According to the proposition by Kumar and Siddharthan (1994) indicating that the benefits of R&D on export performance may vary across industries, we separate manufacturing firms in Thailand into four groups as by Pavitt taxonomy (classified by industrial structure). These four groups of industries consist of supplier-dominated industries (SDOM), scale intensive industries (SCAI), specialized supplier industries (SPEC), and science based industries (SCIB). Each group of industries is estimated separately. For the reason discussed above, non-Thai firms have been excluded from our sample. Hence, from this point, all firms in the sample are Thai firms. Regarding the LR-test of Thai firms, the Tobit model is appropriate for estimations. The Tobit estimated results are classified by industrial structure and are presented in Table 6.3.

Table 6.2

Estimated Results for Different Groups of Industry

	Variables	SDOM	SCAI	SPEC	SCIB
R&D intensity	*RDINT*	2.3723** (2.05)	0.5308* (1.90)	0.2101 (0.22)	0.1990 (1.39)
Skilled labors	*SKILL*	0.0664 (0.47)	-0.1036 -(0.60)	-0.2021 -(0.78)	0.1775 (0.80)
Size	*SIZE*	0.0897*** (4.93)	0.0811*** (4.59)	0.1298* (1.92)	0.0001 (0.00)
Size2	*SIZE2*	-0.0020*** -(2.86)	-0.0028*** -(3.95)	-0.0052 -(0.71)	0.0005 (0.67)
Constant		-0.2756*** -(4.31)	-0.1767*** -(2.87)	-0.1962** -(2.15)	-0.2394*** -(2.59)
Sigma		0.6273	0.5982	0.5483	0.6777
Log-likelihood		-283.21	-285.75	-110.25	-177.28
LR chi2, Wald chi2		51.03	26.43	11.2	6.78
Prob > chi2		0.00	0.00	0.02	0.15
Pseudo R2		0.0826	0.0442	0.0483	0.0188
Number of Observation		371	376	161	234

Note: Figures in this table are marginal effects calculated at mean; t-statistics are in parenthesis
Dummy variables of industrial structure are not shown
* statistically significant at 10% level of significance
** statistically significant at 5% level of significance
*** statistically significant at 1% level of significance

The estimated results in Table 6.2 show that the effects of R&D intensity on export performance vary among groups of industries. Discussions on each variable are explained below.

The marginal effects of *RDINT* are positive and significant in the estimations of SDOM and SCAI samples, while being positive and insignificant in SPEC and SCIB. For firms in SDOM industries, if the R&D intensity increases (decreases) by one million baht, the conditional expected export intensity increases (decreases) by 0.3723 units. For firms in SCAI industries, if the R&D intensity increases (decreases) by one million baht, the conditional expected export intensity increases (decreases) by 0.5308 units. For SPEC and SCIB, an increasing in R&D intensity does not affect a firm's export performance.

SKILL is positive in SDOM and SCIB estimations, and negative in SCAI and SCIB estimations. Nevertheless, this variable is insignificant in all models. We suggest that skilled labor does not influence export performance in all groups of industries.

The marginal effects of *SIZE* are positive and significant in SDOM, SCAI, and SPEC, and being positive but insignificant in SCIB, *SIZE*. The significantly positive effects reveal that if firm's total number of employees increases (decreases) by one hundred workers, the conditional expected export intensity increases (decreases) by 0.0897 unit for firms in SDOM industries, 0.0811 unit for firms in SCAI industries, and 0.1298 unit for firms in SPEC industries. For firms in SCIB, an increase in the firm's size does not affect their export performance.

SIZE2 has a negative sign and is significant in the estimations of SDOM and SCAI industries, while it is a negative sign but is insignificant in the estimation of SPEC. For SCIB estimation, *SIZE2* is a positive sign and is insignificant. Our results indicate that, in SDOM and SCAI industries, there is an inverted U-shaped relationship between a firm's size and export performance. The inverted U-shaped relationship between a firm's size and export performance is not present for the case of SPEC and SCIB industries.

In summary, this study finds that, in Thai manufacturing firms, the R&D intensity only improves export performance for firms that belong to supplier dominated, (SDOM) and scale intensive (SCAI) industries. Our finding result is similar to the results of Kumar and Siddharthan (1994) for India and Dijk (2000) for Indonesia. It supports that, in developing countries, R&D intensity determines export performance only for low and medium technology industries.

6.2 The Comparative Analysis of Exporting Firms and Non-Exporting firms

6.2.1 The Results of the Analysis of Variance

From the econometrics results, we ascertain that all constant terms are significant. It implies that there are other variables influencing the conditional expected export intensity. In other words, firm's export performance is influenced by other factors. The estimated results allow us to reconsider our initial concern that, apart from R&D intensity, R&D behavior may also affect export performance[1]. In order to examine our hypothesis, this study employs six criterions on the R&D behavior discussed in chapter 5 to observe whether the R&D behavior between exporting firms and non-exporting firms are different.

To examine the difference in R&D behavior among NE, SSE, and LSE, this study uses the analysis of variance (ANOVA)[2] technique. At first, firm's characteristics and R&D intensity are considered. Segregating firm's R&D intensity and characteristics among three sub-samples provides us a draft picture before continuing further analysis. Results of mean comparison are presented in Table 6.3.

In Table 6.3, an average R&D intensity of LSE is 0.05 million baht, while NE and SSE have average R&D intensity of 0.02 and 0.03 million baht respectively. Our finding shows that LSE have a larger R&D intensity than SSE and NE. When analyzing with ANOVA, the results of mean comparison do not give statistically significant differences. However, the study also verifies mean difference by using t-test to compare means of NE and LSE[3]. We find that R&D intensity between the two groups is significantly different. It is possible that variances of NE, SSE, and LSE are not equal, thus in this case using ANOVA yields incorrect results, the results from t-test are more reliable. For this reason, we conclude that there is difference in R&D intensity between exporting firms and non-exporting firms.

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[1] Although econometric results suggest that there are other factors which determine export performance, we can not add other factors in our estimations due to the limitations of the data. Furthermore, this study focuses on the effect of R&D. Other factors can be ignored.

[2] This study mainly uses one-way ANOVA and t-test between NE and LSE to examine the difference; t-tests between other sub-samples are not considered.

[3] T-test of mean difference in R&D intensity between NE and LSE is 2.859, which is statistically significant at 90% level of confidence.

On average, LSE has 433 employees, while SSE and NE have 378 and 381 workers respectively. It is obvious that average employees of SSE and NE are almost the same. The comparison of firm's total employees suggests that NE, SSE, and LSE have no difference in firm's size.

For skilled labor, on average, the share of skilled labor in the total number of employees in SSE is 0.22, for LSE its 0.21 and for NE registers at 0.18. The comparison result of skilled labor does not give any statistically significant differences, indicating that LSE, SSE, and NE have no difference in the numbers of skilled labors.

Overall, the means comparison results indicate that exporting firms have more R&D intensity than non-exporting firms, while they have no differences in skilled labor and firm's size. This implies that, among Thai-firms that carry out R&D, the R&D intensity is a discriminating factor between exporting firms and non-exporting firms but skilled labor and firm's size are not the factors.

Table 6.3

The Test for Equality of Means of R&D Intensity, Firm's size, and Skilled labor

	All Firms with R&D	NE (%Export =0)	SSE (0<%Export <50%)	LSE (%Export ≥ 50%)	Sig.
R&D intensity*	0.03 (0.08)	0.02 (0.03)	0.03 (0.08)	0.05 (0.11)	0.21
Size*	396 (509.89)	381 (444.77)	378 (522.03)	433 (562.23)	0.82
Skilled labor*	0.20 (0.22)	0.16 (0.18)	0.22 (0.23)	0.21 (0.23)	0.36
N	164	51	63	50	

Note: All figures reported in the table are mean of each variable, standard deviation is in parenthesis

* R&D intensity, size, and skilled labor are measured as in the estimated model. R&D intensity is R&D expenditures (million baht) over total employees, firm's size is measured by total employees, and skilled labor is measured by graduated workers in total employees.

The following section compares the difference in the in-house R&D, the numbers of scientists and engineers, and the number of products designed by firms (firm's own design products) includes share of products designed by firms according to customer requirements in total sale as well as share of products designed and sold under own brand in total sale) among NE, SSE, and LSE. The results of comparison are shown in Table 6.4.

Table 6.4

The Test for Equality of Means under the Aspects of Technology-Follower

	All Firms with R&D	NE	SSE	LSE	Sig.
		%Export =0	(0<%Export <50%)	Export≥ 50%	
The in-house R&D	0.90 (0.26)	0.93 (0.21)	0.88 (0.28)	0.90 (0.26)	0.66
Numbers of scientists and engineers	0.07 (0.10)	0.06 (0.09)	0.10 (0.12)	0.06 (0.07)	0.12
Share of products designed by firms according to customer requirements in total sale*	0.15 (0.29)	0.15 (0.29)	0.10 (0.21)	0.22 (0.35)	0.09
Share of products designed and sell under own brand in total sale*	0.35 (0.43)	0.26 (0.41)	0.51 (0.45)	0.25 (0.39)	0.01
N	164	51	63	50	

Note: All figures reported in the table are means of variables and the standard deviation is in the parenthesis

*Numbers of firms reported own design products are 157 (45 non-exporting firms, 62 exporting firms, and 50 major-exporting firms)

From Table 6.4, on average, NE conducts in-house R&D more than SSE and LSE. Share of in-house R&D in the total of R&D activities of NE accounts for 0.93. In other words, 93% of R&D activities are performed within firms (7% are contracted by a second party). The similar interpretation goes to SSE and LSE whose shares of the in-house R&D in the total of R&D activities are 0.88 and 0.90 respectively. However, the differences in the level of the in-house R&D among the three sub-samples are trivial. All sub-samples report large share of the in-house R&D. In sum, this study finds that exporting firms and non-exporting firms have no differences in level of the in-house R&D activities.

For the numbers of scientists and engineers, on average, the ratio of scientists and engineers in the total number of employees is 0.06 for NE and LSE, and 0.10 for SSE. This can be interpreted as, given 100 employees; SSE employs 10 scientists and/or engineers, while SSE and NE employ 6 scientists and/or engineers. Nevertheless, this factor is statistically insignificant, which shows that exporting firms and non-exporting firms have no difference in the numbers of scientists and engineers.

With regard to product design, the first discriminating aspect that emerges is share of products designed by firms according to customer requirements in total sales. The share of products designed according to customer requirements in total sales are 0.22 for LSE, 0.15 for NE and 0.10 for SSE.

The share of products designed and sold under their own brand for a given the total sales is also proved to be a factor that discriminates export. Share of products designed by firms and sold under their own brand in the total sales of SSE is 0.51, while it is equal to 0.26 for NE and 0.25 for LSE.

Overall, it can be observed that the exporting firms (both SSE and LSE) of owned designed products on average are slightly above the non-exporting firms (NE). However, it is important to note that, based on the definition of design products in NSTDA survey; the data used in our study encompasses a broader view. In practice, the characteristics of "design" in NE, SSE, and LSE are probably dissimilar. Unfortunately, the limitation of the data does not permit us to analyze it in more detail.

In conclusion, our findings suggest that the number of firm's own design products succeed in discriminating in NE, SSE, and LSE. Exporting firms have much more propensity of own design products in higher proportion than of non-exporting firms.

Another applied factor in our analysis is the types of R&D, including the basic research, the applied research, and the experimental development. The results of the analysis of variance by the types of R&D are shown in Table 6.5.

Table 6.5

The Test for Equality of Means of the Types of R&D

	All Firms	NE	SSE	LSE	Sig.
		%Export =0	(0<%Export<50%)	Export≥ 50%	
Basic Research	0.64 (0.31)	0.59 (0.31)	0.63 (0.31)	0.70 (0.32)	0.26
Applied Research	0.28 (0.30)	0.31 (0.29)	0.29 (0.31)	0.25 (0.29)	0.64
Experimental Development	0.08 (0.11)	0.10 (0.12)	0.08 (0.12)	0.05 (0.09)	0.10
N	164	51	63	50	

Note: All figures reported in the table are mean of each variable and standard deviation is in parenthesis

From Table 6.5, the study shows that, on average, the share of R&D expenditure distributed for the basic research of LSE is 0.7, while those of SSE and NE are 0.63 and 0.59, respectively. In other words, about 70%, 63%, and 59% of R&D expenditures are spent on the basic research, by respectively, LSE, SSE, and NE. However, the results of comparison do not give any statistically significant difference.

For the applied research, the share of R&D expenditure distributed for the applied research is equal to 0.25 for LSE, 0.29 for SSE and 0.31 for NE. Alternative speaking, LSE spends approximately 25% of their R&D expenditure on the applied research, while SSE spends 29%, and NE spends 25%. The result of comparison, however, does not give any statistically significant differences.

On average, the share of R&D spending on the experimental development as a total of R&D expenditures is 0.05 for LSE. It shows that LSE allocates 5% of their R&D expenditures on experimental development. The share of R&D spending on experimental development as a total of R&D expenditures is 0.08 for LSE and 0.10 for NE. SSE spent 8% of their R&D expenditures on experimental development, while NE spends 10% of R&D expenditures on this activity. Differences from the basic and the applied research, this result of comparison is statistically significant different. Overall, we conclude that exporting firms and non-exporting firms have no differences in conducting basic or applied research, but non-exporting firms have more activities on experimental development than exporting firms.

Table 6.6

The Test for Equality of Means of Objectives of R&D

	All Firms	NE	SSE	LSE	Sig.
		%Export =0	(0<%Export <50%)	Export≥ 50%	
Improve production process	0.39 (0.49)	0.50 (0.51)	0.29 (0.46)	0.40 (0.49)	0.07
Develop new production process	0.32 (0.47)	0.29 (0.46)	0.33 (0.48)	0.34 (0.48)	0.87
Improve quality of existing products	0.62 (0.49)	0.75 (0.44)	0.56 (0.50)	0.58 (0.50)	0.09
Develop new products	0.67 (0.61)	0.61 (0.49)	0.76 (0.76)	0.62 (0.49)	0.32
Granted patents	0.09 (0.28)	0.10 (0.30)	0.05 (0.21)	0.12 (0.33)	0.37
N	164	51	63	50	

Note: All figures reported in the table are mean of each variable and standard deviation is in parenthesis

With regard to the objectives of doing R&D, it is quite surprising that, on average, NE reports higher levels of success in improving production processes and improving the quality of existing products than SSE and LSE. The results of comparison give statistically differences. Contrasting to previous studies, NE seems to succeed in improving in production process and product quality more than SSE and LSE. In other words, it can be said that non-exporting firms succeed in improving in production process and product quality more than exporting firms. Moreover, it should also be noted that the results suggest that SSE typically do R&D for developing new products, while LSE frequently performs R&D for developing new production process. Nevertheless, firm’s objective to develop new products and production processes is not significantly different. Alternative speaking, exporting firms and non-exporting firms have no difference in developing new products and production process.

One possible explanation that NE has the higher numbers of success in improving production processes and improving the quality of the existing products is that several Thai firms frequently carry out R&D to improve product quality and production processes corresponding to customers in the domestic market. They do not perform R&D with the aim to improve product quality or production processes for export. Unfortunately, this study cannot analyze this issue in more detail due to data limitation.

Table 6.7

The Test for Equality of Means of External Collaboration in R&D

	N*	All Firms	NE	SSE	LSE	Sig.
			%Export =0	(0<%Export <50%)	Export≥ 50%	
Customers, buyers	88	3.65 (1.29)	3.47 (1.11)	3.84 (1.35)	3.55 (1.43)	0.46
Locally-owned suppliers	83	3.02 (1.24)	2.90 (1.23)	3.23 (1.26)	2.84 (1.21)	0.44
Foreign-owned suppliers	71	2.80 (1.25)	2.60 (1.04)	2.93 (1.39)	2.88 (1.31)	0.60
Parent/associate company overseas	44	2.80 (1.64)	2.31 (1.75)	3.00 (1.57)	3.00 (1.69)	0.45
Public research institutes	77	2.43 (1.26)	2.56 (1.25)	2.32 (1.27)	2.44 (1.31)	0.78
Private non-profit	50	1.92 (1.23)	1.76 (1.20)	1.89 (1.15)	2.14 (1.41)	0.70
Universities	74	2.62 (1.28)	2.39 (1.20)	2.76 (1.32)	2.67 (1.33)	0.57
Business Service Providers	59	2.10 (1.24)	1.80 (0.89)	2.21 (1.50)	2.33 (1.18)	0.40
Technical Service Providers	63	2.25 (1.16)	2.05 (1.13)	2.42 (1.30)	2.27 (0.96)	0.54
Competitors	60	2.47 (1.40)	2.29 (1.27)	2.32 (1.44)	3.00 (1.47)	0.27

Note: All figures reported in the table are the mean of each variable and standard deviation is in parenthesis

* Many firms report "0" for external collaboration. Zero means, "Not known". Hence, we ignore those firms. N represents numbers of firms reporting level of external collaboration from 1 to 5

From Table 6.7, LSE reports the importance of collaboration in R&D with parent and associated companies overseas, private non-profit firms, business service providers, and competitors. SSE reports the importance of collaboration in R&D with customers, foreign and local suppliers, parent and associated companies overseas, universities, and technical service providers. Conversely, NE reports the importance collaboration in R&D with public agents.

However, in general, the exporting firms (SSE and LSE) reveal the degree of cooperation with the external agents slightly higher than that of the non-exporting firms (NE). Nevertheless, none of the R&D collaboration succeeds in discriminating among our sub-samples. That is, exporting firms and non-exporting firms have no difference in the level of collaboration in R&D.

From the results presented above, on the whole, even though the comparison of the degree of external collaboration in R&D does not give any statistically significant differences, the statistical evidences show that exporting firms mostly experience higher levels of collaboration than non-exporting firms. This reflects a tendency for exporting firms to associate and develop better relations with other agents.

6.2.2 <u>The Discussion on the Analysis of Variance</u>

According to the analysis of variance, among Thai owned firms that undertake R&D, large-share exporting firms (LSE), small-share exporting firms (SSE), and non-exporting firms (NE) have differences in the R&D intensity, the experimental development, the number of own design products (both design by customer requirement and design for selling under their own brand), and the objectives of R&D.

The difference in firm’s export has a relationship with difference in R&D intensity. Exporting firms have higher R&D intensity than non-exporting firms. The reason is as discussed in the results for the tobit model. R&D intensity is important to compete in the export markets.

Exporting firms have higher in proportion of own design product than non-exporting firms. Our results are as we expected, the difference in firm’s export has a relationship with the difference in own design product. Based on Forbes and Wield (2000), product design is important for the technology-follower firms to compete with competitors. Given the fact that firms dealing in the export markets are confronted with more competitors than firms present in the domestic markets, therefore it is reasonable to say that exporting firms have more numbers of owned design products than non-exporting firms.

Another discriminating factor is doing R&D in a form of the experimental development. Non-exporting firms spend on the experimental development in higher proportions than exporting firms. Moreover, non-exporting firms have much more success in improving product quality and production process. These results are different from preceding studies. As stated earlier, unanticipated results may come from the reason that many Thai firms conduct R&D with the purpose of improving product quality and production process by concentrating on the domestic market.

Exporting firms and non-exporting firms have no differences in other factors. Skilled labors and firm’s size are not discriminating factors to the firm’s export. In other word, among Thai firms with R&D, exporting firms and non-exporting firms have no difference in proportions of skilled labors and firm’s size.

Both exporting firms and non-exporting firms report large share of the in-house R&D in total R&D activity. On the whole, Thai firms (both exporting firms and non-exporting firms) normally carry out R&D by themselves rather than outsourcing to other agents.

The findings suggest that both non-exporting firms and exporting firms have no difference in perceiving the important of external knowledge. The proportion of scientists and engineers, which indicates firm's capacity in learning and exploiting external knowledge and new technology, is not significantly different between exporting firms and non-exporting firms. Taking into account the results of external collaboration, additionally, this indicates that exporting firms and non-exporting firms do not much different in level of collaboration in R&D.

Exporting firms and non-exporting firms have not much differences in the types of R&D. Exporting firms seem to carry out the basic research more than non-exporting firms, but not significantly different. For the objectives of R&D, exporting firms and non-exporting firms have no differences in developing new products and processes, and granted patents.

CHAPTER 7

CONCLUSION

7.1 Summary

After the economic crisis in 1997, R&D began to play an important role on Thailand. In the public sector, the Thai government implemented R&D incentives including tax allowances and soft loans. In the private sector, the amount of R&D expenditures considerably increased from 512 million baht in 1997 to 4,094 million baht in 2001. One of the firm's objectives to implement R&D is to recover competitiveness and export performance which decreased during the economic crisis (Intarakumnerd, 2004).

However, the benefits of R&D on the export performance to firms in Thailand remain ambiguous. The effect of R&D on the export performance varies by country's specific characteristics. For example, R&D improves the export performance of the developed countries, but is not for the developing countries (Posner, 1961; Vernon, 1966). In developing countries, the benefits of R&D vary across industry (Kumar and Siddharthan, 1994).

In light of these concerns, this study, therefore, attempts to analyze the role of R&D on export performance of manufacturing firms in Thailand. This study consists of two parts. Firstly, we estimate the effect of R&D intensity on firm's export intensity. Secondly, we investigate the difference in R&D behavior between exporting firms and firms without export.

Based on the theoretical viewpoint, R&D contributes benefits to the firms in two forms; the former is the cost reduction (from an increasing in the productivity), the later is the product development (from an enhancing in the creativity). Overall, R&D boosts the firm's performance which promotes competitiveness. In the aspect of the international trade, R&D can improve export performance.

In case of Thailand, there are two important country's characteristics that should be concerned; the importance of MNEs in Thai economy, and the nature of developing countries. First of all, several multinational enterprises (MNEs) in Thailand carry out R&D in their parent offices and import the R&D outputs to their affiliates in Thailand. Thus the R&D behavior of MNEs may not match with their export performance. Second of all, by nature of developing country, manufacturing firms in Thailand are technology-followers. The role of R&D under the scheme of the technology follower is different from the technology leader (Forbes and Wield, 2000). In addition, the manufacturing firms in Thailand may not possible to have performance of exporting high-technology products although they have R&D (Kumar and Siddharthan, 1994). The three above issues are considered as the framework of our analysis.

In the first part, this study employs the regression analysis to investigate the effect of R&D intensity on firm's export performance. Other related factors such as firm's size and ownership are also taken into account. To estimate the model of export performance, this study applies LR-test to test the single censored tobit model against the Cragg' two stage specification. The results of LR-test show that the tobit model is more appropriate, thus using it throughout our study.

The model of export performance is estimated in three stages. At first, this study estimates the model by using the data from all of the firms, and then estimates the model with Thai firms and non-Thai firms (foreign firms and joint venture firms) separately as a second stage. Estimating Thai firms and non-Thai firms independently allows us to verify R&D behavior of non-Thai firms. Our finding reveals that non-Thai firms report higher level of export share, but their export performances are not determined by R&D intensity. Nevertheless, it can not be concluded that R&D do not improve export performance of non-Thai firms. Export performance of non-Thai firms may derive from exploiting R&D output performed in their countries. However, this study does not go over that issue. Non-Thai firms are not considered in this study.

For Thai firms, export performance is determined by R&D intensity and firm's size, while skilled labor has no influence on export performance. R&D intensity positively influences export performance. R&D improves productivity of firms and then reduces costs of export products. Also, it helps increasing firm's probability to succeed in developing new products and production processes.

As for firm' size, this study found that the relationship between firm's size and export performance is an inverted U-shaped. This finding indicates that the large firms have superior export performance than the small firms, but for firms which their sizes are larger than the critical size; large firms may have not much of export. One feasible reason is that the large firms have more resources to cover costs of penetrating the export market than the small firms do. Moreover, the large firms can manage the lower financial costs and the lower transportation costs per unit of exports. Conversely, it is also possible that the very large firms tend to sell their products on the domestic markets rather than export them (Wakelin, 1998). For skilled labor, surprisingly, our finding shows that it does not determine export performance of Thai manufacturing firms.

The third stage of the estimation separates the Thai manufacturing firms into four groups by Pavitt taxonomy, consisting of supplier dominated industries (SDOM), scale intensive industries (SCAI), specialized supplier industries (SPEC), and science based industries (SCIB). Each group of the industries is estimated separately. This study found that the R&D intensity positively affects the export performance of firms in supplier dominated industries and scale intensive industries. Nevertheless, there is no influenced on export performance of firms in specialized supplier and science based industries.

In sum, the estimated result provides us three important issues;

- R&D intensity positively determines export performance of Thai firms, but does not influence export performance of non-Thai firms. This finding indicates that the export performance of non-Thai firms is not in line with the level of R&D intensity and requires other analytical framework to explain (Markusen 1984).
- For Thai firms, export performance is determined by R&D intensity and firm's size, while skilled labor has no influence on export performance. Hence, an increasing in R&D intensity conduces an increasing in export performance of Thai manufacturing firms.
- However, the benefits of R&D on export performance of Thai firms exist only in supplier dominated industries and scale intensive industries. Based on Dijk (2000), it can be said that R&D may improve export performance of firms in low

and medium technology industries but may not improve export performance of firms that belong to high technology industries.

For the second objective, this study uses the analysis of variance (ANOVA) to compare the R&D behavior of exporting firms and non-exporting firms. The analysis is performed on Thai firms with R&D by regarding the aspect of technology-follower (Forbes and Wield, 2000) and some factors mentioned by the preceding studies (Lefebvre et al., 1998; Roper and Love, 2002; Rodriquez and Rodriquez, 2005). Thai firms with R&D are divided into three groups; the non-exporting firms (NE), the small-share exporting firms (SSE), and the large-share exporting firms (LSE). We found that, in Thai firms undertaking R&D, the share of products designed by firms in the total sale and the R&D intensity of the three groups are significantly different. On average, share of own design products in total sale of the exporting firms are higher than that of the non-exporting firms. Likewise, the exporting firms have the higher R&D intensity than the non-exporting firms do. The outcomes seem to suggest that the R&D intensity and product design are the important consideration to exporting firms.

Other concerned discriminating behaviors are the experimental development, the product quality improvement and the production process upgrading. Unexpectedly, the non-exporting firms report the higher level of the experimental development, the product quality improvement, and the production process upgrading than the exporting firms. It is likely that Thai firms carry out R&D only with the purpose of improving product quality and production process for the domestic market. In conclusion, for the second objective, this study found that the exporting firms are discriminated from the non-exporting firms with the R&D intensity and the products design by firms.

Overall finding result of this study is similar to the results of the studies of R&D and export performance in other developing countries, for instance, India (Kumar and Siddharthan, 1994), Indonesia (Dijk, 2002) and China (Guan and Ma, 2003). It supports the argument that R&D intensity determines export performance of firms in developing countries. However, its benefits vary by industrial structure and ownership.

7.2 Limitation and Suggestion for Further study

There are some limitations in this study. One limitation is derived from the restrictions of the data. Firstly, the data collected by NSTDA is cross-section data, which do not allow us to examine the effects of R&D more than one period. However, one period is too short to a time to evoke the effects of R&D since R&D investments require some period of time to yield R&D output. Firms with high R&D intensity in this period may obtain benefits of R&D in next period. The use of the cross-section data does not permit us to capture this effect. In addition, many previous studies propose that, alternatively, the export also causes the R&D. Again, the use of the cross-section data restricts the causality test. For the future research, the growth rate of the export and the growth rate of R&D intensity or the panel data are more appropriate for studying in this topic.

Secondly, several data collected with a very broad definition. It is favorable to give a general picture of R&D in Thailand. At the same time, the analysis that uses the data with a broad definition does not provide us with specific and precise conclusions.

Thirdly, due to the reason that some of the data are not available, this study excludes some important variables in the estimation. There are actually not only studied variables but also many variables which affect the export performance such as the capital and labor ratio, the labor cost, and the productivity. Hence, the researcher should find alternative source of data to analyze the model for a better result in the further research.

Another important limitation is due to the limitation of quantitative analysis. The quantitative analysis does not give much information on firm's R&D behaviors. For example, it can not distinguish the different kinds of designs. Firms may design the new products for the domestic market or for the export markets. The characteristics of design products in both markets may well be dissimilar. The quantitative analysis does not allow us to fully investigate into the detailed information. In-depth study should be continued henceforth.

Finally, this study found that the export performance of firms in specialized supplier industries and science-based industries are not influenced by R&D intensity.

Due to the limitation of data and analytical framework, our analysis is restricted and fails to explain the export performance of firms in these industries. However, the specialized supplier industry firms and the science-based industry firms take an important role in the export of Thailand. It is beneficial to investigate the factors that determine the export performance in both industries in the future studies.

APPENDICES

APPENDIX A

DEFINITION OF RESEARCH AND DEVELOPMENT (R&D)

This study uses data from "The Thailand R&D/Innovation Survey 2003" collected by NSTDA for an analysis. In that survey, research and development (R&D) is defined based on Frascati Manual (2002) by OECD. The definitions of R&D and other related variables in this study are presented below.

"Research and development (R&D) comprises of creative work undertaken on a systematic basis in order to increase the stock of knowledge of man and society, and the use of this stock in order to devise new applications".

Table A.1

Examples of R&D Activities

R&D	NOT R&D
• Development of prototypes	• Scientific and technical information services
• Construction of pilot plants	• Routine testing and standardization
• Trial production (if it implies full-scale testing and subsequent further design and engineering	• Patent and license work not related to any R&D project
• Industrial design and drawing directly linked to R&D	• General purpose data collection, including market research

Source: Frascati Manual (2002)

The term R&D covers three activities:

1) Basic research

A basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of an underlying foundations of phenomena and observable facts, without any particular application or use in view.

2) Applied research

Applied research is an investigation undertaken with the purpose of acquires new knowledge. It is directed primarily towards a specific practical aim or objective.

3) Experimental development

Experimental development is systematic work, drawing on knowledge gained from research and practical experience, which is directed to producing new materials, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.

Table A.2

Examples of the Basic Research, the Applied Research, and the Experimental Development

Basic Research	Applied Research	Experimental Development
Study on a given class of polymerization reactions under various conditions, of the yield of products and of their chemical and physical properties	Optimizing one of these reactions with respect to the production of polymers with given physical or mechanical properties (making it of particular utility)	Investigating and evaluating possible methods of producing the polymer and perhaps articles to be made from it.
Study on a crystal's absorption of electromagnetic wave propagation at different frequencies	Study wireless technology emphasizing on cellular technology	Develop a mobile phone prototype
The determination of the amino acid sequence of an antibody molecule	Investigations undertaken in an effort to distinguish between antibodies for various diseases	Experimental development then consists of devising a method for synthesising the antibody for a particular disease on the basis of knowledge of its structure and clinically testing the effectiveness of the synthesised antibody on patients

Source: Frascati Manual (2002)

APPENDIX B

PAVITT TAXONOMY

This study classifies industries by Pavitt taxonomy (Pavitt, 1984). This method classifies industry associated with their different characteristics on innovation behavior, product organization, and competitive factors. He proposed four categories of industry including supplier dominated industries, specialized supplier industries, scale intensive industries, and science based industries.

In supplier dominated industries, in general, new technologies are introduced by suppliers of machinery and capital goods. In-house R&D is small. Supplier dominated sectors are generally mature industries such as textile and food industry. Scale intensive industries produce mainly bulk materials such as cement and steel. Technology change comes from an improvement in design, operation of the production process, and learning by doing. Technology change in this sector is mainly in the form of incremental change. Specialized suppliers industries generally consist of machinery and instrument industries. Science based industries include pharmaceutical, electronics, and chemical industries. In this group, in-house R&D and external collaboration are major sources of technology change.

Table B.1

Summary of Pavitt Taxonomy

Sector characteristics	Industry	Technology accumulation	Source of technology
Supplier dominated	Agriculture, construction, Services, Traditional manufacturing	Import technology / Little R&D	Specialized suppliers
Scale intensive	Petroleum and coal, iron and steel, motor vehicles, transportation equipments	Design, Operation , and learning by doing (Process innovation)	Internal
Specialized suppliers	Machinery building, instruments	Design & development	Clients
Science based	Chemical products, Electronics products, Pharmaceutical products	Academic research, Search for new technology	In-house R&D, external collaboration

Source: Pavitt (1984), Abhinorasaeth (2007)

APPENDIX C

INDUSTRIAL CLASSIFICATION

Table C.1

Classification of industry by Pavitt taxonomy

TSIC	Industries	This study	Pavitt(1984)	Laursen and Meliciani (1999)	Dijk (2000)
15	Manufacture of food and beverage processing	SCAI	SCAI	SCAI	SDOM
17	Manufacture of textile	SDOM	SDOM	SDOM	SDOM
18	Manufacture of wearing apparel	SDOM	SDOM	SDOM	SDOM
19	Manufacture of leather products	SDOM	SDOM	SDOM	SDOM
20	Manufacture of wood and wood products	SDOM	SDOM	-	SDOM
21	Manufacture of paper and paper products	SDOM	SDOM	-	SDOM
22	Printing and publishing	SDOM	-	-	SDOM
24	Manufacture of basic chemicals and other chemicals products	SCIB	SCIB	SCIB	SCIB
25	Manufacture of rubber and plastic	SCAI	SCAI	SCAI	SCAI
26	Manufacture of glass and non-metallic mineral products	SCAI	SCAI	SCAI	SCAI
27	Manufacture of basic iron and steel	SCAI	SCAI	SCAI	SCAI
28	Manufacture of fabricated metal product exclude machine	SCAI	SCAI	SCAI	-
29	Manufacture of machinery and equipment	SPEC	SPEC	SPEC	SPEC
31	Manufacture of electrical machinery	SPEC	SCIB	SPEC	SCAI
32	Manufacture of television, radio, and communication equipment	SCIB	SCIB	-	-
33	Manufacture of medical, precision, optical instruments, watches, and clocks	SCIB	-	SCIB	SCIB
34	Manufacture of motor vehicle and parts	SCAI	SCAI	SCAI	SCAI
36	Manufacture of furniture	SDOM	-	-	SDOM

APPENDIX D

THE TOBIT MODEL AND CRAGG'S TWO STAGES SPECIFICATION

The tobit model or censored regression model (Tobin, 1958) was formulated based on the fact that the dependent variable is truncated at a certain point. In this study we censored at zero. The model is defined as follow

$$y_i^* = \beta' x_i + u_i \qquad \text{(B.1)}$$

$$y_i = \begin{cases} y^* & \text{if } y_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \qquad \text{(B.2)}$$

β is a k x1 vector of unknown parameters. x_i is a k x 1 vector of known constants. u_i are residuals that are independently and normally distributed, with mean zero and common variance σ^2 ($u_i = N(0,\sigma^2)$). We observed $y_i = y_i^*$ only if y_i^* >0 and set $y_i = 0$ if $y_i^* \le 0$.

For the observations y_i^* that are zero, we have

$$\mathrm{P}(y_i^* = 0) = P(u_i < -\beta' x_i) = (1 - \Phi_i) \qquad \text{(B.3)}$$

For the observations y_i^* that are greater than zero, we have

$$P(y_i^* > 0) = P(u_i > -\beta' x_i) = \frac{1}{(2\pi\sigma^2)^{1/2}} e^{-(1/2\sigma^2)(y_i - \beta' x_i)^2} \qquad \text{(B.4)}$$

where F_i is normal density function[1] and f_i is normal distribution function.

Since we have censored observations with non-negative, applying OLS may provide biased results. The Maximum Likelihood method is more appropriate.

The likelihood function is

$$L = \prod_{y_i > 0} \frac{1}{(2\pi\sigma^2)^{1/2}} e^{-(1/2\sigma^2)(y - \beta' x_i)^2} \prod_{y_i = 0} (1 - \Phi_i) \qquad \text{(B.5)}$$

Φ_i is standard normal cumulative distribution function evaluated at $\beta' x / \sigma$. The likelihood function consists of two parts; discrete and continuous distributions.

[1] See Maddala (1996)

The log-likelihood function is presented as follow.

$$\ln L = \sum_{y_i>0}\left\{-\frac{1}{2}\left[\log(2\pi)+\ln\sigma_2^2+\frac{(y-\beta' x)^2}{\sigma^2}\right]\right\}+\sum_{y_i=0}\ln(1-\Phi_i) \qquad \text{(B.6)}$$

Maximize $\ln L$ with respect to β and σ^2 , we obtain $\hat{\beta}$ and $\hat{\sigma}^2$ as coefficients and variance of the tobit model.

However, since y^* is unobserved variable, there are differences in the marginal effects and the coefficient estimated from nonlinear regression ($\frac{\partial E\left[y_i^* \middle| x_i\right]}{\partial x_i}=\beta$) is not what will usually of interest. Greene (2003) proposed that the marginal effect of the tobit model is

$$\frac{\partial E\left[y_i \middle| x_i\right]}{\partial x_i}=\beta.\Phi\left(\frac{\beta' x_i}{\sigma}\right) \qquad \text{(B.7)}$$

An extension of the tobit model was introduced by Cragg (1971). Cragg's model allows one set of parameters to determine the probability of limit observation, and a second set of parameters to determine the density of the non-limit observation. The model basically assumes two things. First the probability of a limit observation (a zero) is given by a probit model with parameter vector β_1.

$$P(y_i=0)=1-\Phi(\beta_1' x_i) \qquad \text{(B.8)}$$

Second, it is assumed that the density of y_i, conditional on being a non-limit (positive) observation, is that $N(\beta' x_i,\sigma^2)$, truncated at zero. Thus,

$$P(y_i>0)=\frac{1}{\Phi(\beta_2' x_i/\sigma)}\frac{1}{(2\pi\sigma^2)^{1/2}}e^{-(1/2\sigma^2)(y_i-\beta_2' x_i)^2} \qquad \text{(B.9)}$$

The likelihood function is

$$L=\prod_{y>0}\frac{1}{\Phi(\beta_2' x_i/\sigma)}\frac{1}{(2\pi\sigma^2)^{1/2}}e^{-(1/2\sigma^2)(y_i-\beta_2' x_i)^2}\prod_{y=0}\left(1-\Phi_i(\beta_1' x\right) \qquad \text{(B.10)}$$

We define the indicator function I_i=1 if $y_i>0$ and I_i=0 if $y_i=0$. By taking log on both sides, we obtain the log likelihood function

$$\ln L = \sum_{i=1}^{0} \left\{ (1-I_i)\ln\Phi(-\beta_1' x_i) + I_i \begin{bmatrix} \ln\Phi(-\beta_1' x_i) - \ln\Phi(-\beta_2' x_i/\sigma) \\ -1/2\ln(2\pi\sigma^2) - (1/2\sigma^2)(y_i - \beta_2' x_i)^2 \end{bmatrix} \right\} \quad \text{(B.11)}$$

If $\beta_1 = \beta_2/\sigma$, Cragg's two stages specification reduces to the tobit model.

In practical, Cragg's two stages specification is estimated by probit model and truncated model. Each stage is estimated separately.

Similarly with tobit model, in the probit model y_i^* is unobserved variables. Hence, we use observed variable y_i as proxy of y_i^*. If unobserved variables are not positive, observed variables will be zero. However, the probit model uses dummy variables in case of unobserved variables are positive, rather than value of y_i^* as the tobit model. The model is defined as follow.

$$y_i^* = \beta_1' x_i + u_i$$

$$y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{(B.12)}$$

u_i is assumed iid and standard normal distribution. Therefore, the likelihood function corresponds to the model is

$$L = \prod_{y_i=1} (\Phi(\beta_1' x_i)) \prod_{y_i=0} (1-\Phi(\beta_1' x_i)) \quad \text{(B.13)}$$

The log likelihood function is

$$\ln L = \sum_{y_i=1} \log\Phi(\beta_1' x_i) + \sum_{y_i=0} \log(1-\Phi(\beta_1' x_i)) \quad \text{(B.14)}$$

$\hat{\beta}_1$ and $\hat{\sigma}_1^2$ can be derived by Maximum Likelihood estimation in the same way of the tobit model. The marginal effects of probit model is

$$\frac{\partial E[y_i | x_i]}{\partial x_i} = \beta_1 . \phi(\beta_1' x_i) \quad \text{(B.15)}$$

where ϕ is probability density function of standard normal.

In the second stage, truncated regression is introduced. The density function of y_i is the truncated normal, where c is truncation point. A model is defined as follow.

$$y_i^* = \beta_2' x_i + u_i$$

$$y_i = \begin{cases} y_i^* & \text{if } y_i^* > c \\ \text{cannot observe} & \text{otherwise} \end{cases}$$

$$f(y_i) = \frac{f(y^*)}{P(y^* \geq c)} \quad \text{where } y^* \sim N(\beta_2' x_i, \sigma^2) \tag{B.16}$$

We are interest in the distribution of y_i given that y_i is greater than truncation point. This model is quite similar structure to censored regression model. The main difference arises from the fact that in the censored regression model the exogenous variable x_i are observed even for the observation for which y_i > c. In the truncated regression model, such observations are completely eliminated from the sample.

The likelihood function of the truncated model is

$$\prod_{i=1}^{n} \frac{\frac{1}{(2\pi\sigma^2)^{1/2}} e^{-(1/2\sigma^2)\left(y-\beta_2' x_i\right)^2}}{1-\Phi\left(\frac{c-\beta_2' x_i}{\sigma}\right)} \tag{B.17}$$

The log likelihood function is

$$\ln L = \sum_{y>0} \left\{ -\frac{1}{2} \left[n \log(2\pi) + n \ln \sigma_2^2 + \sum_{i=1}^{n} \frac{\left(y-\beta_2' x\right)^2}{\sigma^2} \right] \right\} + \sum_{i=1}^{n} \ln \left(1 - \Phi_i \left(\frac{c-\beta_2' x}{\sigma^2} \right) \right) \tag{B.18}$$

Proceeding maximization will give the estimated results. The marginal effect of this model is

$$\frac{\partial E\left[y_i \middle| y_i > c \right]}{\partial x_i} = \beta_2 (1 - \lambda_i^2 + \alpha \lambda_i) \tag{B.19}$$

Where $\alpha_i = (c - x_i' \beta_2)/\sigma$ and $\lambda_i = \dfrac{\phi(\alpha_i)}{1-\Phi(\alpha_i)}$

In order to find the appropriate model to estimate, we use likelihood ratio test (LR-test). A single censored tobit model is considered as the restricted model, while Cragg's two stages specification is concerned as the unrestricted model. The restricted model is tested against the unrestricted model. The test statistic (λ) can be computed by

$$\lambda = 2\left[(\ln L_{probit} + \ln L_{truncated}) - \ln L_{tobit}\right]$$

L_{probit} is the likelihood of probit model, $L_{truncated}$ for the truncated model, and L_{tobit} for the tobit model.

If the test statistics (λ) is greater than the critical value of the chi-squared distribution, Cragg's two-stages specification should be preferred to the single censored tobit model. By contrast, if the test statistics (λ) is less than the critical value of the chi-squared distribution, LR test suggested that the tobit model is more validity.

APPENDIX E

ESTIMATED RESULTS AND LR-TEST

Table E.1

Estimated Results and LR-test of Whole Sample

Variables	Tobit	Probit	Truncated
R&D intensity	0.4445*** (2.94)	0.9867*** (2.71)	0.3019 (0.56)
Skilled labors	0.0684 (0.46)	0.0330 (0.62)	-0.0279 -(0.27)
Size	0.0039*** (6.63)	0.0201*** (6.42)	0.0102* (1.90)
Size2	-0.0001*** -(4.16)	-0.0002*** -(4.38)	-0.0001 -(0.81)
Ownership	0.0362*** (4.48)	0.1200*** (4.35)	0.0754 (1.34)
Constant	-0.1980*** -(4.58)		0.1217 (1.36)
Sigma	0.6039		0.5232
Log-likelihood	-1338.90	-1119.86	-202.21
LR chi2, Wald chi2	114.43	109.91	28.12
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.041	0.047	
LR test	**33.66**	**33.66**	**33.66**
Number of Observation	1695	1695	840

Note: Figures in this table are marginal effects calculated at mean; t-statistics are in parenthesis

Dummy variables of industrial sectors are not shown

* statistically significant at 10% level of significance

** statistically significant at 5% level of significance

*** statistically significant at 1% level of significance

Table E.2

Estimated Results and LR-test of Sub-Samples by Ownership

	Thai Firms			**Non-Thai Firms**		
Variables	**Tobit**	**Probit**	**Truncated**	**Tobit**	**Probit**	**Truncated**
R&D intensity	0.3324*** (3.22)	0.7856*** (3.03)	0.0763 (0.43)	0.2453 (0.66)	0.3849 (0.54)	0.0109 (0.28)
Skilled labors	0.0159 (0.17)	0.0141 (0.21)	0.1561 -(0.17)	0.0242 (0.24)	0.0423 (0.49)	-0.0446 -(0.32)
Size	0.0643*** (6.43)	0.0488*** (6.47)	0.0150* (1.69)	0.0136** (3.26)	0.01189*** (2.94)	0.0027 (0.44)
Size2	-0.0013*** -(3.86)	-0.0011*** -(4.25)	0.0005 -(0.67)	-0.0001** -(2.33)	-0.0001** -(2.04)	0.0000 (0.16)
Constant	-0.2354*** -(4.23)		0.0789 (0.60)	0.0103 (0.16)		0.0466 (0.37)
Sigma	0.6272		0.5561	0.5573		0.4768
Log-likelihood	-871.34	-745.57	-115.12	-453.05	-362.64	-83.91
LR chi2, Wald chi2	74.79	76.24	15.93	76.24	15.53	14.62
Prob > chi2	0.0000	0.0000	0.0258	0.0021	0.0298	0.0412
Pseudo R2	0.0412	0.0486		0.0486	0.021	
LR test	3.3	3.3	3.3	12.99	12.99	12.99
Number of Observation	1142	1142	504	553	553	336

Note: Figures in this table are marginal effects calculated at mean; t-statistics are in parenthesis

Dummy variables of industrial sectors are not shown

* statistically significant at 10% level of significance

** statistically significant at 5% level of significance

*** statistically significant at 1% level of significance

In order to find the appropriate model of estimation, this study use likelihood ratio test (see appendix C).

The test statistic of the whole sample is calculated by

$$\lambda = 2\left[(\ln L_{probit} + \ln L_{truncated}) - \ln L_{tobit} \right]$$

For the estimation of whole sample (Table E.1), the calculated test statistic is

$$\lambda_{whole\_sample} = 2\left[(-1119.86 - 202.21) + 1338.90\right]$$
$$\lambda_{whole\_sample} = 33.66$$

The test statistic is 33.66. The test statistic is greater than the critical value of the chi-squared distribution with 8 degrees of freedom at 95% level of confidence. The result of LR-test on the whole sample suggests that the Cragg's two stage specification is more suitable

For Thai firms (Table5.2), the test statistic is

$$\lambda_{Thai} = 2\left[(-754.57 - 115.12) + 871.34\right]$$
$$\lambda_{Thai} = 3.3$$

The test statistic is 3.3. The test statistic is less than the critical value of the chi-squared distribution with 7 degrees of freedom at 95% level of confidence. The result of LR-test suggests that the single censored tobit model is more suitable than the Cragg's two stage specification.

For non-Thai firms (Table5.2), the test statistic is

$$\lambda_{non-Thai} = 2\left[(-362.64 - 83.91) + 453.05\right]$$
$$\lambda_{Thai} = 12.99$$

The test statistic is 12.99. The test statistic is less than the critical value of the chi-squared distribution with 7 degrees of freedom at 95% level of confidence. The result of LR-test suggests that the single censored tobit model is more appropriate than the Cragg's two stage specification.

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