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Chapter 1

Innovation and Competition in Thailand: Case Studies of Electronics and Plastics Industries*

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Abstract: In this paper, we study the relationship between the level of innovative activities of firms in Thailand and the level of competition they face. Using the Orbis database, we found that the Thai private sector, especially the manufacturing sector, had obtained more patents over the period of our study. One explanation for this increase is the intensifying level of market competition, which pushed firms to be more innovative in order to survive and grow. We also conduct detailed case studies of two manufacturing firms – Eastern Polymer Group and Delta Electronics (Thailand) – both of which are leaders in innovation in their respective sectors. Our case studies broadly confirm the findings that firms tend to increase their innovative activities to cope with increasing competition in the market. The innovative activities performed by both firms have also led to them having higher market power than other firms in their industries, reflected by their higher values of the Lerner index. We conclude by suggesting some policy recommendations to promote innovative activities in the Thai private sector.

Key Words: innovation; competition; patent; firm; Thailand

1. Introduction

Thailand has set the target to escape from the "middle-income trap" and to transform itself into a developed country by 2037. To achieve this goal, it needs to focus on restructuring its economy to generate higher-value-added products. In short, Thailand has to become a

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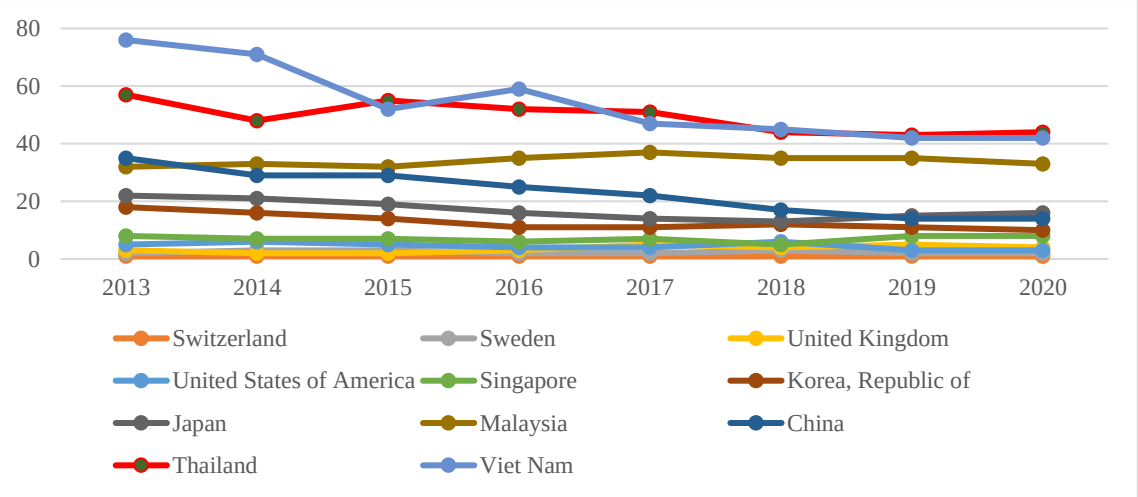
knowledge-based economy, which concentrates on technological developments, innovation, and human capital.

In an effort to accomplish its development goal, Thailand has identified some targeted industries to be promoted. These are the so-called 12 "S-Curved" industries: they are next-generation automotive, smart electronics, agriculture and biotechnology, food for the future, affluent wellness and medical tourism, biofuels and biochemicals, digital economy, medical hub, automation and robotics, aviation and logistics, national defense, and education and human resource development. The Thai government has also established the Eastern Economic Corridor (EEC), a special economic zone, to attract inward investment into the promoted sectors.

However, attracting FDI in targeted sectors alone would not be sufficient. Thailand also needs to increase its innovation inputs and outputs. In terms of innovation performance, as ranked by the Global Innovation Index (GII) (Figure 1), Thailand had improved slightly in the past decade. In contrast, South Korea, China and Vietnam had greatly improved their innovation performance over the same period.

Figure 1: Global Innovation Index (GII) During 2013-2020



Note: The Global Innovation Index (GII) provides an annual ranking of innovation performance of 131 countries and economies in 2020, based on 80 indicators involving institutions, human capital and resource, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, and creative outputs.

Source: Global Innovation Index1

1 Accessed from https://www.globalinnovationindex.org/analysis-indicator

Previous research by Rattanakhamfu and Itthiphatwong (2020) found that the number of innovative firms is still limited in Thailand, judging from the number of patents granted to them. Among these innovative firms, many were historically foreign-owned. Since the early 2000s, Thai firms have started to own more patents and become more innovative. But while Thai firms have outnumbered foreign-owned ones, the shares of patents owned by majority-foreign owned firms are still higher than those owned by majority-Thai owned firms. Furthermore, firm sizes are associated with the number of patents owned.

Given its slow improvement in innovation performance, Thailand has to exert more effort in promoting innovative activities, especially in the private sector. This paper will examine the relationship between innovation and market competition with an aim to find insights that can be used to guide a policy to promote innovation activities among Thai firms.

The second section reviews literature regarding the relationship between innovation and market competition. The third section gives an overview of innovation in the Thai context. The fourth section examines the relationship between innovation and competition in Thailand. The last section provides conclusions and policy recommendations for the Thai government.

2. Literature Review

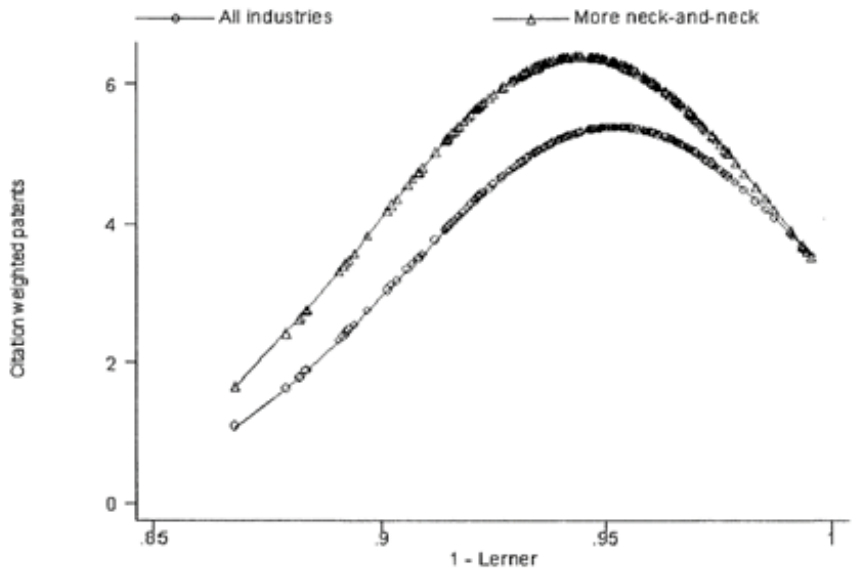
Joseph Schumpeter views capitalism as an evolutionary process with innovation – "new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise create" – as the main impulse driving the engines of capitalism. In his seminal work *Capitalism, Socialism and Democracy* (1943), Schumpeter proposed the, then, highly controversial thought: the idea that monopolies lead to more innovation than competitive markets. Defining monopolies as "those single sellers whose markets are not open to the intrusion of would-be producers of the same commodity and of actual producers of similar ones," Schumpeter noted that monopoly prices are not necessarily higher than the competitive level, nor the level of output necessarily lower. This is owing to the benefits monopolies enjoy, which firms under a competitive market structure do not. For example, monopolies may enjoy disproportionately higher financial standing, a wider sphere of influence and are better able to attract talent. These factors also allow monopolies to introduce new methods of

production in a way that is "hardly conceivable with perfect—and perfectly prompt—competition from the start," as occurs under perfect competition with no barriers to entry.

Dasgupta and Stiglitz (1980) set up the theoretical model of the market in different competitive environments and solved for a partial equilibrium; they gained several insights on the nature and consequences of competition on R&D. In line with Schumpeter's framework, R&D investment is more likely in a market presently dominated by a monopolist than in a competitive market, simply because there are more profits to be gained in the less competitive post-invention market. But competition in R&D can lead to even more investment in research than in monopolistic markets, sometimes resulting in excessive expenditure on R&D relative to the social optimum.

Although there is empirical evidence supporting Schumpeter's suggestion, such as the previously mentioned Dasgupta and Stiglitz (1980), Gilbert and Newberry (1982), and Hashmi and Van Biesebroeck (2016), which is to be mentioned subsequently, there is an alternative idea proposed in the literature, where the Schumpeterian effect is only part of a larger system of effects. One of the most influential papers is by Aghion et al. (2005). They posit that the relationship between the two variables forms an inverted-U shape. That is, the level of innovation increases with the level of competition until it reaches the peak of the inverted-U shape, but then subsequently decreases (Figure 2).

Figure 2: Innovation and Competition: The Neck-and-Neck Split



Source: Aghion et al. (2005), p.720

The inverted-U shape can be explained theoretically in terms of the tension between two concurrent effects: the 'Schumpeterian effect' and the 'escape competition effect.' The former suggests that more competition reduces profits along with the incentive to innovate. On the other hand, the latter suggests that firms innovate to avoid neck-to-neck competition with their rivals since a successful escape means that the firm can enjoy more profits. In an economy, when the level of competition is low, a larger proportion of sectors feature neck-to-neck competition and the escape competition effect dominates. The more neck-to-neck the competition in an industry is, the steeper the inverted-U curve is predicted to be, as depicted in Figure 2. Conversely, as the level of competition intensifies, the profit incentives to be gained decreases and the Schumpeterian effect dominates.

Aghion et al. (2005) found strong evidence of an inverted-U relationship between competition and innovation by using data from the United Kingdom (UK). Innovation is measured by the average number of patents taken out by firms in an industry, weighted by the number of times each patent is cited, to acknowledge the heterogeneity among them. Competition, the other key variable, is measured in relation to the Lerner index (price-cost margin). The use of these measures for innovation and competition are illustrated in Figure 2 above. Using the Lerner index, as opposed to the Herfindahl concentration index, benefits this research because it circumvents the issue of having to define particular product and geographic markets; the degree of competition some multi-national firms analysed face cannot be captured by constraining research to a local geographical boundary.

Recent empirical studies investigating the relationship between industry concentration and innovative activity have mixed results. For example, Tingvall and Poldahl (2006) and Hashmi (2013) found evidence to support the hypothesis of the inverted-U relationship, while Beneito, Rochina-Barrachina and Sanchis (2017) obtained a positive relationship between competition and patents.

Following Aghion et al. (2005), Hashmi (2013) used data from the United States (US) to show that the technological gap influences the relationship between competition and innovation. He also found that the inverted-U relationship applies in the case of the UK, but not for the US, where the relationship is mildly negative. Unlike Aghion et al. (2005), Hashmi (2013) provided industry-level partial equilibrium analysis, which carries the advantage of being able to avoid unnecessarily restricting different industries to having the same level of competition.

In his analysis, he incorporated the Lerner index to measure for competition level but controlled for the endogeneity of competition using a source-weighted average of industry exchange rates as an instrument for the variable. Innovation is also measured using citation-weighted patents. The industry-level technological gap is arrived at by taking an average of the firm-level technology gap.

A possible explanation for the above results can be captured by assuming a smaller technological gap in UK manufacturing industries compared to their US counterparts, making the competition more neck-to-neck rather than leader-laggard. Accordingly, the UK manufacturing industry, with neck-to-neck competition, can induce innovation due to the 'escape competition effect.' However, in the case of the US, laggards can only innovate from the spill-over of leaders in highly competitive settings; since the 'escape competition effect' does not apply, the 'Schumpeterian effect' dominates, and the relationship between competition and innovation is negative.

Both Aghion et al. (2005) and Hashmi (2013), however, did not factor in the possibility of laggard firms exiting the industry. Beneito, Rochina-Barrachina and Sanchis (2017) repeated their analysis with data on Spanish manufacturing firms from the Survey of Business Strategies (ESEE), introducing the possibility of inefficient firms facing the threat of exit when competition intensifies. The key contribution of their model is the exit rate, which is measured as the proportion of firms exiting the market that year due to bankruptcy. With the addition of this measure, coupled with the empirical data, it was revealed that the relationship between competition and innovation is positive and does not follow an inverted-U shape.

While most empirical works focus on analysing the relationship between market competition and innovation at the cross-industry level, some studies focus on the relationship in a single industry. For example, Goettler and Gordon (2011) investigated whether AMD spurs Intel to innovate more in the microprocessor industry. They measure innovation directly through tracking the technology's performance on benchmark tasks, instead of measuring the variable indirectly using patents. Furthermore, they estimated consumer preferences and firms' innovation efficiencies, which determine the costs and benefits of innovation, in a dynamic model; they then solved for equilibrium in various competitive scenarios. Consistent with Schumpeter's predictions, the rate of innovation in product quality would be 4.2 percent higher if Intel were a monopolist. Similar findings apply in the case of a duopoly where the market remains highly concentrated: it was found that equilibrium innovation rates increase monotonically as preferences for quality increase and as price sensitivity declines.

Similarly, Hashmi and Van Biesebroeck (2016) analysed the relationship between competition and innovation in the automotive industry on a global scale. They set up the model of industry equilibrium with forward-looking innovation decisions and estimated parameters; they treated innovation as a continuous variable, differing from existing models that treat innovation as a 0-1 decision. Under their dynamic model, the firm can influence market share and profits by choosing the price of their product and investment in R&D, with price only impacting current profits and has no impact on future decisions. They found that market structure has a nuanced effect on innovation incentives, making it difficult to summarise overall patterns.

Regarding papers related to innovation and competition in Thailand, Srithanpong (2014) found that production plants in the food production and chemical production industries are more likely to invest in R&D and are more innovative compared to plants in other industries. His analysis follows a two-step model: first, research activity influences innovation output, and second, innovation output influences productivity. Innovation, in particular, is modelled as a binary indicator proxied by both product and process innovation. It is a function of latent innovation effort and a vector of other explanatory variables. A shortcoming of this study, however, is precisely the problematic variable definition: innovation surveys available convey relatively little information on firm characteristics, especially for non-innovative firms.

Based on empirical studies, in Thailand, the success of R&D in producing innovation depends on several factors. Charoenporn (2005) examined a sample of 310 firms in the Thai manufacturing sector using data collected from the Thailand R&D/Innovation Survey 2000 by the National Science and Technology Development Agency (NSTDA). He found that, in line with Soutaris (2000), "the availability of technological human resources, R&D intensity, competitive market condition, [access] to technology information, and good external communication are the determinants of innovative success" in a developing economy such as Thailand. Furthermore, he also found that product-innovative firms need a higher degree of innovative success determinants than process-innovative firms.

Recent literature on innovation in Thailand is by Sujarittanonta and Kamsaeng (2017). In *Competition: Missing Piece in Innovation Equation*, they identified the relationship between competition and innovation in Thailand as following an inverted-U shape at the firm level. To uncover the level of competition, Sujarittanonta and Kamsaeng (2017) weigh the firm-level Lerner index by sales to capture the stronger competitive impact of larger firms. The Lerner index was calculated using data from the Stock

Exchange of Thailand Market Analysis and Reporting Tool (SETSMART) and the relevant industry for the firm was identified using two-digit International Standard of Industrial Classification (ISIC) codes. The firm's R&D intensity, namely the ratio between total R&D expenditure plus one to total sales, was calculated from a survey data conducted by National Science Technology and Innovation Policy Office (STI). The STI also supplied figures for TFP, hence technological gap, calculations.

Finding an inverted-U shape lends at least partial evidence that the Schumpeterian effect is in place and that monopolies need not lead to less consumer welfare since they induce innovation. They conclude that "competition regulation should emphasize an objective of maximizing dynamic efficiency where innovation is a main concern, rather than focusing solely on static efficiency that aims to reduce market power and hence an incentive to innovate." Yet, they do not find a significant relationship between competition and innovation in non-manufacturing industries; thus, there remains the need for further investigation on the issue to form coherent policy suggestions.

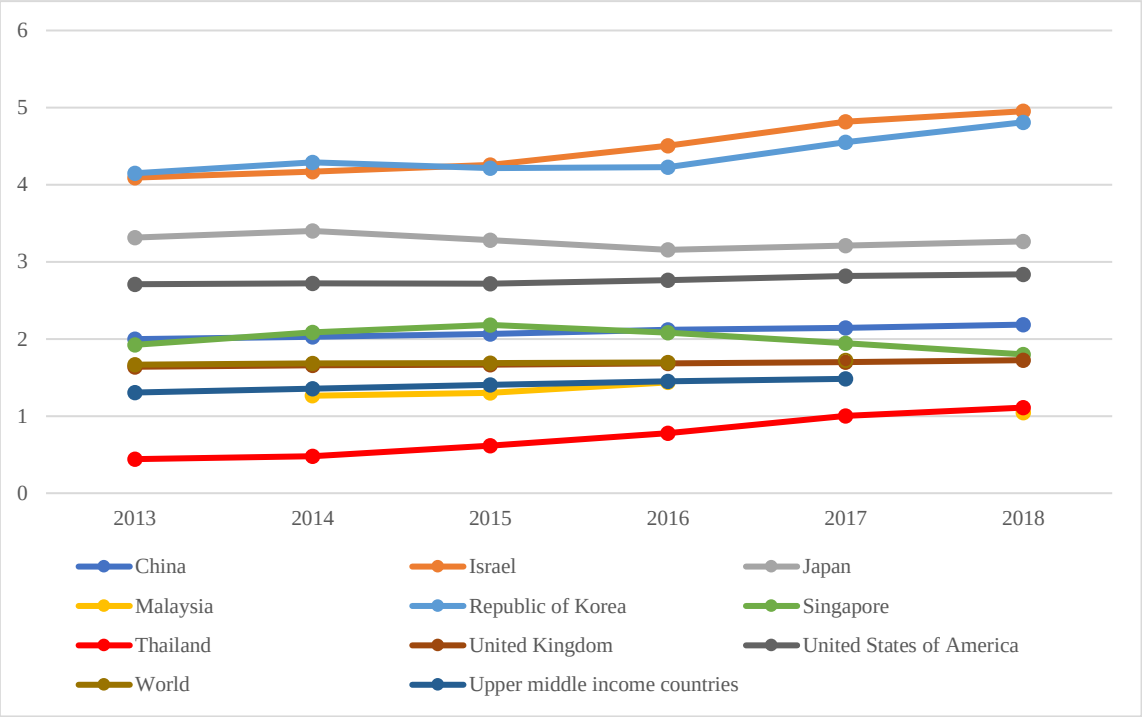
Our paper contributes to the literature in several ways. Firstly, our paper analyses the relationship between the level of innovative activities of firms in various sectors in Thailand and the level of competition they face. Secondly, our paper provides detailed case studies of two manufacturing firms – Delta Electronics (Thailand) and Eastern Polymer Group and – both of which are leaders in innovation in their respective sectors. Finally, the results of this study help provide a better understanding of the relationship between innovation and competition in manufacturing sectors in Thailand in order to guide policies to promote innovation activities among Thai firms.

3. Overview of Thailand's Innovation

Thailand has spent relatively little on R&D since 2013. Thailand's gross domestic expenditure on R&D (GERD) has increased gradually. In 2019, it reached 182 billion baht or 1.11 percent of GDP in 2019. Compared with other upper medium-income countries[2], Thailand's R&D intensity is lower and is lagging far behind developed countries, such as South Korea, Japan, and Israel (Figure 3).

2 World Bank (2020) classified upper middle-income countries as countries with gross national income (GNI) 4,046 - 12,535 USD per year. In 2020, there were 56 upper middle-income countries, such as Indonesia, Malaysia, Thailand and China. (Source: Umar Serajuddin and Nada Hamadeh, "New World Bank country classifications by income level: 2020-2021," World Bank,

Figure 3: GERD as a Percentage of GDP



Sources: UNESCO3; MASTIC4; National Research Foundation5; NXPO6

Furthermore, the share of public-funded R&D expenditure in Thailand has continued to decline since 2014 (Figure 4). Of the total GERD, the public-funded GERD has reduced from 24 percent in 2014 to 12 percent in 2017. In contrast, our neighbouring countries, such as Singapore and Malaysia, have a much higher ratio of public-funded GERD to increase their national innovation capabilities. For example, Singapore's public

July 1, 2020, https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2020-2021.)

3 "Science, technology and innovation: Gross domestic expenditure on R&D (GERD), GERD as a percentage of GDP, GERD per capita and GERD per researcher," UNESCO, http://data.uis.unesco.org/index.aspx?queryid=74.

4 Malaysian Science and Technology Information Centre (MASTIC), https://mastic.mosti.gov.my/statistic?field_statistic_category_target_id=192.

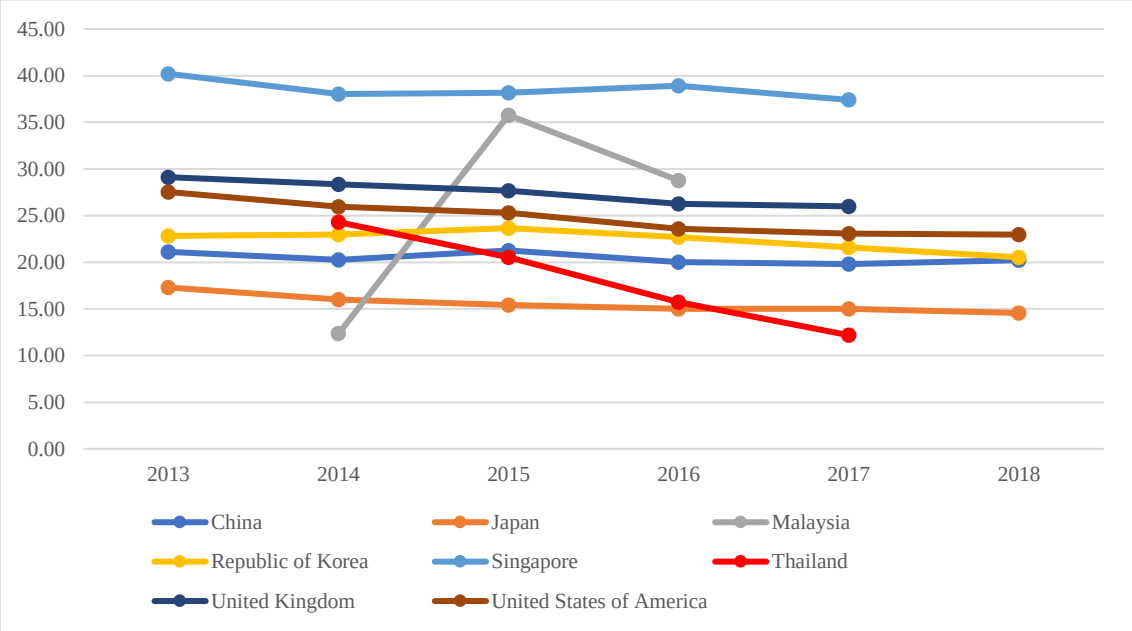
5 "National Survey of R&D in Singapore 2018," National Research Foundation, December, 2019, https://www.a-star.edu.sg/docs/librariesprovider1/default-document-library/news-events/publications/national-survey-of-r-d-2018.pdf.

6 "NXPO announces survey results of 2018 R&D expenditure and R&D personnel," Office of National Higher Education Science Research and Innovation Policy Council, June 30, 2020, https://www.nxpo.or.th/th/en/5008/.

sector expenditure on R&D accounted for 38 - 40 percent of total R&D expenditure during 2013 - 2017. Similarly, most advanced countries, such as South Korea, Germany, the US and the UK, have significant public funding of R&D, contributing to more than 20 percent of GERD.

In general, the share of public and private R&D expenditure varies over the path of national economic development. When the level of economic development is low, the public sector often plays the role of the main investor in R&D expenditure to enhance the national innovative capabilities because the private funding of R&D is scarce. On the other hand, as the economy develops, private funding becomes more abundant, and public funding should gradually reduce its share of national R&D investment. In the case of Thailand, however, the share of public funding of R&D fell too quickly.

Figure 4: Ratio of Public Research Funding to Total GERD



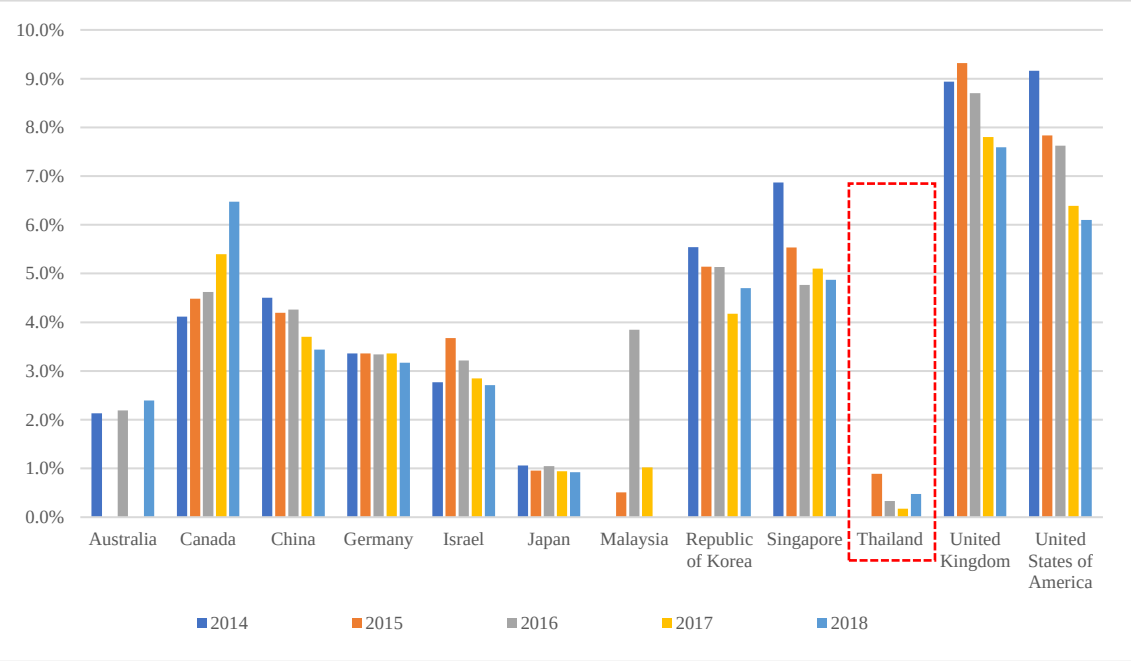
Source: UNESCO7

Besides the low share of public funding of R&D, the level of government funding to support private investment in R&D is relatively small, having accounted for less than 1 percent of total private investment on R&D during 2014 - 2018 (Figure 5). On the other hand, governments of some developed countries, such as the US, the UK, Canada, Singapore and South Korea, provided funding to the private sector to support

7 Ibid.

R&D, averaging 5 - 8 percent during the same period. It is noted that these advanced countries are in a period of declining funding of R&D to the private sector as their economies are more developed. Their business sector is playing a growing role in R&D investment; concurrently, the government sector's role becomes more muted. Illustratively, the US government contributed to 30 percent, and 20 percent of the private sector funding for R&D in the 1980s and 1990s, respectively, but this figure has dropped to about 10 percent or less since 2000.

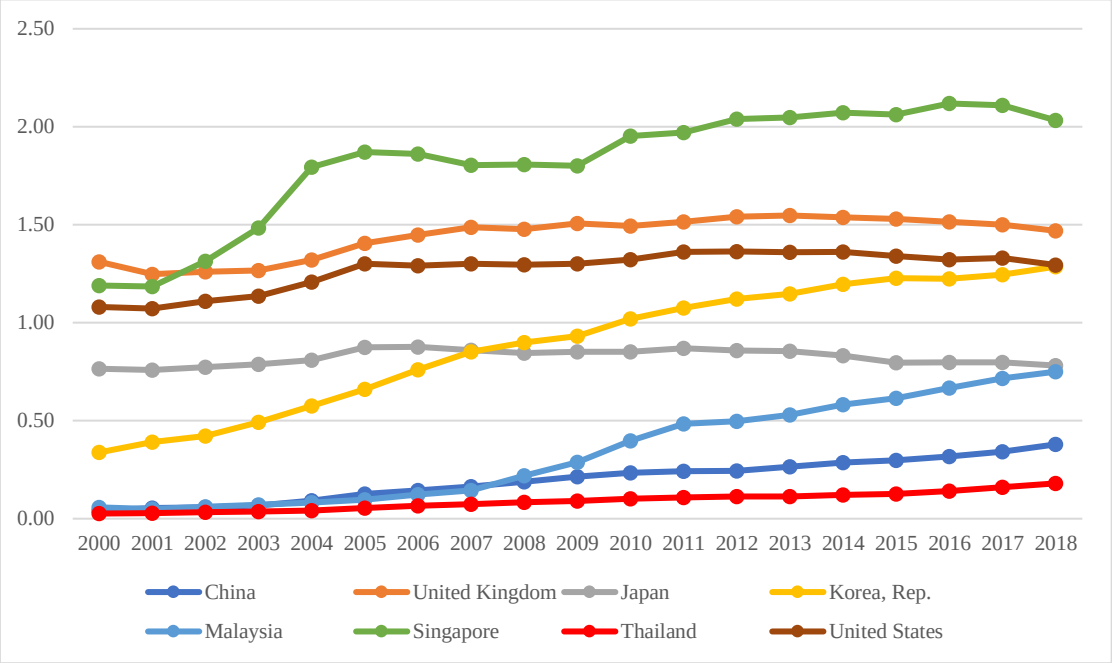
Figure 5: Ratio of Private R&D Investment Funded by the Public Sector



Source: UNESCO

Now, we turn to consider Thailand's R&D output. In terms of the number of scientific and technical journal articles per 1,000 population, Thailand was at a similar level to Malaysia and China in 2000. However, Malaysia and China rapidly surpassed Thailand over the last two decades (Figure 6). Noticeably, South Korea and Singapore have also made significant progress in the area of scientific and technical journal articles.

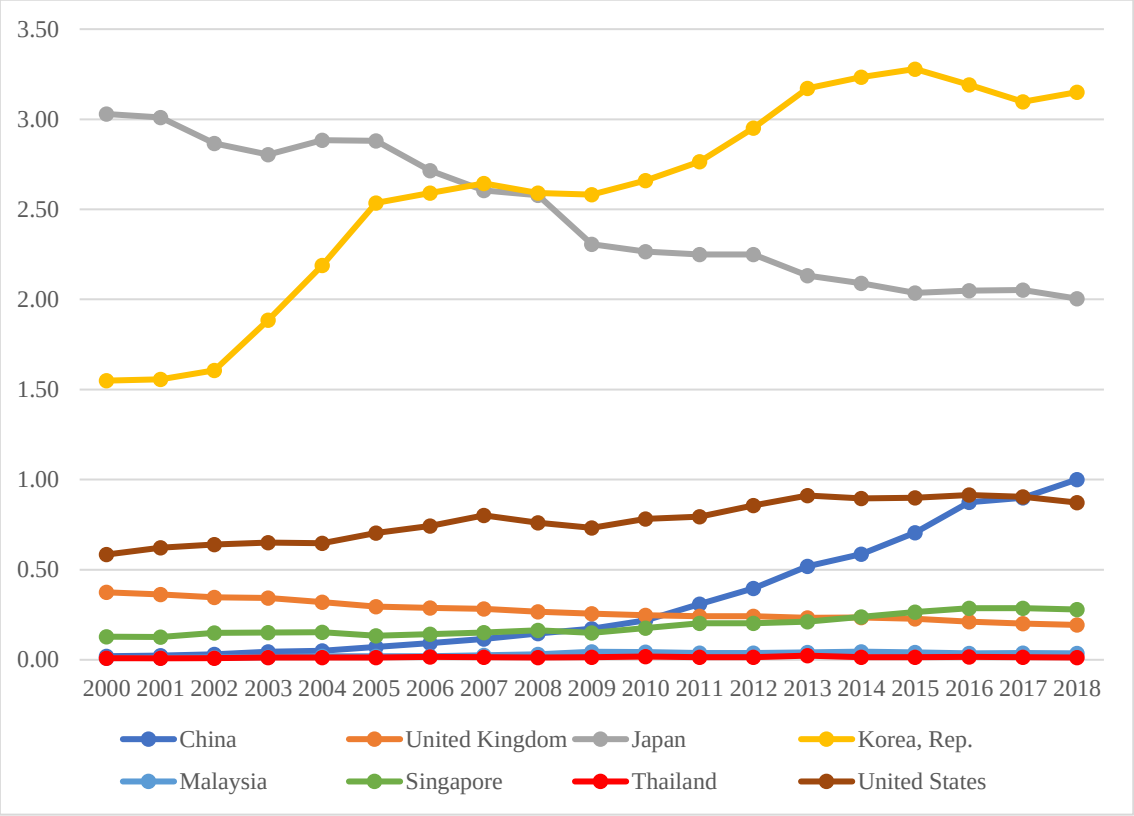
Figure 6: Number of Scientific and Technical Journal Articles per 1,000 Population



Source: World Bank

In line with the preceding analysis, in terms of patent applications filed by residents, Thailand performed similarly to Malaysia and China in 2000 (Figure 7). However, China significantly improved its performance over time to the extent that its performance in 2018 has exceeded some countries such as the US. Again, South Korea had made striking progress in patenting activity over the period between 2000 - 2018.

Figure 7: Number of Patent Applications by Residents per 1,000 Population



Source: World Bank

Overall, Thailand has made more progress in R&D input than in R&D output. Thailand's GERD as a percentage of GDP has increased from 0.4 percent in 2013 to 1.1 percent in 2018. This is mainly the result of the significant contribution of the private sector expenditure on R&D, which accounted for 35 percent of total GERD in 2000 and increased to 80 percent of total GERD in 2017.[8] As for R&D outputs, Thailand, Malaysia and China used to be at the same level in 2000. However, China and Malaysia have both surpassed Thailand in terms of R&D output performance over the past twenty years.

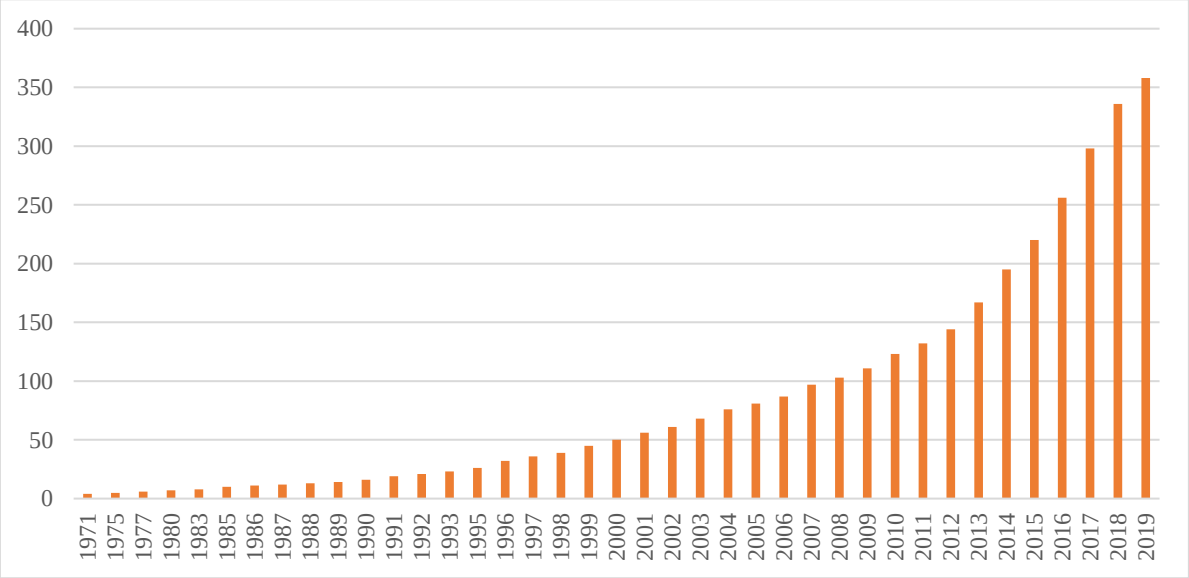
8 "Research and development investment in Thailand," Office of National Higher Education, Science, Research and Innovation Policy Council, accessed from http://stiic.sti.or.th/stat/ind-rd/rd-t001/ on December 1, 2020)

4. Innovation and Competition

In this section, we analyse the relationship between innovation and competition. We start by describing the overall picture of innovation across industries in Thailand. Then, we study the innovative activities and market competition in specific industries, namely, the semiconductor and other electronic components manufacturing and plastic product manufacturing.

Using the number of patents granted as the proxy indicator of firms' innovative activities, we found that there were 358 innovative firms during 1970 - 2019, with 2,854 patents granted to them during the period (Figure 8).

Figure 8: Number of Innovative Firms in Thailand



Source: The authors, calculated from the Orbis IP database

Excluding firms with missing data, our dataset is composed of 335 innovative firms with a total of 2,662 patents granted (Table 1). Manufacturers were found to engage in innovative activities much more so than other sectors, accounting for up to 62.8 percent of patents granted, and are followed by the wholesale and retail trade (27.5 percent) and the administrative and support service sectors (3.9 percent). The manufacturing sector also had the highest number of firms with patents granted: 49.3 percent of total firms with granted patents were in the manufacturing sector, followed by the wholesale and retail trade (27.2 percent) and the professional, scientific and technical service sector (4.8 percent).

Table 1: Number of Patents Granted and Number of Innovative Firms, Classified by Industries

NACE Rev. 2 main section	Number of patents granted	Share (%)	Number of firms with patents granted	Share (%)
Agriculture, forestry and fishing	3	0.1	2	0.6
Mining and quarrying	10	0.4	2	0.6
Manufacturing	**1,672**	**62.8**	**165**	**49.3**
Electricity, gas, steam and air conditioning supply	12	0.5	6	1.8
Construction	23	0.9	16	4.8
Wholesale and retail trade; repair of motor vehicles and motorcycles	**733**	**27.5**	**91**	**27.2**
Transportation and storage	6	0.2	5	1.5
Accommodation and food service activities	3	0.1	2	0.6
Information and communication	7	0.3	4	1.2
Financial and insurance activities	4	0.2	4	1.2
Real estate activities	14	0.5	12	3.6
Professional, scientific and technical activities	65	2.4	**16**	**4.8**
Administrative and support service activities	**104**	**3.9**	6	1.8
Public administration and defence; compulsory social security	2	0.1	1	0.3
Human health and social work activities	1	0.0	1	0.3
Arts, entertainment and recreation	3	0.1	2	0.6
Total	**2,662**	**100.0**	**335**	**100.0**

Source: The authors, calculated from the Orbis IP database

Within the manufacturing sector, the Top 5 industries with the highest number of patents granted are household appliances manufacturing; commercial and service industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; semiconductor and other electronic components manufacturing; and plastic product manufacturing (Table 2).

We also examine the relationship between innovation and market structure at the industry level in two selected industries – the semiconductor and other electronic components manufacturing and plastic product manufacturing; both are among the Top 5 innovative industries and are related to S-Curve industries.

To measure the market power in each industry, c_{jt}, we apply the Lerner index (price-cost margin), commonly used in the literature:

$$\mathrm{li}_{it} = \frac{\text{operating profit}_{it} - \text{financial cost}_{it}}{\text{sales}_{it}}$$

$$\mathrm{c}_{jt} = \frac{1}{\mathrm{N}_{jt}} \sum_{i \in j} \mathrm{li}_{it}$$

Here, i indexes firms, j indexes industries, t indexes time and N_{jt} is the number of firms in industry j in year t. The value of the Lerner index is between 0 and 1. The lower the value of the index, the more competition the firm faces; the higher the value, the higher the market power the firm has. As pointed out earlier, the use of the Lerner index, as opposed to the Herfindahl concentration index, has the benefit of being able to avoid having to define particular product and geographic markets. To compute the Lerner index in each industry, we use all firm data points that lie in between the tenth and ninetieth percentiles in the Lerner index distribution to avoid the problem of outliers.

Table 2: Top 20 Industries with the Highest Number of Patents Granted and with the Highest Number of Firms with Patents Granted

NAICS 2017 code	NAICS 2017 description	Number of patents granted	Share (%)	Number of firms with patents granted	Share (%)
3352	Household Appliances Manufacturing	498	18.7	7	2.1
3333	Commercial and Service Industry Machinery Manufacturing	322	12.1	4	1.2
3334	Ventilation, Heating, Air-Conditioning, and Commercial Refrigerator Equipment Manufacturing	237	8.9	6	1.8
3344	Semiconductor and Other Electronic Components Manufacturing	193	7.3	7	2.1
3261	Plastic Product Manufacturing	171	6.4	17	5.1
3399	Other Miscellaneous Manufacturing	162	6.1	18	5.4
3259	Other Chemical Product and Preparation Manufacturing	88	3.3	1	0.3
5331	Lessors of Nonfinancial Intangible Assets	86	3.2	1	0.3
4234	Professional and Commercial Equipment and Supplies Merchant Wholesalers	72	2.7	12	3.6

3341	Computer and Peripheral Equipment Manufacturing	60	2.3	4	1.2
3252	Resin, Synthetic Rubber, and Artificial Synthetic Fibres and Filaments Manufacturing	44	1.7	8	2.4
5417	Scientific Research and Development Services	41	1.5	5	1.5
3112	Grain and Oilseed Milling	36	1.4	4	1.2
3363	Motor Vehicle Parts Manufacturing	33	1.2	9	2.7
3329	Other Fabricated Metal Product Manufacturing	24	0.9	5	1.5
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	24	0.9	1	0.3
3351	Electric Lighting Equipment Manufacturing	24	0.9	2	0.6
3251	Basic Chemical Manufacturing	23	0.9	4	1.2
5614	Business Support Services	23	0.9	3	0.9
3262	Rubber Product Manufacturing	22	0.8	5	1.5
	Others	479	18.0	212	63.3
	Total	**2,662**	**100.0**	**335**	**100.0**

Source: The authors, calculated from the Orbis IP database

4.1. Semiconductor and Other Electronic Components Manufacturing

In Thailand's semiconductor and other electronic components manufacturing sector, there were 7 firms with patents granted during 1970 - 2019 (Table 3). Among these innovative firms, Delta Electronics (Thailand) PCL. is the leader; its innovations account for more than 80 percent of the total patents granted in the industry. More details on Delta Electronics (Thailand) PCL. can be found in Box 1 below.

Table 3: Innovative Firms in the Semiconductor and Other Electronic Components Manufacturing

Company name	Number of patents granted	Share (%)
Delta Electronics (Thailand) PCL.	158	81.87
Hitachi Metals (Thailand) Co. Ltd	29	15.03
Mektec Manufacturing Corporation (Thailand) Ltd.	2	1.04
Ener Saver (Thailand) Co. Ltd.	1	0.52
Salom Electric (Thailand) Co. Ltd.	1	0.52
Johnson Control-Hitachi Component (Thailand) Co. Ltd.	1	0.52
SVI PCL.	1	0.52
Total	**193**	**100.00**

Source: The authors, calculated from the Orbis IP database

Box 1: Case Study on Delta Electronics (Thailand) PCL

Delta Electronics (Thailand) PCL is the Thai subsidiary of Delta Electronics, an electronics manufacturing company headquartered in Taiwan. Delta is listed on the Stock Exchange of Thailand but over half of its shares are owned by international Delta entities. The Bangkok office oversees Delta's operations in all of Southeast Asia, India, and Australia. The company was established in 1988 and currently focuses on three business segments: 1. manufacturing power electronics, such as fan and thermal management systems and electric vehicle solutions, 2. automated systems, and 3. infrastructures, such as ICT infrastructure and energy infrastructure. The company's stated goal is "to provide the most efficient and reliable energy-saving solutions for customers."[9] In 2019, Delta had an annual revenue of 51 billion baht. It has recently benefitted from increased demand as the US-China trade war forced buyers to buy more from Thailand.

Delta's approach to innovation is driven by a keen eye for markets with high growth. Many of Delta's innovations are targeted around future-oriented industries; its five-year strategic plan focuses on industrial automation, data centres, electric vehicles, renewable energy and energy storage systems. As Delta's CEO explained, "We believe in the importance of researching and developing new technologies that correspond to global megatrends."[10]

Several innovations have drawn wide interest. One is the development of "quick charge" charging systems for electric vehicles which is intended to support growing demand for electric cars in the future[11]. Delta has also been responsive to

9 "Annual Report 2019," Delta Electronics (Thailand) Public Company Limited, https://www.deltathailand.com/en/pdf/ir/Annual_Report_Delta_2019_EN.pdf.

10 "Delta wins Thailand electric vehicle charging company of the year 2019," Biz Focus Magazine, May 26, 2019, https://bit.ly/3rC3ycZ.

11 "Delta joins Amata to develop Smart City in EEC," Prachachat Turakij, October 5, 2020, https://www.prachachat.net/economy/news-531776.

emerging issues in Thai society. In 2019, the company exhibited innovations aimed at regulating air quality inside buildings, such as green home solutions and air filtration systems[12], in response to worsening air quality in Bangkok and other areas in Thailand. Additionally, Delta is known for its digital infrastructure, including cloud services, artificial intelligence, and IoT solution, which helps power services such as smart manufacturing and smart surveillance.

Delta's approach to innovation involves both internal investment into research and development and partnering with external partners. Delta has research centres around the world, such as Thailand, China, India, Germany and the US, and in 2018 spent 6.8 percent of sales revenue on R&D. In Thailand, 535 people were employed, and 5.26 percent of operating revenue was spent to conduct R&D in that year. Delta has also cooperated with other companies to collaborate on innovation. For example, it is considering partnering with the Amata Group to jointly develop "Smart City" plans in industrial estates in the Eastern Economic Corridor. Delta also partnered with the Ministry of Industry to set up the "Delta Angel Fund" to support start-ups related to industrial automation, energy management and future-oriented innovation[13]. This partnership resulted in new products such as Thailand's first EV charging platform, sterilizing robots and cane-cutting machines aimed at reducing air pollution. Finally, Delta has also partnered with universities to set up "Delta Industrial Automation Labs," which are equipped with cutting-edge automation technology. The labs will help alleviate the shortage of engineers skilled in industrial automation[14].

Source: The authors, compiled from various sources

The average Lerner index of the semiconductor and other electronic components manufacturing is around 0.2 - 0.3. As a leading company in the industry, Delta has a much higher value of the Lerner index than other firms, reflecting its higher market power (Table 4). Based on the interview with a Delta Electronics executive, electronics manufacturers are likely to compete for cost control because prices of older models often go down, while costs, such as labour and raw materials, tend to go up all the time. Large firms without R&D would produce labour-intensive products that result in a low profit margin. On the contrary, small companies providing system integration (SI) services may have a high profit margin because they sell customized solutions, thereby positioning themselves not merely as designers but also as solution-makers. To escape from the cost competition and low profit margin, Delta executives have a policy to sell "live" fish, not "dead" fish. That is, their products need to be adjusted and improved upon frequently.

12 ″Delta Future Industry Summit 2020,″ Biz Focus Magazine, October 21, 2020, https://bit.ly/3jyefKF.

13 ″Delta Angel Fund is granted to SMEs and start-ups to support the business to success,″ Prachachat Turakij, August 28, 2020, https://www.prachachat.net/economy/news-513065.

14 ″Smart Lab and Smart Classroom for Food- Agriculture 4.0,″ Krungthep Turakij, November 11, 2017, https://www.bangkokbiznews.com/news/detail/780731.

Therefore, Delta has continuously invested in R&D. Delta also focuses on their profit margin rather than sales.

Table 4: The Lerner Index for the Semiconductor and Other Electronic Components Manufacturing Sector

Lerner Index[1]	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Delta Electronics (Thailand)	0.26	0.29	0.46	0.48	0.46	0.46	0.43	0.41	0.41
All firms[2]	0.18	0.20	0.22	0.25	0.27	0.28	0.28	0.28	0.28

Notes: [1] Lerner index is calculated by the share of gross profits in sales.

[2] The shown Lerner index is the average value for all firms. To avoid the problem of outliers, we use all firm data points that lie in between the tenth and ninetieth percentiles in the Lerner index distribution. The total number of firms is 179, 192, 380, 496, 511, 509, 505, 520 and 481 firms for 2011-2019, respectively.

Source: The authors, calculated from the Orbis Asia-Pacific database

4.2. Plastic Product Manufacturing

In Thailand's plastic product manufacturing sector, there were 17 firms with patents granted during 1970 - 2019 (Table 5). The Top 2 innovative firms, namely Nippon Steel & Sumikin Materials (Thailand) Co. Ltd. and Aeroklas Co. Ltd., accounted for more than half of patents granted in the sector. It is noted that Aeroklas Co. Ltd. and Eastern Polypack Co. Ltd. are subsidiaries of the Eastern Polymer Group (EPG).

While Nippon Steel & Sumikin Materials (Thailand) Co. Ltd. is a wholly owned Japanese subsidiary of Nippon Steel Chemical & Material Co. Ltd., EPG is wholly Thai owned (see the case study of EPG in Box 2 below).

Table 5: Innovative Firms in Plastic Product Manufacturing

Company name	Number of patents granted	Share (%)
Nippon Steel & Sumikin Materials (Thailand) Co. Ltd.	53	30.99
Aeroklas Co. Ltd.	43	25.15
Poranunt Co. Ltd.	16	9.36
Royal Industries (Thailand) PCL.	14	8.19
Nawaplastic Industries Co. Ltd.	8	4.68
Asian Mos Co. Ltd.	8	4.68
Cosmo Group PCL.	7	4.09
Royal King Infant Products Co. Ltd.	6	3.51
Pasina Co. Ltd.	6	3.51
Eastern Polypack Co. Ltd.	2	1.17
The Next Foam Co. Ltd.	2	1.17
Yuen Yong Enterprises Co. Ltd.	1	0.58
Union Precision Engineering Co. Ltd.	1	0.58
Asada Chemical Co. Ltd.	1	0.58
Enzpire Industry Co. Ltd.	1	0.58
Bookook Tech Co. Ltd.	1	0.58
Chiem Cosmetic Packaging Co. Ltd.	1	0.58
Total	**171**	**100.00**

Source: The authors, calculated from the Orbis IP database

Box 2: A Case Study of Eastern Polymer Group (EPG)

Eastern Polymer Group (EPG) is a holding company founded by the Vitoorapakorn family. The group is a specialist in the polymer and plastics conversion industry. Its main wholly owned subsidiaries include Eastern Polypack (EPP), which focuses on one-time-use plastic packaging, and Aeroklas, which specializes in automotive parts and accessories. Exports make up around 10% of EPP's revenue, with main destinations being South Korea, Canada, Australia and other ASEAN countries. Aeroklas's revenue is 70% export, mainly to countries in North America and Europe. As of 2019, EPG had an annual revenue of 10 billion baht, with Aeroklas and EPP contributing 4.7 billion baht and 2.4 billion baht, respectively. EPP was founded in 2001 through EPG's purchase of Thai Modern Plastic Industry, while Aeroklas was founded when EPG expanded into the automotive parts industry in 1996.

EPG has many strengths. Firstly, EPP is known for its wide product range, with the ability to utilize a wide variety of plastics, while Aeroklas has a comprehensive offering of truck parts, including bed liners, canopies, deck covers and side steps. Secondly, EPG has received several international accreditations, and its brands are trusted by large multinationals. Thirdly, EPG's size and efficient management make it capable of fast and wide delivery. Aeroklas, in particular, has a global reach, with

subsidiaries in the US and Australia (for distribution), and China and Malaysia (for production). It is the world's top producer of truck bed liners.

Product innovation has been a crucial factor in EPG's success. EPP holds 44 patents and Aeroklas holds 83 patents and petty patents combined. One key development for EPP was a plastic container that can both be frozen at a temperature of -40 °C and microwavable for over three minutes. This is crucial for food sold in convenience stores; 7-11 and CP's EzyGo brand currently use EPP's packaging. Another innovation is the production of a sturdier plastic cups for instant noodles which prevent taste spoilage[15]. Aeroklas invented technology for installing flexible bed liners without the need to drill into the car.[16] It has also focused on making its products more recyclable and protective.

EPG continues to invest at least 1% of annual revenue into R&D[17]. It has also benefitted from technology transfer via acquisitions: Aeroklas Australia purchased companies such as Flexiglass and its fibreglass canopy technology, along with Bocar and its heavy-duty trays.

EPG's main strength is to create innovative products and protect them with patents. According to deputy CEO Chalieo Vitoorapakorn, the company believes in innovation as a path towards becoming the market leader, rather than engaging in price wars or cutting costs. An example of this approach was the aforementioned innovation in instant noodle packaging, which increased manufacturing costs by less than 30% but reduced taste spoilage. This innovative corporate culture was set from the very top. EPG president Pawat Vitoorapakorn established the EPG Innovation Centre[18] and retains the title of Chief Innovation Officer, so he can supervise the centre's research and lead the company towards innovation.

Source: The authors, compiled from various sources

Similar to the semiconductor and other electronic components manufacturing sector, the average value of the Lerner index for the plastic product manufacturing sector is about 0.2. Unlike other firms in the industry, Aeroklas Co. Ltd. and Eastern Polypack Co. Ltd, which are subsidiaries of EPG, have larger values of the Lerner index, reflecting their higher market power (Table 6). The interview with EPG's executives revealed that the company's business model is innovation-led growth. EPG has owned approximately 600 patents and petty patents, enabling EPG to grow from having sales of approximately

15 ″Chalieo Vitoorapakorn leads the EPG group to the top 3 in the world,″ Prachachat Turakij, February 20, 2014, https://bit.ly/3jxhzG1.

16 ″Annual Report 2020,″ Eastern Polymer Group Public Company Limited, March 2020, p.25, https://investor.epg.co.th/misc/ar/20200623-epg-ar2020-en-03.pdf.

17 ″EPG innovation family under creative innovation organization,″ Money and Wealth, August 2016, http://www.epg.co.th/Portals/0/news/Money%20and%20Wealth%20EPG.PDF.

18 ″Rubber man stretches his innovative power,″ Bangkok Post, December 6, 2014, https://www.bangkokpost.com/thailand/general/447615/rubber-man-stretches-his-innovative-power.

0.3 million USD about 40 years ago to over 330 million USD at present. The company definitely believes in innovation as a path towards becoming the market leader, rather than engaging in price wars or cutting costs.

Table 6: The Lerner Index for the Plastic Product Manufacturing Sector

Lerner Index[1]	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Aeroklas Co. Ltd.	0.29	0.30	0.29	0.28	0.29	0.27	0.27	0.27	0.31
Eastern Polypack Co. Ltd.	0.22	0.28	0.26	0.27	0.30	0.29	0.42	0.39	0.44
All firms[2]	0.16	0.17	0.17	0.18	0.19	0.21	0.21	0.20	0.21

Notes: [1] Lerner index is calculated by the share of gross profits in sales.

[2] The shown Lerner index is the average value for all firms. To avoid the problem of outliers, we use all firm data points that lie in between the tenth and ninetieth percentiles in the Lerner index distribution. The total number of firms is 1,080, 1,090, 2,086, 2,480, 2,482, 2,481, 2,547, 2,614 and 2,606 firms for 2011-2019, respectively.

Source: The authors, calculated from the Orbis Asia-Pacific database and EPG financial statement data

5. Conclusion and Policy Recommendations

It is well known that innovation is an important engine of a country's growth. Thailand has tried to improve its competitiveness through innovation. In terms of R&D inputs, Thailand's GERD as a percentage of GDP has increased from 0.4 percent in 2013 to 1.1 percent in 2018 as a result of significant private sector R&D expenditure, which accounted for 35 percent of total GERD in 2000 and increased to 80 percent of total GERD in 2017.[19] While R&D input has increased, Thailand still lags behind on R&D outputs. Despite being at par with Malaysia and China in 2000, both countries had managed to surpass Thailand in terms of R&D output performance over the past twenty years.

How can we improve Thailand's innovation performance? The private sector plays a main role in innovative activities. Since Aghion et al. (2005), it has been hypothesized and empirically confirmed that the level of innovative activities of firms

19 Office of National Higher Education, Science, Research and Innovation Policy Council, accessed from http://stiic.sti.or.th/stat/ind-rd/rd-t001/ on December 1, 2020.

increases with the level of competition they face until the level reaches the peak of the inverted U-shaped curve, before subsequently decreasing. In particular, Sujarittanonta and Kamsaeng (2017) confirmed the hypothesis in the case of Thailand and argued that competition is the missing piece from the Thai innovation policy framework.

In this paper, we study the relationship between the level of innovative activities of firms in various sectors in Thailand and the level of competition they face. Using the Orbis database, we found that the Thai private sector, especially the manufacturing sector, has obtained more patents over the period of our study. One explanation for the increase is that the Thai private sector has been facing increasing competition in the market and need to be more innovative to survive and grow.

We then analyse the level of innovation of firms in Thailand in two specific industries, namely, the semiconductor and other electronic components manufacturing and plastic product manufacturing industries. The number of patents granted is used as a proxy for innovation output in each sector, while calculations based on the Lerner index is used as a proxy for the market power. We also conducted detailed case studies of two manufacturing firms – Delta Electronics (Thailand) and Eastern Polymer Group – both of which are leaders in innovation in their respective sectors. Our case studies broadly confirm the findings that firms tend to increase their innovative activities to cope with increasing competition in the global market. As a result of their innovative activities, both Delta Electronics (Thailand) and Eastern Polymer Group have higher market power than other firms in their industries, as reflected by their higher values of the Lerner index.

Policy Recommendations

If a policy goal is to promote innovation activities in an economic sector, it is important to determine whether the level of competition in the sector is on the left or the right-hand side of the peak of the inverted U-shaped curve.

As Thailand is a small and open economy, most large firms in the manufacturing sector are forced to export and face competition in the global market. Since many manufacturing firms in Thailand are increasing their innovation activities, they are presumably situated on the left-hand side of the inverted-U peak where the level of competition is relatively low. Hence, there is already demand for innovation activities, but still at low level.

As a result, government intervention aimed at promoting innovation should focus on the supply-side, i.e., helping firms to lower the cost of conducting innovation. This can be done through providing research grants and tax incentives to promote such

activities, facilitating the mobility of R&D manpower from the public to the private sectors and facilitating foreign R&D personnel and highly skilled professionals to work in Thailand.

The same supply-side interventions can be used to assist firms that are on the right-hand side of the inverted U-shaped curve – those facing severe competition that tend to lower the innovation activities.

Additionally, liberalisation of trade may be needed to induce innovation in some sectors. Firms in the service sector seem to engage less in innovative activities. Many of them face little competition, partly due to the "non-tradable" nature of their services.

Thus, these sectors need to be liberalized to allow more competition to promote innovation. This is the big "missing piece" in innovation policy in Thailand, pointed out by Sujarittanonta and Kamsaeng (2017). In particular, the Foreign Business Act (FBA) should be radically revised to allow free entry of foreign service-providing firms, unless explicitly prohibited. In other words, the mode of service liberalization should be based on a "negative-list" approach, instead of the current "positive-list" one.

Finally, the Trade Competition Act should be enforced more strictly to prevent blatant abuse of dominance and collusion.

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