Research Paper

The Impact of R&D Expenditures on Industry Growth: Evidence from Thai Industries

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Abstract

This paper investigates the impact of R&D expenditures on industry growth considering firm sizes characteristic and targeted industry policy based on annual surveys of the private R&D and innovation in Thailand over the period 2012 – 2016. Using two-way fixed effects models with interaction terms, the main finding is that the targeted industry policy can enhance the positive impact of R&D on growth. Besides, there is sufficient evidence that the impact of R&D on industry growth differs across firm sizes not only the targeted industries group but also the untargeted industries group. Without a targeted industry policy, the impact of R&D on growth is a significantly positive impact for small and medium firms which can imply that the general R&D policies more likely benefit to small and medium enterprises. With a targeted industry policy, on the other hand, the positive impact of R&D on growth significantly increases only for small firms. Compared to the untargeted industry group, the positive impact of small and large firms under targeted industry policy increase while the positive impact of medium firms does not. It reflects that the targeted industry policy seems to benefit for small and large firms. Therefore, the government should retain the targeted industry policy as well as creating more incentives for small and large firms.

Keywords: R&D expenditures, Industry growth, R&D intensity, Two-way fixed effects model, Unbalanced panel data, Firm sizes, Targeted industry

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The Impact of R&D Expenditures on Industry Growth: Evidence from Thai Industries

I. Introduction

Generally, Research and Development (R&D) expenditures are one of the main factors to push the economic growth (Andersson et al., 2012). It also encourages many R&D activities; such as research, knowledge, and innovation. In practice, however, many empirical studies discover that the impact of R&D relies on the different characteristics of each country, industry or firm such as regulations, competition, and firm size.

In Thailand, low R&D investment is one of the important issues that was mentioned in the Thailand Economic Monitor report by the World Bank Group (World Bank Group, 2018). Based on the World Bank database, figure 1. [see Figure 1.] depicts that the trend of R&D expenditures to GDP of Thailand is flat and lags behind from the average level of the upper-middle income countries even though the current level was ranked the third highest in Southeast Asia (The World Bank). In addition, the problem of smaller shares of R&D firms in Thailand compared to other countries in Southeast Asia is also mentioned in the World Bank East Asia and Pacific Regional Report (Andrew and Sudhir, 2019). In the report, the authors indicate that more R&D expenditures per worker generate higher volume of GDP per capita (Ibid.). In that sense, the economic growth still has potential room to increase by stimulating the new entry of firms that conducting R&D in order to increase R&D investment.

A closer look at the R&D expenditures and GDP of Thailand, figure 2. [see Figure 2.] exhibits that although the R&D expenditures have continuously increased since 2009, the ratio of R&D expenditures to GDP is just a little hike. Moreover, the growth of GDP has increased slowly since 2014. This fact may point out the problem of slow growth caused by the low level of R&D expenditures from the small number of R&D firms in Thailand. The possible reasons are the costly, risky, and time-consuming of the R&D process, the lack of skilled labor, political instability, sophisticated business, and the inefficiency of intellectual property protection which cannot encourage the entry of new firms or R&D researchers (World Bank Group, 2018 and Cornell University, INSEAD, and WIPO, 2018).

Furthermore, the historical data from the National Science Technology and Innovation Policy Office (STI) in figure 3. [see Figure 3.] shows the contribution of the R&D expenditures of Thailand which includes public R&D[1] and private R&D[2]. Before the global financial crisis, the government took a key player for R&D expenditures with a ratio of 60% of the total R&D expenditures. In the post-crisis period, however, the private R&D has continuously increased and reached a peak in 2017 while the public R&D has slowly increased. It was possible that the government had a budget shortage due to the economic stagnation and the need to recover for the big flood in 2011, and political instability which delaying the policy implementation of the government. Therefore, the government tries to promote the private sector to invest in R&D by relaxing regulations for R&D enhancement. The ratio of R&D expenditures between the private sector and the public sector in 2017 was about 80:20. Obviously, the private sector becomes to be a key player of R&D expenditures in Thailand now.

In 2016, the government has promoted Thailand 4.0 initiative which is an economic model for moving an economy from a middle-income trap to a high-income range by transforming the Thai industry from a production-based to an innovative technology service-based. As a result, the government decided to increase R&D and focused on investment in digital infrastructure. Besides, a new R&D policy named a new growth engine strategy has created. Under the new growth engine strategy, industries that have high potential to growth and interesting for global investors are set as targeted industries (Thailand Board of Investment: BOI, 2017). The benefits that a company in the targeted industry will get such as income tax exemption, import duty exemption, and work permit and visa facilitation (Bangkok Global Law, n.d. and Weerawutiwong, 2018).

Even though the current policies of the government try to promote private R&D investment, there is no concrete evidence to support that the more private sector invests, the more they benefit. Therefore, this paper aims to investigate the impact of R&D expenditures on industry growth considering with targeted industry policy and firm sizes in order to answer the following questions. First, does the targeted industry's policy encourage the impact of R&D expenditures on industry growth? Second, If so, do the encouraging of the impact of R&D expenditures on industry growth by the targeted industry differ across firm sizes?

In fact, many researchers had studied the impact of R&D expenditures on growth at the micro-level analysis, and they found a positive impact of R&D on growth and found that the

[1] Public R&D is the total amount of R&D spending by the government including with academic institutions, non-profit organization, and state enterprise (STI)
[2] Private R&D is the total amount of R&D spending by the private sector (STI)

smaller firms will get higher growth. However, most of the studies were based on the data in developed countries, not in Southeast Asia like Thailand yet. To the best of my knowledge, the analysis related to the impact of R&D and growth in a developing country like Thailand is not variety, especially in the micro-level analysis due to a limitation of data access. Moreover, previous studies have not yet investigated the role of firm sizes and targeted industry policy in the analysis of the impact of R&D on growth at the industry-level yet. Therefore, this paper will analyze the impact of R&D expenditures on growth at the industry-level by considering the role of firm sizes and targeted industry policy using a micro-data survey of Thai industries in order to verify the role of firm sizes on industry growth and evaluate the effect of targeted industry policy in Thailand. The results may reveal the impact of the current policy so that the government can realize the problem and correctly make a policy intervention.

Regarding the data and methodology, this paper uses the annual survey data of private R&D and innovation activities in Thailand which obtained from the STI for the period 2012 to 2016. At the firm-level data, a pooled cross-sectional data after combining the separated random sampling survey data in each year limits an ability to calculate the growth rate or lagged variables for using in the analysis. Therefore, the author decides to transform the pooled data to be a panel dataset by an averaged grouping of firm-level to industry-level classified by 2 digit-ISIC code, firm size, and survey year. As a result, the data used in analyzing the growth is for the industry-level analysis instead. To estimate the impact of R&D expenditures on industry growth, this paper uses a linear two-way fixed effects model. The two-way fixed effects used in the analysis are industry and size fixed effect, and year fixed effect to control for different characteristics of industries across firm sizes, and years specific fluctuation of all industries during the survey years.

The key findings are that firm sizes matter for the different impact of R&D intensity on industry growth not only the targeted industries group but also the untargeted industries group. Without a targeted industry policy, all firm sizes have a positive relationship between R&D on growth. However, the positive impact of R&D on growth is statistically significant for small and medium firms which can imply that the general R&D policies more likely benefit to small and medium enterprises (SMEs). With a targeted industry policy, nevertheless, the positive impact of R&D on growth increase for small and large firms which can imply that the targeted industry policy can increase the positive impact of R&D on industry growth.

The remainder of the paper is arranged as follows: Section II explains the current policies for R&D promotion in Thailand, Section III provides a literature review, Section IV explains the source of data used in analysis and summary descriptive statistics, Section V describes hypotheses and methodology, Section VI discusses on regression results, Section VII concludes the key findings and proposes policy implications.

II. The Current Policies for R&D Promotion in Thailand

Before 2016, the policies to promote private R&D investment were launched to support the R&D activities of R&D firms as a general without specific industry groups. In 2016, however, the government has launched a new policy to support R&D activities for specific industry group so-called targeted industry in order to encourage more investment in R&D for the industry that has potentiality and interesting for global investors (BOI, 2017). The targeted industry policy is created to encourage the Thailand 4.0 initiative so-called a new growth engine (Ibid.). In the same year of this policy launched, moreover, the government aims to increase the R&D expenditures per GDP from 0.6% in 2015 to 1% in 2018 and 1.5% in 2021 (The Innovation Policy Platform).

The general policies launched before 2016 includes 2 phases (NSTDA, 2016). Phase 1 is a set of policies created to support the company that is working at the initial stage of R&D since the government realizes the high cost of the business in this stage (Ibid.). Most of the incentives in this phase are money support such as soft loan program supporting the Thai SMEs, the right to reimbursement supporting the startup, and grants to support the testing phase of innovation projects, and R&D activities' expenses (Ibid.). Meanwhile, phase 2 is a set of policies created to support the company that extends the R&D projects to produce into commerces or develop its own product and process (Ibid.). The incentives in this phase are technical support for Thai SMEs, a tax credit for R&D and innovation expenditures supporting the qualified company[3], money support for qualified Thai SMEs[4] and regional R&D project, and the credit guarantee and joint venture supporting the startup (Ibid.).

[3] The qualified company is the company or corporate partnership that has been listed as the recipient of R&D and innovation from the Revenue Department and invests in R&D and innovation. The qualified company can get a tax exemption for 3 times of the actual R&D and innovation expenditure [300% of actual paid] (Weerawutiwong, 2018). The policy is available for 5 years from Jan 1, 2015 to Dec 31, 2019. Before that period, the company got tax exemption only 200% of the actual R&D expenditure.

[4] The qualified Thai SMEs is SMEs that have ability to complete the innovation project within 2 years or innovation service provider that specializes in Engineering, Sciences, and Agroindustry or management and has work experienced in those areas at least 3 years.

Regarding the targeted industry policy launched in 2016, the total number of the targeted industry is 10 industries which include five traditional industries and five high-tech industries (BOI, 2017). These industries are selected based on the industry that has potentiality and interesting for global investors (Ibid.). The five traditional industrial sectors are Agriculture and Food, Automotive, Electrical & Electronics, Petrochemicals, and Tourism while the five high-tech industrial sectors are Aerospace, Automation & Robotics, Digital, Bio-Energy and Bio-Chemicals, and Medical and Healthcare (Ibid.). Since the benefits for the targeted industries are beyond the general regulation. Therefore, the government has to create a special regulation to open the room for those industries to get the extra benefit. As a result, the companies in those targeted industries have to get approval from the Thailand Board of Investment (BOI) before getting the benefits.

Under the targeted industry policy, several benefits are provided to the targeted industry such as corporate income tax (CIT) exemption up to 15 years[5], import duty exemption for imported machinery or goods that used for R&D or testing, personal income tax exemption for foreign researchers and specialists, investment support's fund, allowing foreigner hold company's shares up to 100%[6], allowing foreign investors to engage in leasehold land for 99 years[7], and facilitating work permit and visa for foreign specialists, investors (Bangkok Global Law, n.d. and Weerawutiwong, 2018). The government, besides, has set a specific area in the eastern part so-called Eastern Economic Corridor in order to encourage the hub for all targeted industries (Harnhirun, n.d.). The reason for choosing this area is easy to access by several kinds of transportation (Ibid.).

Overall, the current policies for private R&D promotion are likely to give more benefit to targeted industries and SMEs. As the data used in the analysis is available for categorizing targeted industry and non-targeted industry, therefore, this paper will focus on the impact of targeted industry policy on growth.

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[5] Normally, the industry out of the targeted industry that got approval from the BOI will get the corporate income tax exemption up to 8 years.

[6] Under the Foreign Business Act, B.E. 2542, generally, foreigners are allowed to hold the share of the company not exceeding 49% of total shares. Under the Investment Promotion Act, B.E. 2520, however, they are allowed to hold the shares up to 100%.

[7] Under the Civil and Commercial Code or the Commercial and Industrial Lease of Immovable Property Act B.E.2542 allow no more than 30 years and 50 years respectively.

III. Literature Review

Many researchers studied the impact of R&D expenditures on growth at the micro-level analysis; both industry-level and firm-level. Most of them tried to control the different characteristics of firms or industry such as firm age, firm size and industry group. Although, they used different measurements of growth such as sales growth, employment growth, labor productivity growth, and Total Factor Productivity (TFP) growth, the results of the impact of R&D on growth usually were found a positive impact. A quick survey of a related literature review is summarized as follow;

At the firm-level analysis, a survey of empirical analysis for the impact of R&D and productivity in manufacturing sector by Mairesse and Sassenou (1991) reveals that many researchers used the Cobb-Douglas production function with the key explanatory variable such as R&D capital and R&D intensity[8] to investigate the impact of R&D and productivity, and found the positive and significant relationship between them. Furthermore, they suggest that researchers should care industry and firm characteristics when estimating the impact (Ibid.).

Considering firm-size characteristics, for instance, Yang and Huang (2005) used a panel data of electronic firms in Taiwan during 1986-1999 and applied Generalized Method of Moments (GMM)[9] estimator to analyze the impact of R&D and firm growth under controlling with firm size. They found a significantly positive relationship between them, especially in small firms (Ibid.). Besides, Demirel and Mazzucato (2012) found the positive impact of R&D on growth of US pharmaceutical firms during 1950-2008 at the whole industry-level. By controlling firm size, patenting, and persistent patenting in a simple firm growth model and using GMM estimator, however, they found the positive impact of R&D on growth only for small firms that persistence in patenting at least five years (Ibid.). Similarly, Oliveira and Fortunato (2017) constructed a dynamic firm growth model with serial correlation in the error term and applied the GMM estimator with a panel data of Portuguese manufacturing firms during 1990-2001, and they found the higher positive impact of R&D on growth in small firms. Daunfeldt and Elert (2011) investigated this relationship using listed firms in Sweden between 1998-2004 and found

[8] The R&D intensity is likely to be used since it is easier to calculate than the R&D capital. Generally, the R&D intensity is measured by the ratio of R&D to sale or value added and the productivity can be either labor productivity or TFP (Mairesse and Sassenou, 1991).

[9] Generalized Method of Moments proposed by Arellano & Bond (1991) is used for estimating a dynamic model of both balanced and unbalanced panel data which assumed that there is no serial correlation in the error term and no strictly exogenous in dependent variables.

that size and growth are correlated in both aggregate level and specific industry. As there are many different characteristics across industries, they state that industry characteristics are matter whether the relationship of size and growth are found or not (Ibid.).

At the industry-level analysis, Griliches (1998) studied the relationship between R&D and TFP growth from the survey data in the USA during 1959-1976 by applying a Cobb-Douglas production function. Under separately subperiod estimation, he found a positive and significant relationship between R&D intensity and TFP growth (Ibid.). Likewise, Cameron (2000) studied the impact of R&D on TFP growth by using the panel data of UK manufacturing during 1972-1992. He controlled for autocorrelation by using a single lagged dependent variable in a dynamic model and estimated the model by fixed effect estimator (Ibid.). The interesting thing in his model is the interaction term between industry characteristic with R&D in order to allow the difference across industries (Ibid.). He found a positive significant impact of R&D expenditures on growth, and its impact is different across industries characteristics (Ibid.). The higher capital to labor ratio and higher imports increase the positive impact while the human capital, market concentration, export characteristics have an insignificant impact on the elasticity of R&D (Ibid.).

In the context of R&D promotion and growth, Wang (2013) studied the impact of R&D subsidies on firm growth based on a panel data of manufacturing in an industrial park of Taiwan during 1991-1999. By using FE model, he found the positive relationship between R&D subsidy and firm growth, except for the growth of R&D employment. The result in line with Hussinger (2007), he studied the relationship between public R&D subsidies and R&D intensity using German innovative manufacturing firms during 1992-2000 estimated by two-step selection model, and he found a positive impact of the public R&D subsidies on R&D intensity.

All in all, many research had already studied about the impact of R&D expenditures on growth at the micro-level analysis, and the empirical results reveal that R&D and growth are mostly found a positive relationship and firm sizes relate to a different impact of R&D on growth. To the best of my knowledge, however, previous studies have not yet investigated the role of firm sizes and targeted industry in the analysis of the impact of R&D on growth at the industry-level yet. Moreover, most of the literature studied based on the data in developed countries. In fact, the analysis related to the impact of R&D and growth in a developing country like Thailand is not variety, especially in the micro-level analysis due to a limitation of data access. Therefore, this paper will analyze the impact of R&D expenditures on growth at the industry-level by considering the role of firm sizes and targeted industry policy by using a micro-data survey of

Thai industries in order to verify the role of firm sizes on industry growth and evaluate the effect of targeted industry policy in Thailand. The results may reveal the impact of the current policy so that the government can realize the problem and correctly make a policy intervention.

IV. Data

The data used in the analysis is a combination of an annual survey of the private's R&D and innovation in Thailand over the period 2012 – 2016 obtained from the STI. The sampling process and collecting survey are operated by Chulalongkorn University under the assignment of the STI (STI, 2018). There are 2 groups of sampling. One is a list of corporations; that have revenue greater than 12 million Baht and are not in the list of the previous survey; obtained from the database of the Business Online Public Company Limited (BOL), and the other is the companies that have R&D activities based on the previous surveys (Ibid.). For the first group, the sample size was randomly selected from the database after grouping by industry based on ISIC 2 digit, and firm size based on the value of the fixed asset under the regulation of the Ministry of Industry[10](Ibid.). For the second group, all companies are surveyed (Ibid.). The survey data covered 44 industries including Thai and foreign firms (Ibid.). On average, the response rate is about 45% for the first group and 84% for the second group.

The reasons for using this survey data are as follow; it is the best and most reasonable source of micro-level survey data of private R&D in Thailand, this data is also used for estimating as national private R&D expenditures, and the survey data are surveyed both R&D and non-R&D firms which can reduce self-selection problem. However, the data used in the analysis did not cover unregistered firms and firms that had revenue under the threshold (12 million Baht). As the Li and Rama (2015) explain that most of the data in developing countries are truncated due to either the lag of informal firms or the exclusion of firms by threshold setting which may cause to get a biased result. By comparing the results from data in developing countries and in developed countries, they report that the bias of the relationship between firm size and productivity is downward bias (Ibid.). Since the data for private R&D at micro-level in Thailand is limited and only operated by the STI, so the author has to tradeoff

[10] Firm size; which are small (S), medium (M), and large firm (L); is categorized by the value of fixed assets followed by the definition of the Ministerial regulations defining the amount of employment and the value of fixed assets of the Small and Medium Enterprises, B.E. 2545 (2002). For the manufacturing and service sector, S = Fixed asset value up to 50 million Baht, M = Fixed asset value 51-200 million Baht, L = Fixed asset value above 200 million Baht. For the Wholesale/retail trade, S = Fixed asset value up to 50 million Baht, M = Fixed asset value 51-100 million Baht, L = Fixed asset value above 100 million Baht.

and decides to use this data in the analysis. With those concerns, thereby, the important thing to keep in mind is a possibility to a downward bias in estimation due to the truncated data used in the analysis.

The steps for preparing dataset are as follow. Firstly, selecting the data that will be used and combining those data in each year to be a single dataset. Secondly, cleaning the missing data of the main interesting variables that are: total R&D expenditure, sale, and employees, and the extreme data[11] occurred by estimation. The total number of observation of the pooled dataset after cleaning is 13,730 observations. As the survey data was operated separately and randomly selected from the different population occurred in each year, so the pooled data of all survey generates the pooled cross-sectional dataset which restricts the way to calculate the growth rate or time lag of the variables of interest. Thirdly, transforming the pooled cross-sectional dataset to be a panel dataset by grouping from the firm-level to the industry-level. To avoid the possible bias from the grouping process, the condition of grouping was followed the STI's grouping in the sampling process. Thus, the firm-level dataset was averaged grouping by using ISIC 2-digit code (ISIC2D) and firm size. Finally, the pooled dataset becomes to be an unbalanced panel dataset which has 590 observations in total.

Besides, the author generates some new variables which are used as the main variables of the study at the firm-level and averaged grouping to the industry-level such as productivity and R&D intensity. The productivity is calculated by dividing the total sales by the total employees while the R&D intensity is the ratio of R&D expenditures to the total sales. For the category variables, industry category is generated followed by the ISIC2D which has 44 industry categories while size category is generated followed by the firm size grouping which has 3 categories. Moreover, a dummy is generated named targeted2016[12] where the value 1 is equal to the targeted industry that available in 2016 and 0 otherwise.

Table 1 [see Table 1. and Appendix 1.] shows the summary descriptive statistics of the main variables classified by firm sizes. On average, the productivity of all industries is about 6.82 while R&D intensity is about 0.15. The average productivity growth rate of all industries

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[11] Extreme data categorized by the STI is an estimated value of R&D expenditure or R&D expenditure to sale or full time equivalent (FTE) personnel RD or FTE to sale that has standard deviation higher double than the same industry and size or has highest value among all companies in the 99th percentile.

[12] Since some of 10 targeted industries are new industry and do not have their own industry category. Therefore, the targeted industries in the analysis will include only agriculture, food, motor vehicles, computer, electrical machinery, chemicals, tourism, and health services.

is approximately 20% on average. Generally, the large firms probably to have a high capacity to hire many employees, least budget constraint, and have a market power to extend sell volume, so large firms get the highest level of productivity due to the largest amount of sales and employees, but their average productivity growth is the lowest at about 13%. For the SMEs, the productivity of small firms does not much differ from medium firms. When looks closer to the productivity across many levels of percentile, moreover, the productivity of small firms is higher than medium firms not only in the high percentile but also at the minimum level of productivity. It seems that small firms may have more productive than medium firms in terms of human capital management since a smaller number of employees in small firms can generate a high level of sale volumes. In addition, the productivity growth of small firms is the highest among all firm sizes.

Meanwhile, the average R&D intensity of large firms is the smallest while medium firms are the highest even though the level of R&D expenditures of large firms are the biggest. It reveals that the current level of R&D expenditures of large firms is extremely low when compared to their sales. While the small firms have higher R&D intensity than large firm in both mean and almost all levels of percentile. Compared to medium firms, small firms have average R&D intensity lower than medium firms just 0.06, but small firms have highest productivity growth. This fact reflects that small firms may need more R&D investment than others in terms of improving the quality of process and product to encourage their ability to sales. Besides, when looking at the R&D intensity only for the targeted industry in 2016, the small firms become the highest one (higher than large firms about three times, on average). Meanwhile, the number of researchers compared to total employees is very low for all firm sizes which indicates that R&D companies currently confront personnel R&D shortage.

In summary, large firms have the lowest R&D intensity and productivity growth even though their sales, employees, and R&D expenditures are highest. Meanwhile, small firms have the highest productivity growth though their sales, employees, and R&D expenditures are the lowest. Moreover, medium firms have the highest R&D intensity, but their productivity growth is just intermediate.

V. Hypotheses and Methodology

1. Hypotheses

Based on the 2 research questions, the hypotheses of each question are as follow;

Hypothesis I. The targeted industry is expected to encourage the impact of R&D expenditures on industry growth.

Actually, R&D policies are a tool of the government in order to encourage the level of R&D in the market by giving financial support which is a direct intervention or by providing tax incentive which is an indirect intervention (OECD, 2004). However, a kind of policy that government subsidy in specific industry sector so-called targeted industry subsidies can generate problems such as information asymmetry between government and firms, difficulty to measure the knowledge externalities, and uncertainty for the government to predict the right company for getting the subsidy (Aghion and Howitt, 1998).

In the literature review section, researchers found the positive relationship between R&D subsidies and firm growth (Wang, 2013 and Hussinger, 2007). Based on the literature, therefore, the targeted industry is expected to enhance the impact of R&D expenditures on industry growth.

Hypothesis II. Firm sizes matter for the different impact of R&D expenditures on industry growth. Small and large firms in targeted industries are expected to increase the positive impact of R&D expenditures on industry growth while the medium firms do not.

The theory related to the relationship of firm growth and firm size named Gibrat's law is frequently discussed. Under Gibrat's law by Robert Gibrat in 1931, firm growth does not rely on firm size (Daunfeldt and Elert, 2011). Many research test the existence of this law, and many of them found the inexistence of the law which means that there is some relationship between firm growth and size (Ibid.). For example, Daunfeldt and Elert (2011) found that small firms have a positive relationship with growth, especially when considering within a specific industry. Distante et al. (2017) report that when the rejection of Gibrat's law happens, there are 2 kinds of finding which are in an opposite way; some research found a positive relationship with growth in large firms while others found a positive relationship in small firms. In the literature section, besides, researchers found the significantly positive relationship between R&D and firm growth relative to small firms (Yang and Huang, 2005, Demirel and Mazzucato, 2012, and Oliveira and Fortunato, 2017).

Regarding the benefits of the targeted industry policy, they are likely to reduce the administrative cost of the private sector and save more earnings from the tax exemption which increase the potential of firms to invest, produce, and hire more. In fact, more R&D activities also enhance the knowledge spillover across firms and industries which can reduce marginal cost (Sengupta, 2004). Generally, small and medium firms (SMEs) would confront with a budget constraint when compared to large firms because the small firms might get a harder chance to access the finance due to a lower credit (Andrew and Sudhir, 2019). Under the targeted industry policy, small firms may get benefit from reducing their funding cost and enhance the ability to invest. Becker (2013) explains that the government subsidies and tax credits policies have a positive relationship on private R&D investment, and the public R&D subsidies are most benefit for small firms which have experience more financial access. Moreover, he describes that large firms have the potential to invest in R&D even no public subsidy, so the effect of subsidy would positive and insignificant on R&D investment (Ibid.). Thereby, he recommends that targeted subsidy could be more effective for large firms (Ibid.).

Besides, the tax exemptions under the targeted industry policy may higher benefit for large firms since they can save a lump sum of their money from the tax exemptions. In the survey data, the large firms have the highest volume of sales. Suppose they had to pay corporate income tax which is calculated from the revenue, they would pay the biggest amount. Regarding the survey data, the median of productivity growth, sales volume, and a number of employees of small and large firms in targeted industries are higher than the same size of firms that are not in targeted industries while medium firms are conversely.

As the data used in the analysis will be controlled for industry and firm size, so the Gibrat's law is supposed to be rejected which means that the impact of R&D on growth will differ across firm sizes. Furthermore, the survey data and the literature support to expect that the targeted industry policy seems to benefit for small and large firms. Thus, small and large firms are expected to increase the power of encouraging impact of R&D expenditures on industry growth by targeted industry while the medium firms do not.

2. Model and Methodology

To proof the two hypotheses above, we decided to apply the econometrics regression model adapted from the model of Cameron (2000). Since some of the data used in the model of Cameron (2000) are not available such as TFP and R&D stock, so we decided to use the labor productivity growth as a measurement of industry growth and R&D expenditures to a total sales as a measurement of R&D intensity. Besides, all explanatory variables are used in term of lagged variables in order to avoid the endogeneity. After using a histogram on R&D

intensity, the logarithm form of variables is better to use than level form because it provides normal distribution.

As the data used in this analysis probably has a problem from omitting variables bias from heterogeneous characteristics among industries, firm sizes and year. Mairesse and Sassenou (1991) explain that a panel data can omit unobserved effects from different characteristics either firm or industry by assuming that they are invariant or slowly change over time, and researchers should care about the industry and firm characteristics when estimating the impact. This suggestion is in line with the suggestion of Daunfeldt and Elert (2011), so the author decides to use two-way fixed effects (2FEs) instead of one-way fixed effect. The 2FEs include industry and size fixed effect and year fixed effect to control for unobserved effects from different characteristics of industries across firm sizes, and year specific fluctuation of all observations during the survey years.

Under the assumption of fixed effect, the 2FEs are assumed to correlate with the explanatory variables, so the 2FEs estimator treats these fixed effects as unknown parameters in order to avoid the bias of the coefficients of regressors (Fischer, 2010). However, the error term is assumed to uncorrelated with all regressors and both fixed effects (Rios-Avila, 2013). In the case of 2FEs that has a small number of individual fixed effect and time fixed effect are not too many, either Ordinary Least Square (OLS) or Least Squares Dummy Variable (LSDV) perform well for estimation (Derin, 2003). However, when the number of those fixed effects are huge, the LSDV encounters with a degree of freedom's loss (Ibid.). Meanwhile, the OLS estimator still possible to use but it might be busy to estimate the result since the OLS has to calculate the coefficient for vast dummy variables from those fixed effects (Ibid.). For the case that has one observation in some groups, moreover, Correia (2015) explains that the regression that keep these groups so-called singleton groups is inconsistent not only the estimation but also the understated of standard error which leads to the overstated in the statistical significance and reduce the correctness of inference (Ibid.). With the high level of fixed effects, he suggests that the singletons should be dropped in order to reduce bias (Ibid.). Therefore, this paper will estimate the linear two-way fixed effect model by using the "reghdfe" command in STATA developed by Correia (2014) because this command has already taken into account about the singletons issue.

Since the variables of interest are R&D intensity, targeted industry, and firm sizes. Similar to Cameron (2000), the interaction terms of each variable with R&D are used to allow the R&D impact to vary across firm sizes and can test the hypotheses. Thus, the linear two-way fixed effects models that are used for testing each hypothesis are as follow;

Model for testing hypothesis I (Model 1)

$$\text{ProductivityGrowth}_{jst} = \beta_0 + \beta_1 \ln(R\&Dintensity)_{jst-1} + \beta_2 Targeted2016_{jst} * \ln(R\&Dintensity)_{jst-1} + \mu_{js} + \lambda_t + \varepsilon_{jst}$$

Model for testing hypothesis II (Model 2)

$$\text{ProductivityGrowth}_{jst} = \beta_0 + \beta_1 \ln(R\&Dintensity)_{jst-1} + \beta_2 M * \ln(R\&Dintensity)_{jst-1} + \beta_3 L * \ln(R\&Dintensity)_{jst-1} + \beta_4 Targeted2016_{jst} * \ln(R\&Dintensity)_{jst-1} + \beta_5 M * Targeted2016_{jst} * \ln(R\&Dintensity)_{jst-1} + \beta_6 L * Targeted2016_{jst} * \ln(R\&Dintensity)_{jst-1} + \mu_{js} + \lambda_t + \varepsilon_{jst}$$

where; Productivity Growth = difference in natural logarithm of the ratio of sales to employees

ln(R&Dintensity) = natural logarithm of the ratio of R&D expenditures to sales

M = a dummy variable for firm size where 1 = firm size M and 0 otherwise

L = a dummy variable for firm size where 1 = firm size L and 0 otherwise

Targeted2016 = a dummy variable for targeted industries available in 2016 where 1 = targeted industry in 2016 and 0 otherwise

μ_{js} = industry and size fixed effect

λ_t = year fixed effect

ε = error term

j = industry, s = firm sizes, and t = year

VI. Results and Discussions

1. Results

Firstly, the author using a panel regression to test the model specification of each model by using the Hausman test[13]. After regressing the models separately for fixed effect and random effect and using the Hausman test, the results suggested that the fixed effect model is more suitable than random effect model for all three models [see the result in Appendix 2]. To ensure

[13] Hausman (1978) established a model specification test for choosing between fixed effect (FE) and random effect (RE). The null hypothesis is the RE is preferred while the alternative hypothesis is the FE is preferred, so when the result of the test indicates to reject null hypotheses, it means that FE is preferred (Wooldridge, 2016).

that the 2FEs are reasonable for those models, moreover, the author regressed those models including dummies for 2 FEs by OLS with robust in standard error and used joint test[14] for those set of dummies. The result of the joint test indicates that the 2FEs are needed [see the result in Appendix 3]. Based on the tests, there are strong support for using the 2FEs model.

Then, the author regressed each model to test each hypothesis by using the command that supports for the 2FEs model named "reghdfe" in STATA developed by Correia (2014). The results of all models are shown in Table 2., and the marginal effects of R&D intensity classified by firm sizes and the comparison of marginal effects among each firm size for all models are shown in Table 3. [see Table 2. and Table 3.].

Considering the result of the first model, in the absence of targeted industry policy, the impact of R&D intensity on productivity growth was found a positive impact and statistically significant at 5% level. On average, a 1% increase in R&D intensity relates to a 0.13% increase in productivity growth, ceteris paribus. With the targeted industry policy, the positive impact of R&D intensity on productivity growth slightly increases by approximately 0.004 percentage point. By using lincom[15] command in STATA for testing the statistically significant level, the result indicates that the positive impact under targeted industry is still statistically significant at 10% level.

For the second model, the result indicates that firm sizes matter for the different impact of R&D intensity on industry growth not only the targeted industries group but also the untargeted industries group. Without targeted industry policy, on the one hand, the coefficient of R&D intensity of small firms is statistical significance at 5% level. On average, a 1% increase in R&D intensity of small firms that are not targeted industries is associated with an increase in productivity growth by approximately 0.15%, holding others fixed. Whereas, the positive impacts of R&D intensity on productivity growth for medium and large firms that are not targeted industries are only 0.21% and 0.05%, respectively. By using lincom command in STATA, we found that the positive impact of medium firms is statistically significant at 10% level. Compared to small firms, the medium firms have a higher positive impact about 0.06 percentage point while the large firms have a lower positive impact about 0.10 percentage

[14] The joint test is conducted by "testparm" command in STATA. The null hypothesis is all coefficients of those dummies are equal to zero and the alternative one is some of them are not equal to zero.

[15] The "lincom" command in Stata is usually used for calculating t-stats, z-values, p-values, and confidence intervals of the linear combinations of coefficients which is useful for testing the statistically significant of the coefficients [STATA].

point, respectively. With targeted industry policy, on the other hand, the coefficient of interaction term of R&D intensity for small and medium firms are statistically significant at 5%. The marginal effect of R&D intensity still has found a positive impact on growth for all firm sizes which are 0.23% and 0.13%, 0.05%, respectively. Compared to the untargeted industry, the positive impacts of small and large firms are increased by 0.08 and 0.04 percentage point, respectively. Meanwhile, the positive impact of medium firms in targeted industries is reduced by 0.08 percentage point. By using lincom command in STATA, we found that the positive impact of small firms increases significantly.

Figure 4. [see Figure 4.] shows the difference in slope coefficients of R&D intensity between targeted industry and without targeted industry. Both slopes of small firms are shown the positive slope, but the slope of small firms in targeted industries is steeper than those in untargeted industries which indicates that the positive impact of small firms in targeted industries is higher than those that are not targeted industries. Similarly, the positive slope coefficient of large firms that are targeted industries is steeper than those that are not targeted industries. Conversely, the positive slope coefficient of medium firms in targeted industries is less steep than those in untargeted industries which means that the positive impact of R&D intensity on productivity growth for medium firms in the targeted industries is lower than those that are not targeted industries. These facts signal that small and large firms that are targeted industries may consume the benefits from the targeted industry policy.

To test the robustness of the results [see Appendix 4.], we used the same estimator to regress the same models with subgroups such as manufacturing sector and services sector. The results still find a positive relationship between R&D and growth for both sectors and the signs of each regressor almost the same, except medium firms in the manufacturing sector that are not targeted industries. The level of significance and magnitude change in some models. For the manufacturing sector, small firms have the highest positive impact whether targeted industries or not, but the statistically significant impact was found only for small firms that targeted industries. Considering the service sector, medium firms have the highest positive impact only the untargeted industries and have the lowest positive and significant impact for the targeted industries. Large firms in the service sector that are targeted industries get the highest positive impact of R&D on growth. In comparison, the positive impact for firms in the manufacturing sector is smaller than in the service sector. Besides, we regressed those models with the same estimator but changed the measurement of R&D intensity from the ratio of R&D expenditures to sales to the ratio of researchers to employees. The impact of R&D intensity on growth is found a positive significant at 5% level. Although the statistical significance of the interaction term between R&D intensity and targeted industry of small and medium firms are disappeared, the sign of other regressors still the same and slightly change in magnitude. Small firms still have the highest positive impact of R&D on growth whether targeted industries or not.

2. Discussions

Comparing the expected results and the actual findings, the result of first model reveals that targeted industry can enhance the positive impact of R&D on growth which is consistent with the expected result stated in the hypothesis I. For the result of the second model, the positive impacts of R&D on growth differ across firm sizes for both targeted industry and untargeted industry. Moreover, the positive impacts become higher for small and large firms in targeted industries, but the positive impact of medium firms is lower than those that are not targeted industry. Therefore, the targeted industry policy does not increase the positive impact of R&D on growth for medium firms. The finding from the second model is also consistent with the expectation stated in hypothesis II.

In addition, the finding of a positive impact of R&D on productivity growth across firm sizes is in line with the literature. In the absence of targeted industry policy, the positive impact is higher for small and medium firms so-called SMEs. This finding can imply that the general policy for R&D promotion is more benefit to SMEs. Considering the targeted industry policy in 2016, the positive impact of medium firms slightly shrink about 0.08 percentage point while other sizes have a higher positive impact on growth, especially the small firms. Becker (2013) explains that the R&D policies such as subsidies and tax credits are found a positive impact on R&D investment and mostly for small firms because they can reduce the budget constraint while the positive impact for large firms is insignificant because they have least financial access and have a high potential to invest than others. The finding is consistent with his explanation.

Overall, the results indicate that firm sizes matter for the different impact of R&D intensity on industry growth not only the targeted industries but also the untargeted industries. Based on the annual survey data of Thai industries during 2012-2016, we found a positive impact of R&D on growth, but its impact is statistically significant only for small and medium firms which can imply that the general R&D policies are more benefit to SMEs. With a targeted industry policy, the policy can enhance the positive impact for small and large firms. Among other firm sizes, however, the positive impact of small firms increases significantly because the policy may higher reduce the financial constraint and their cost than the industry outside the target and other firm sizes. Meanwhile, medium firms seem to least benefit from the targeted industry policy. Therefore, it can imply that the targeted industry policy benefits only for small and large firms.

VII. Conclusion and Policy Implications

This paper investigates the impact of R&D expenditures on industry growth considering with firm sizes characteristic and targeted industry policy. Based on the annual survey of the private R&D and innovation in Thailand over the period 2012 – 2016, the key findings are that there is sufficient evidence that the impact of R&D on industry growth differs across firm sizes not only the targeted industries group but also the untargeted industries group. Without a targeted industry policy, all firm sizes have a positive relationship between R&D on growth. However, the positive impact of R&D on growth is statistically significant for small and medium firms which can imply that the general R&D policies more likely benefit to SMEs. With a targeted industry policy, the policy can enhance the positive impact of R&D on growth for small and large firms, but the enhancement is statistically significant only for small firms.

As the current level of R&D in Thailand still lags behind the averaged level of the upper-middle income countries. Montmartin and Massard (2015) explain that the government should implement R&D subsidy when market failure leads to a low level of R&D. Moreover, the results indicate that the targeted industry policy can enhance the positive impact of R&D on growth even just for small and large firms. Andrew and Sudhir (2019) explain that targeted policy is an important factor to raise productivity growth because the resources are allocated within the specific industry group that has higher labor productivity. Therefore, the government should retain the policy. Besides, a set of policy recommendations that the author would like to propose to the government are as follow;

1. For the untargeted industry group, the government should create more incentive not only for SMEs but also for large firms, and provide more technical support for them such as shared lab center, law and operation advisory center, and education program.

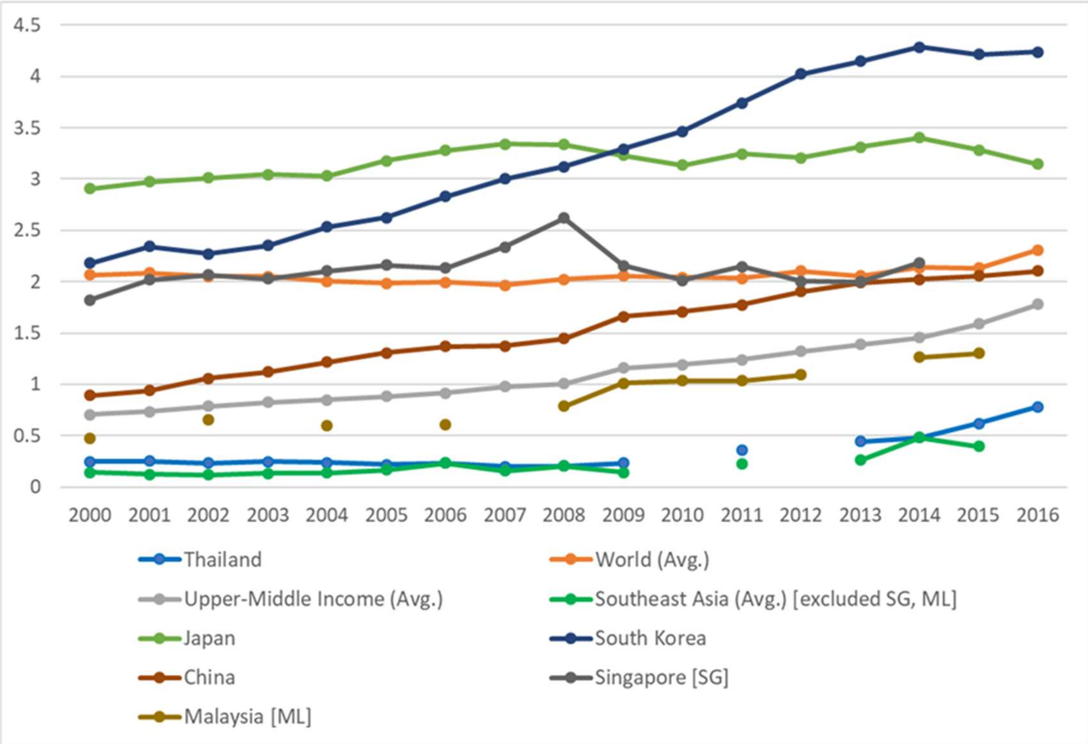
2. For the targeted industry group, the government should extend the incentive for small and large firms in parallel with creating a site visit program or center for hearing and response to the actual problems not only for medium firms but also for small and large firms.

3. In order to improve the quality of data collection and enhance the effectiveness of monitoring and analysis, the government should provide more budget support to the STI.

The data used in the analysis does not cover unregistered firms and firms that had revenue under the threshold (12 million Baht). However, the data of private R&D at micro-level in Thailand is limited and only operated by the STI, so we had to tradeoff and decided to use this data. With this concern, thereby, the important thing to keep in mind is a possibility to has a downward bias in estimation due to the truncated data. Besides, the period of data during 2012-2016 is insufficient to capture the long-run effect of R&D on growth in particular the targeted industry policy which launched in 2016. Therefore, if the longer period and untruncated data were available, the analysis of long-run effect of R&D on growth and the treatment effect using a difference in difference estimator could be covered in the further study. Regarding the finding of Andrew and Sudhir (2019), the current share of R&D firms in Thailand is very low, so the further study would be nicer to find the causes related to the decision of private sector to entry in R&D investment in order that the government can sharply create a policy for encouraging the new entry of R&D firms.

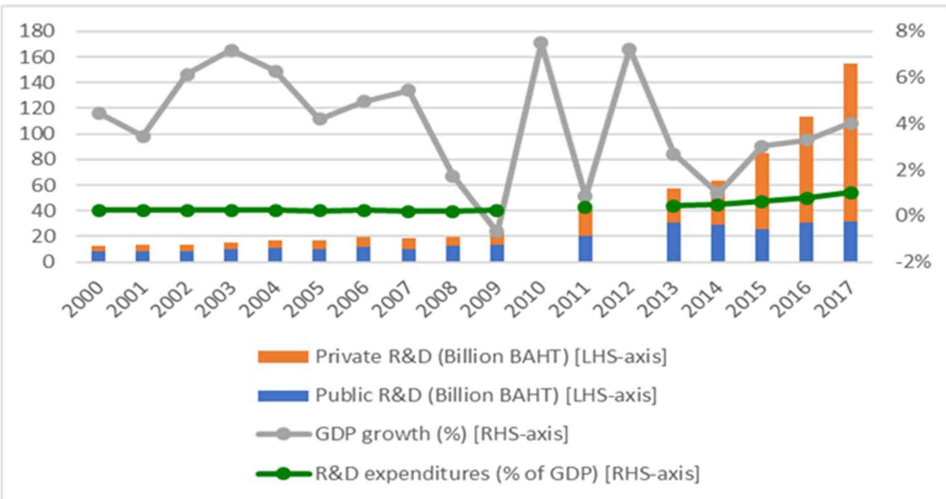
Figures

Figure 1. The trend of R&D expenditures to GDP of Thailand compared to selected countries and world average, 2000-2016



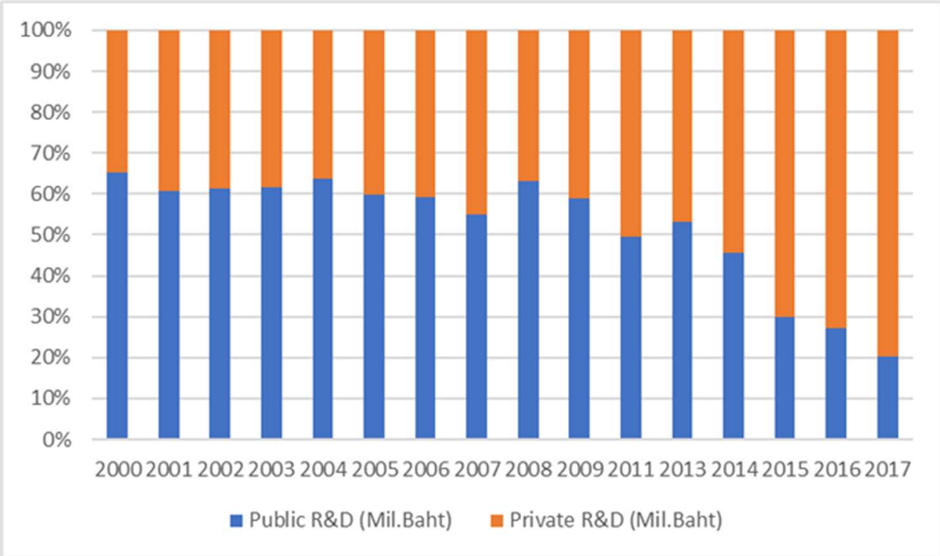
Source: The World Bank and STI, plotted by author

Figure 2. Closer look at R&D expenditures and GDP of Thailand, 2000-2017



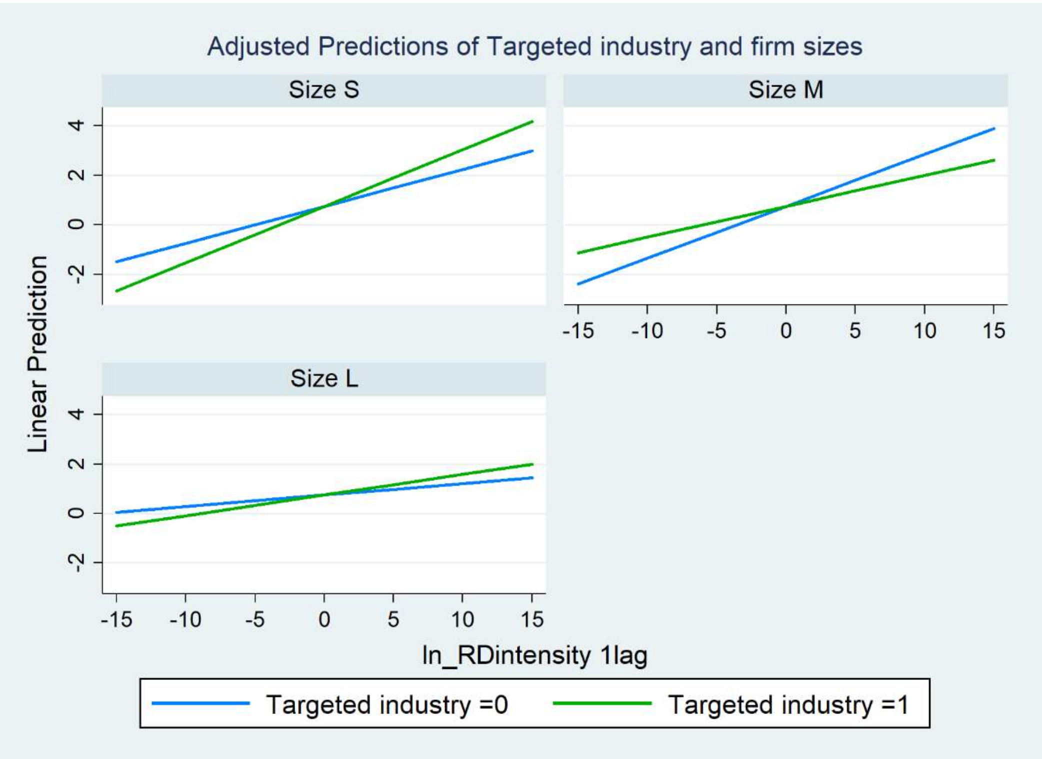
Source: The World Bank, STI, and NSEDB and plotted by author

Figure 3. The ratio of public R&D to private R&D, 2000-2017



Source: STI and plotted by author

Figure 4. The difference in slope coefficients of R&D intensity between targeted industry = 1 and = 0 classified by firm sizes



Tables

Table 1. Summary descriptive statistics of the main variables classified by firm sizes

Variable of interest		Mean	SD	Min	Max	P10	P25	P50	P75	P90	Count
Total Sales (mil. Baht)	**Total**	4,833.44	36,663.85	5.61	549,059.60	63.52	130.43	389.86	1,555.03	5,812.26	590
	S	135.67	135.19	7.05	889.79	31.43	61.42	90.64	161.57	279.94	190
	M	420.83	291.05	5.61	2,638.19	118.78	259.99	381.15	507.65	680.36	199
	L	13,642.82	61,970.54	55.55	549,059.60	1,073.51	1,479.02	3,032.29	6,221.89	14,403.36	201
Total R&D (mil. Baht)	**Total**	11.72	46.21	0.00	633.96	0.22	0.93	2.17	6.03	19.22	590
	S	2.73	5.35	0.00	54.00	0.15	0.55	1.35	2.68	5.47	190
	M	3.25	4.67	0.00	33.87	0.10	0.83	1.77	3.71	7.88	199
	L	28.60	76.19	0.00	633.96	0.82	2.00	6.80	19.94	44.22	201
Total Employees	**Total**	551.66	923.96	10.00	10,080.00	61.94	113.25	237.80	554.00	1,300.79	590
	S	110.04	79.39	10.00	462.00	35.00	56.25	84.24	132.00	226.34	190
	M	286.72	276.88	40.00	2,245.56	114.42	167.50	216.67	316.63	451.67	199
	L	1,231.41	1,308.74	84.00	10,080.00	285.50	503.88	914.24	1,351.67	2,490.00	201
Total Researchers	**Total**	5.53	9.51	0.00	103.50	0.37	1.12	2.88	6.65	12.00	590
	S	2.63	3.65	0.00	24.00	0.15	0.53	1.67	3.00	6.33	190
	M	3.71	3.98	0.00	31.29	0.25	1.21	2.63	5.07	7.85	199
	L	10.07	14.36	0.00	103.50	1.17	2.83	6.03	11.30	20.30	201
Productivity	**Total**	6.82	18.22	0.00	203.39	0.96	1.57	2.77	5.37	11.25	590
	S	3.32	7.43	0.12	96.34	0.72	1.07	1.97	3.24	6.27	190
	M	4.06	9.32	0.00	109.39	1.02	1.48	2.26	3.65	6.02	199
	L	12.84	28.00	0.66	203.39	1.83	2.92	5.36	10.09	19.10	201
R&D intensity	**Total**	0.15	1.41	(0.28)	29.66	0.001	0.003	0.01	0.03	0.12	590
	S	0.18	1.00	(0.28)	12.58	0.002	0.011	0.03	0.07	0.21	190
	M	0.24	2.22	0.00	29.66	0.001	0.002	0.01	0.02	0.10	199
	L	0.03	0.10	0.00	0.98	0.001	0.002	0.004	0.01	0.03	201

Variable of interest		Mean	SD	Min	Max	P10	P25	P50	P75	P90	Count
log R&D intensity	**Total**	(4.52)	1.91	(14.16)	3.39	(6.69)	(5.74)	(4.70)	(3.35)	(2.11)	566
	S	(3.43)	1.59	(7.62)	2.53	(5.18)	(4.45)	(3.37)	(2.60)	(1.54)	182
	M	(4.63)	1.77	(9.30)	3.39	(6.54)	(5.68)	(4.86)	(3.93)	(2.19)	187
	L	(5.42)	1.79	(14.16)	(0.02)	(7.33)	(6.11)	(5.54)	(4.65)	(3.32)	197
Productivity Growth	**Total**	0.20	0.81	(5.80)	6.03	(0.44)	(0.15)	0.07	0.49	0.98	455
	S	0.28	0.82	(2.17)	3.46	(0.40)	(0.13)	0.07	0.59	1.23	145
	M	0.20	0.94	(5.80)	6.03	(0.51)	(0.10)	0.11	0.51	1.03	153
	L	0.13	0.65	(1.45)	3.19	(0.45)	(0.18)	0.05	0.35	0.76	157

Note: Firm size; which are small (S), medium (M), and large firm (L); is categorized by the value of fixed assets followed by the definition of the Ministerial regulations defining the amount of employment and the value of fixed assets of the Small and Medium Enterprises, B.E. 2545 (2002).

For the manufacturing and service sector, S = Fixed asset value up to 50 million Baht, M = Fixed asset value 51-200 million Baht, L = Fixed asset value above 200 million Baht.

For the Wholesale/retail trade, S = Fixed asset value up to 50 million Baht, M = Fixed asset value 51-100 million Baht, L = Fixed asset value above 100 million Baht.

Table 2. Regression Result

	(Model 1) Growth_prod	(Model 2) Growth_prod
ln_R&D intensity1 lag	0.133**	0.149**
	(0.055)	(0.070)
M*ln R&D intensity1 lag		0.060
		(0.124)
L*ln R&D intensity1 lag		-0.103
		(0.083)
Targeted2016*ln R&D intensity1 lag	0.004	0.079**
	(0.038)	(0.039)
M*Targeted2016*ln R&D intensity1 lag		-0.164**
		(0.071)
L* Targeted2016*ln R&D intensity1 lag		-0.042
		(0.062)
_cons	0.779***	0.750***
	(0.245)	(0.242)
Fixed effects	Industry*size effect, Year effect	Industry*size effect, Year effect
Cluster	Industry*size	Industry*size
N	433	433
R^2	0.248	0.259

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

Table 3. Marginal Effects of R&D intensity classified by firm sizes and Pairwise Margins

	Model 1	
	Targeted industry = 0	Targeted industry = 1
Marginal effects	0.133	0.137
	Targeted industry 1 vs 0	
Pairwise Margins	0.004	

	Model 2								
	Targeted industry = 0			Targeted industry = 1					
	S	M	L	S	M	L			
Marginal effects	0.149	0.209	0.046	0.228	0.125	0.084			
	Targeted industry = 0			Targeted industry = 1					
	M vs S	L vs S	L vs M	M vs S	L vs S	L vs M			
Pairwise Margins	0.060	(0.103)	(0.163)	(0.103)	(0.145)	(0.042)			
	Targeted industry 1 vs 0								
	S1 vs S0	M1 vs M0	L1 vs L0	M1 vs S0	L1 vs S0	L1 vs M0	S1 vs M0	S1 vs L0	M1 vs L0
Pairwise Margins	0.079	(0.084)	(0.037)	(0.024)	(0.066)	(0.126)	0.019	0.182	0.079

Note: Negative value in parentheses

Appendices

Appendix 1. Description of Variables

Variable Name	Description
Total Sales	Total amount of sales and operating revenue (Unit: Million Baht)
Total Employees	Total number of employees (Unit: person)
Total R&D	Total amount of R&D expenditures of private sector (Unit: Million Baht)
Total Researchers	Total number of researchers counted by Full-time Equivalent method. (Unit: person-year)
Productivity	The ratio of total sales to total employees
R&D intensity	The ratio of total R&D to total sales
log R&D intensity (ln R&D intensity)	The natural logarithm of R&D intensity
Productivity Growth (Growth_Prod)	The difference in natural logarithm of the productivity
M	A dummy variable for firm size where 1 = firm size M and 0 otherwise
L	A dummy variable for firm size where 1 = firm size L and 0 otherwise
Targeted2016	A dummy variable for targeted industries available in 2016 where 1 = targeted industry in 2016 and 0 otherwise

Appendix 2. Hausman test's result

	(Model 1, FE) Growth_prod	(Model 1, RE) Growth_prod	(Model 2, FE) Growth_prod	(Model 2, RE) Growth_prod
ln_R&D intensity 1lag	0.196***	0.077***	0.209***	0.065*
	(0.044)	(0.021)	(0.074)	(0.035)
M*ln R&D intensity 1lag			0.058	0.024
			(0.106)	(0.025)
L*ln R&D intensity1lag			-0.098	0.009
			(0.108)	(0.025)
Targeted2016*ln R&D intensity1lag	0.027	0.040	0.097	0.135*
	(0.046)	(0.038)	(0.099)	(0.077)
M* Targeted2016*ln R&D intensity1lag			-0.167	-0.202**
			(0.125)	(0.100)
L* Targeted2016*ln R&D intensity1lag			-0.034	-0.056
			(0.123)	(0.097)
_cons	1.075***	0.547***	1.031***	0.548***
	(0.200)	(0.103)	(0.210)	(0.113)
Hausman test	Prob>chi2 = 0.0079		Prob>chi2 = 0.0292	
N	440	440	440	440

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

Appendix 3. Test the reasonability to use two-way fixed effects

	(Model 1) Growth_prod	(Model 2) Growth_prod
ln_R&D intensity1 lag	0.133**	0.149**
	(0.056)	(0.072)
M*ln R&D intensity1 lag		0.060
		(0.123)
L*ln R&D intensity1 lag		-0.103
		(0.091)
Targeted2016*ln R&D intensity1 lag	0.004	0.079*
	(0.037)	(0.047)
M* Targeted2016*ln R&D intensity1 lag		-0.164**
		(0.077)
L* Targeted2016*ln R&D intensity1 lag		-0.042
		(0.068)
_cons	-0.135	0.006
	(0.658)	(0.601)
Industry*size fixed effect (js)	Yes	Yes
Year fixed effect (t)	Yes	Yes
Joint Test for 2FEs using "testparm" in STATA		
- industry*size fixed effect	F = 8.16	F = 52.36
	Prob > F = 0.0000	Prob > F = 0.0000
- year fixed effect	F = 8.48	F = 8.38
	Prob > F = 0.0000	Prob > F = 0.0000
N	440	440
R^2	0.289	0.299

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

Appendix 4. Robustness Check

Dependent Variable is Productivity Growth	Whole Sample-Main result[1]		Subsample-Manufacturing sector		Subsample-Services sector		Whole Sample-using different measurement of R&D intensity[2]	
	(Model 1)	(Model 2)	(Model 1)	(Model 2)	(Model 1)	(Model 2)	(Model 1)	(Model 2)
ln_R&D intensity1 lag	0.133**	0.149**	0.108**	0.133	0.197*	0.235*	0.113**	0.148**
	(0.055)	(0.070)	(0.054)	(0.088)	(0.107)	(0.126)	(0.051)	(0.067)
M*ln R&D intensity1 lag		0.060		-0.032		0.082		-0.109
		(0.124)		(0.089)		(0.225)		(0.108)
L*ln R&D intensity1 lag		-0.103		-0.049		-0.185		-0.016
		(0.083)		(0.108)		(0.152)		(0.103)
Targeted2016*ln R&D intensity1 lag	0.004	0.079**	0.011	0.048*	0.066	0.045	0.0003	0.056
	(0.038)	(0.039)	(0.034)	(0.026)	(0.100)	(0.065)	(0.041)	(0.044)
M*Targeted2016*ln R&D intensity1 lag		-0.164**		-0.047		-0.153**		-0.139
		(0.071)		(0.054)		(0.074)		(0.087)
L* Targeted2016*ln R&D intensity1 lag		-0.042		-0.046		0.144		-0.031
		(0.062)		(0.049)		(0.216)		(0.074)
Industry*size fixed effect (js)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect (t)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
_cons	0.779***	0.750***	0.642**	0.613***	1.126**	1.034**	0.684***	0.652**
	(0.245)	(0.242)	(0.243)	(0.228)	(0.470)	(0.433)	(0.229)	(0.260)
N	433	433	264	264	163	163	427	427
R^2	0.248	0.259	0.334	0.336	0.239	0.257	0.233	0.241

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

Note: [1.] The R&D intensity in both models is measured by the ratio of total R&D expenditures to total sales.
[2.] The R&D intensity in both models is measured by the ratio of total of researchers to total employees

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