วารสารเศรษฐศาสตร์ปริทรรศน์ สถาบันบัณฑิตพัฒนบริหารศาสตร์
ปีที่ 9 ฉบับที่ 1 (มกราคม 2558)

Technological Investment of Thai Industries and Government Supports

Vasu Suvanvihok*

Abstract

This study investigates the behavior of Thai industries' R&D and innovation (RDI) activities, the technological investment, using the institutional framework in analyses. Using firm-level data from Thailand's R&D and Innovation activities survey from theIndustrial sector 2009, the results show that most firms' characteristic and business environment variablesare significantly related to the probabilities of carrying out RDI activities. R&Dexpenditures can be explained significantly by total sales, number of R&D staff, external cooperation with business partners and with universities or public research institutes (PRI). Forinnovations, the expenditures are significantlyrelated with more effect than on the R&D,to total sales and the export portion, experiences, and results of former activities. Decisionson effort allocation of firms' R&D and innovation activities are different. Firms tend to carry out R&D onproducts more than on only processes, or carry outboth. But for innovation activities, firms tend to carry out both product and process innovation. Policy implications propose that government should support firms by providing appropriate information, facilitating cooperation both between the public to private sectors and among private firms, providing proper funding mechanisms, and supporting other related technological activities.

Keywords: R&D, Innovation, Institution, Government support, Thailand

*Consultant, Technopreneur Development and Services Department, National Science and Technology Development Agency, 111 Thailand Science Park, Phahonyothin Road, Khlong Luang, Pathum Thani 12120, Thailand: E-mail - osk_107@yahoo.com

วารสารเศรษฐศาสตร์ปริทรรศน์ สถาบันบัณฑิตพัฒนบริหารศาสตร์
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การลงทุนด้านเทคโนโลยีของภาคอุตสาหกรรมไทยและการสนับสนุนของภาครัฐ

วสุ สุวรรณวิหค*

บทคัดย่อ

วัตถุประสงค์ของงานวิจัยนี้เพื่อศึกษาพฤติกรรมในการลงทุนด้านเทคโนโลยีของภาคอุตสาหกรรมไทย ผลการศึกษาพบว่าตัวแปรคุณลักษณะและสถาบันส่วนใหญ่มีนัยสำคัญต่อการตัดสินใจดำเนินกิจกรรมวิจัย พัฒนาและนวัตกรรม ปัจจัยที่มีผลต่อค่าใช้จ่ายด้านวิจัยและพัฒนาได้แก่ ยอดขาย จำนวนพนักงานวิจัย การร่วมมือกับพันธมิตรทางธุรกิจ มหาวิทยาลัยหรือสถาบันวิจัย ส่วนปัจจัยที่มีผลต่อค่าใช้จ่ายในกิจกรรมนวัตกรรมได้แก่ ยอดขาย สัดส่วนการส่งออก ประสบการณ์ และผลดำเนินการในช่วงก่อนหน้าวัตถุประสงค์ของกิจกรรมวิจัยพัฒนาและนวัตกรรมมีความแตกต่างกัน บริษัทมีแนวโน้มจะวิจัยและพัฒนาเฉพาะผลิตภัณฑ์มากกว่าจะพัฒนากระบวนการหรือทำควบคู่กัน แต่สำหรับกิจกรรมนวัตกรรมบริษัทมีแนวโน้มจะพัฒนาทั้งผลิตภัณฑ์และกระบวนการควบคู่กันข้อเสนอแนะเชิงนโยบายในการสนับสนุนกิจกรรมวิจัย พัฒนาและนวัตกรรมได้แก่ จัดหาข้อมูลข่าวสารอย่างเหมาะสม สนับสนุนให้มีความร่วมมือระหว่างทั้งภาครัฐและภาคเอกชน จัดกลไกการให้ทุนอุดหนุนและสนับสนุนกิจกรรมที่เกี่ยวข้องในด้านเทคโนโลยี

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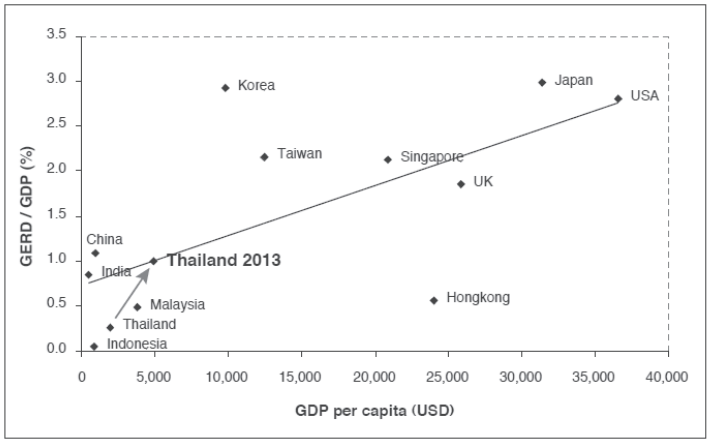
*ที่ปรึกษาฝ่ายบริการพัฒนาผู้ประกอบการทางเทคโนโลยี สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ อุทยานวิทยาศาสตร์ 111 ประเทศไทย ถนนพหลโยธินตำบลคลองหนึ่ง อำเภอคลองหลวง จังหวัดปทุมธานี 12120: Email - osk_107@yahoo.com

1. Introduction

This study focuses on the Technological Investment or herein referred to as Research and Development[14], and Innovation[15] (RDI) activities, the role of business environment and institutional attributes of decisionson the activitiesof the Thai industrial sector. The problem was thatR&D activities inThailand are considered low. The R&D expenditure of Thailand, even increasing over time, averaged only 0.1 percent of GDP in the period from 1999 to 2008 (STI, 2009: 80). As shown in Figure 1, the ratio of Thailand's Gross Expenditure on Research and Development and Gross Domestic Product (GERD/GDP) is considered very low compared to thosecountries whose ratiosare located abovethe trend line, and used R&D as a tool for encouraging economic growth (Ministry of Science and Technology, 2004:14). We can see that most countries having a higher GDP have higher values of GERD/GDP.

Figure 1: Relation of GERD/GDP and GDP per Capita between 2002-2003



Source: Ministry of Science and Technology (2004: 14)

Thailand R&D were done by government, universities and state enterprises (61 percent), and 38 percent done by private sector or industrial firms (NRCT, 2010:3). This figure is however contrary to those of developed countries, where the activities are mostly done byprivate sector.Actually industrial firms are economic agents havingas a main objective the maximizing of profits. They always consider ways to improve their products or services for

[14] "Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications", Frascati Manual (OECD, 2002: 30)

"If the primary objective is to make further technical improvements on the product or process, then the work comes within the definition of R&D. If, on the other hand, the product, process or approach is substantially set and the primary objective is to develop markets, to do pre-production planning or to get a production or control system working smoothly, the work is no longer R&D" (OECD, 2002: 42). We could categorize the latter case as innovation activities.

[15] "Technological product and process (TPP) innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation), Oslo Manual (OECD, 1997: 31).

higher added value and many of them know that one way to do so is to improve their technology for product or service innovation. Institutional factors of the National Innovation System (NIS)[16], or we can simply call the technological environment of firms, are important factors in making decisions on the budget allocation between their normal operations and technological investment or R&D activities. As Patarapong Intarakamnerd, et al. (2002: 1455) proposed that for the studies of NIS in countries less successful in technological catching-up like Thailand, it should focus not only on how innovation related activities start and improve over time, but alsoon factors contributing to stagnancy and those contributing to the long-running perpetuation of weak and fragmented NIS systems. Then, the studies related to the factors encouraging firms to decide to carry out R&D activities are necessary inputs for government to improve its policies and mechanisms that motivate and facilitate firms to initiate and run their R&D projects efficiently.

There were some studies related to firms' R&D activities in Thailand, such as Peera Charoenporn (2005a: 89-122, 2005b: 15-34) and Direk Patmasiriwat (2010: 76 - 106). The studies are investigations of the firms' decisions to carry out R&D activities as well as the R&D spending. Since the former works were rarely used and there are recommendation to explore the issues with, or related to institutional frameworks (Patarapong Intarakamnerd et al., 2002: 1455, Peera Charoenporn, 2005a: 117), which could explain more about thebehavior of firms, this study will apply an institutional framework to help in analyzing Thai industrial firms' decision to pursueR&D and innovation activities.

This study aims to investigate the behavior of Thai industries' R&D and innovation activities so that it could suggest to the related parties how to understand and provide proper responses to encourage overall competencies. The specific objectives of the study are as follows:

1. To investigate and develop conceptual models, using new institutional economic approaches, explaining firms' decisions on technical improvement or R&D activities.
2. To examine the factors contributing to Thai industries' decision regardingR&D activities.
3. To examine the impact of institutional factors onThai industries' expenditures for R&D activities.
4. To recommend the government support the policyfor R&D and innovation activities of Thai industries.

The next section reviews the related literature of R&D and innovations, and institutional frameworks. Theoretical models explaining firm's decisions related to technological investment are presented in section 3. Section 4 describes methodologies employed and data description. Section 5 discusses the empirical results, the effect of socioeconomic and institutional factors on the probability of carrying out R&D or innovation activities and related decisions. Conclusion of the study and discussion are presented in section 6.

2. Literature Reviews

[16]The NIS is the interactive system of existing institutions, private and public firms (either large or small), universities and government agencies, aiming at the production of science and technology (S&T) within national borders. Interaction among these units may be technical, commercial, legal, social and financial as much as the goal of the interaction may be development, protection, financing or regulation of new S&T (Niosi et al., 1993 quoted in Patarapong Intarakamnerd et al., 2002: 1446)

Two interrelated issues are reviewed in this sectionto develop the the oretical framework for analyses, the technological development including R&D and innovation activities of industrial firms, and the institutional economics approach in analyses.

The oretically, Amir (2000) described extensive comparison of the well-known R&D models of d'Aspremont-Jacquemin (AJ) and Kamien-Muller-Zang (KMZ). He analyzed the two models of R&D decisions, and summarized that the KMZ model is probably more appropriate as a model for strategic R&D with spillovers and can apply broadly to a generic industry, on the other hand, the AJ model may be adequate for certain industries with R&D processes.

The group of works containing the largest portion of literature, is about the factors that influence the R&D activities. Some of which are reviewed here; those are Bae and Noh (2001), Zedtwitz and Gassmann (2002), Czarnitzki and Licht (2005) and Griffiths and Webster (2010). The factors found, from their studies, to have an effect on the decision for R&D activities are the degree of a firm's multinationality, differences in R&D internationalization, distribution of public R&D subsidies, past profits, the rate of growth of the industry, and the level of R&D activity over the firm's industry

Another group of studies are about the impact of R&D. Two examples of those are studied by Falk (2007) andCoccia (2012), they analyzed the association between R&D expenditure and the macro economic variables to see the impact.

There were some studies related to firms' R&D activities in Thailand. Peera Charoenporn (2005a: 89-122 and 2005b: 15-34) investigated the determinants of the firms' decision to carry out R&D and innovation of firms, and found that competitive market conditions, the structure of industrial production, firm size, the availability of physical resources, human resources and technology resources influenced firms' decisions to carry out R&D activities, and that contextual variables, business environment conditions, firm-internal competencies, strategic variables, and external communications are the determinants of success in innovation activities. Healso recommended that future studies should include evolutionary economics and a transaction cost economic perspective in the analytical framework. Another study was done by Direk Patmasiriwat (2010: 76 - 106). He investigated R&D spending of industrial enterprises in Thailand between 2001 and 2006, and found that only 8.4 percent of industrial enterprises had R&D budgets, the sum of R&D budgets over five years amounted to 16,316 million baht but the figure showed that R&D spending over time was increasing, and the research intensities varied significantly depending on the industry's ISIC classification code.

From this pointto the end of the section, New Institutional Economics (NIE) literatures and some applications are reviewed. As stated in many literatures, the NIE is one of the major developments of economic theory in the past few decades. Matthews (1986: 903) stated that the economics of institutions has become one of the liveliest areas in our discipline. It has brought us more closely in touch with a number of other disciplines within the social sciences.

The reasons why NIE has grown are the limitations of mainstream neoclassical economics, of which assumptions are little concerned, such as frictionless and zero transaction costs, perfect individual rationality, institutions treated as exogenous, and not concerned with governance,

property rights, and other necessities for controlling human behavior (Coase, 1998:72 and Somboon Siriprachai, 2004:82-83). The other criticized proposition of neoclassical economics was that firms are considered as a production function (Williamson, 1981:548). Marxian and Institutionalist school, both, criticized neoclassical economics for its lack of attention to institutions and hence to the important constraints(Nabli and Nugent, 1989:1336).

Some related studies using the institutional economics approach were done by Bardhan (1989) and Nabli and Nugent (1989), they applied the concept to analysesof economic developmentand growth.Anotherappliedto R&D activities is done by Robertson and Gatignon (1998). They assess the factors explaining whether firms will engage in technological alliances or utilize the more traditional mode of internal R&D, up on which the hypotheses stem from a transaction cost conceptualization. They found that firms pursue technologi calalliances are likely to have less commitment to product category-specific assets, face higher technological uncertainty, to be more capable at measuring innovation performance, to have more successful technological alliance experiences, and to compete in lower growth product categories.

As the relevant academic literatures reviewed above, the study aims to impose the institutional factors, associated with socioeconomic and business rational, to the theoretical framework, with the main-stream economic conceptual, for analyses of firms' related decisions on carry out R&D or innovation activities

3. Theoretical Framework

Technological investment is one of the strategic decisions of firms under the umbrella of their main objective, profit maximization. Such investment increases firms' technology level, by both planned and unplanned discovery, and affects the revenue or profit by making new or improved processes for more efficiency, introducing new or higher performance of products and services solving their target customers' problems. In this section, the conceptual model of firms' decision on conducting R&D or technological investment to increase their technology level and the related decisions, are introduced.

3.1 Firms' Decision on Technological Investment.

The model developed in the study is a modification of a simplified version of a new growth theory developed by Romer (2006: 101-102). He internalized the technology level by introducing research and development, as a production of new technologies, in the original Solow growth model which take this as given. Then, the model of resources allocation between conventional goods production and R&D was constructed.

The market here is considered to be an imperfectly competitive one, with a certain degree of competition varied by industries, so that prices can be different among the firms in the market. The competitive market can be considered as a case in this model, where the price is set to a constant, depending on demand and supply only, and that firms' product differentiation is not affected. Firms' objective is to maximize profit, π_t, over the operation period t. The profit of firms comes from its revenue, which is the product of price, P_t, and number of goods produced, Q_t, minus the cost of capital and labors, C_t. The model can expressed primarily as follows:

$$\underset{a_{Kt},a_{Lt}}{Max}\ \pi_t = P_t[m_t, q_t(g_t; A_t)].Q_t[(1-a_{Kt})K_t, (1-a_{Lt})L_t; A_t] - r_tK_t - w_tL_t \qquad (1)$$

with the budget constraint,

$$K_t = \overline{K}_t \qquad (2)$$

$$L_t = \overline{L}_t \qquad (3)$$

The decision variables a_{Kt} and a_{Lt} represents the portion of firms' capital and labor used for R&D activities or technological investment. Firms' decision, then, is to allocate their resources for production, $(1-a_{Kt})K_t$ and $(1-a_{Lt})L_t$, and the rest for the R&D activities to maximize expected profit over the considered period. The more usage of resources in R&D activities, the less for production. But, it is expected to increase the technology level that makes for higher efficiency and revenue in return.

The price, P_t, depends on the market demand and supply, and firms' product or differentiation, m_t, and the comparative quality or how differentiated of firms' product or services value perceived by customers, q_t, which is related to its general business management, g_t, and technology level, A_t.The production function $Q_t(\cdot)$ indicates that firms use two main resources in producing goods or services to the customers, these are capital, K_t, labor, L_t, and with technology level A_t. The change of technology level is a production function of new technologies or advancement, which is a function of labor, capital used in R&D activities and the level of technology in that period, $R_t(a_{Kt}K_t, a_{Lt}L_t, A_t)$.The tangible resources $\overline{K}_t$ and $\overline{L}_t$ are given as planned over the period, and cost of capital and labor at period *t* are r_t and w_t respectively. In this study, it is not specific whether technology is capital-or labor-augmenting, firms can under take both labor- and capital augmenting technological impro vements.

The firms' decision for each period *t*, will depend on the business or industry environment that reflect the price, the level of resources and technology, goods or service production function, and the capability of firms in developing their technologies. Theoretically, holding other conditions unchanged, firms will decide whether to invest in R&D or not by considering marginal profit through R&D investment (both in perspective (a_{Kt}) of capital and labor (a_{Lt})). Virtually, firms will decide to invest in R&D in cases where $\frac{\partial \pi_t}{\partial a_{Kt}} \geq 0$ and $\frac{\partial \pi_t}{\partial a_{Lt}} \geq 0$.

Firms will decide to allocate their capital and labor resources to R&D or technological investment activities for higher profit, but they will not do so without having enough confident on such conditions. The allocated resources affect the changes in technology level, ∂A_t, which directly contribute to firms' profit, but they cause the firms' resources for their production or services reduced and may lead to the firms losses in total. Within the budget constraint, the allocations can be continued until the marginal profit from the allocation is

zero. Firms can gradually increase their technology level and accumulate retained profit each year for more capital in later year investment.

As the profit or revenue is the productof $P_t(\cdot)$ and $Q_t(\cdot)$, then we get:

$$\frac{\partial \pi_t}{\partial a_{Kt}} = [P_t \cdot \frac{\partial Q_t}{\partial A_t} + Q_t \cdot \frac{\partial P_t}{\partial A_t}] \cdot \frac{\partial A_t}{\partial a_{Kt}} \tag{4.1}$$

$$\frac{\partial \pi_t}{\partial a_{Lt}} = [P_t \cdot \frac{\partial Q_t}{\partial A_t} + Q_t \cdot \frac{\partial P_t}{\partial A_t}] \cdot \frac{\partial A_t}{\partial a_{Lt}} \tag{4.2}$$

Equations (6.1) and (6.2) explain how allocated resources affect the firms' profit, via higher technology level, A_t, which contributed to both the price P_t through the function $q_t(g_t; A_t)$ that increase with the technology level,and the quantity Q_t, of production. The higher technology level can make the products or services of firms more value differentiated for their customer such as higher quality, reliability, safety, more function of usages. This canenable firms to sell their products or services at higher prices. Technology level also reflects the efficiency of production, the higher level of which could make firms produce more products with the same resources, and making more revenue in turn.

The results of the optimization, which is considered as business or fundamental rational, can be written as follow:

$$a_{Kt} = B_{Kt}(P_t, K_t, L_t, A_t) \tag{5.1}$$

$$a_{Lt} = B_{Lt}(P_t, K_t, L_t, A_t) \tag{5.2}$$

In this study, we use firms socioeconomic variables and some of business conditions or environment, referred as contextual variables (Peera Charoenporn, 2005b: 15-17), which would influence the decision of technological investment, as suggested in certain studies, those are industry group, ownership status, number of total employees (Wolfe, 1994), ownership status (Bae and Noh, 2001), experiences of firms in business (Nejad, 1997, Czarnitzki and Licht, 2005), total sales and export portions (Calvert et. al, 1996), categories of manufacturing (Peera Charoenporn, 2005b: 17), and the other relevant technological activities.

3.2 Institutional Attributes of Technological Investment

In making a decision on R&D or technological investment, firms would consider institutional factors beside the fundamental business aspect. These include transaction and information costs in searching and acquiring new technologies, culture of firms or industry in adapting new technology, supporting or facilitated by government, competition within their industries, and cooperation among its related company or industrial association. For this reason, we could impose the institutional attributes to the solution equations (6) as follows

$$a_{Kt} = D_{Kt}[P_t, K_t, L_t, A_t, I_t(i_{1t}, ..., i_{nt})] \tag{6.1}$$

$$a_{Lt} = D_{Lt}[P_t, K_t, L_t, A_t, I_t(i_{1t}, ..., i_{nt})] \tag{6.2}$$

where $I_t(i_{1t},...,i_{nt})$ is the function of the institutional effects on the decision of a firm in allocating its resources for R&D or technological investment, and the institutional attributes may have positive or negative to the decision outcomes.

In the study, some proxies that reflect firms' institutionalization of R&D or innovation activities, including the government roles, to be explored are sources of fund used for investment, number of R&D staff, sources of information, cooperation with external parties, consequence of recent results (including sale of new products), limitations in carrying out, as referred by former studies (Czarnitzki and Licht (2005), Robertson and Gatignon (1998), Amir (2000). These variables will reflect the institutionalization of firm in carringout innovation activities. The limitations, such as lack of funds, human capital, information and others external limitations, would affect the decision on technological investment. Firms which lack of human capital may contract out other parties, such as research companies or public research institutes or universities to carry out their purposes, but in general we expect that the limitation would discourage firms in R&D or innovation activities.

Then, firms' resources allocated to R&D activities, or technological investment, can be calculated as a portion of their available capital and labor, $a_{Kt}K_t$ and $a_{Lt}L_t$, and the total costor expenditures will be $r_t a_{Kt} K_t + w_t a_{Lt} L_t$.

3.3 Decision on Products and Process Improvements

Firms also have to decide to focus on the products, developing a new one or having the old one improved, or the process of production, having more efficiency or lower cost. The portion of each category basically decided by the rational that which part of development contributes more tohigher revenue or profits in the next period. We can use terms in equation (6.1) and (6.2), those are terms $P_t \cdot \frac{\partial Q_t}{\partial A_t}$ which represents the change in revenue or profit affected by more quantity produced resulted from R&D in process improvement, and term $Q_t \cdot \frac{\partial P_t}{\partial A_t}$ which represents such change affected by higher price resulted from R&D in new products or services. Term $\frac{\partial Q_t}{\partial A_t}$ represents the effect of technological change to the quantities of goods or services produced, given the tangible resources unchanged, or we can say it is the efficiency improved by technological change. Term $\frac{\partial P_t}{\partial A_t}$ represents the effect of technological change to the price of products or services sold. Since $\frac{\partial P_t}{\partial A_t} = \frac{\partial P_t}{\partial q_t} \cdot \frac{\partial q_t}{\partial A_t}$, we can explain this as the technological changes affect the price through the value perceived by customer, q_t, which is directly related to the price at which firms can sell. Firms would focus on the product or service development when the condition is as follows,

$$P_t \cdot \frac{\partial Q_t}{\partial A_t} < Q_t \cdot \frac{\partial P_t}{\partial A_t} \tag{7.1}$$

and will focus on the process improvement when the condition is as follows,

$$P_t \cdot \frac{\partial Q_t}{\partial A_t} > Q_t \cdot \frac{\partial P_t}{\partial A_t} \tag{7.2}$$

However, in practice, firms can combine two portions when making decisions and also, can plan to improve the level of product quality or the process efficiency over successive years within the operation period.

From the above conditions, and to maximize firms' profit over the operation period, firms will decided to allocated there resources and select the proper allocation of development efforts, $a_{Kt}^{allot_t}$ and $a_{Lt}^{allot_t}$, depending on the economic rational and institutional environment, which can be written as:

$$a_{Kt}^{allot_t} = D_{Kt}^{allot_t}[P_t, Q_t, A_t, \frac{\partial Q_t}{\partial A_t}, \frac{\partial P_t}{\partial A_t}, I_t(i_{1t}, ..., i_{nt})] \tag{8.1}$$

$$a_{Lt}^{allot_t} = D_{Lt}^{allot_t}[P_t, Q_t, A_t, \frac{\partial Q_t}{\partial A_t}, \frac{\partial P_t}{\partial A_t}, I_t(i_{1t}, ..., i_{nt})] \tag{8.2}$$

Where *allot* $_t$represents the allocation of firms' technology development efforts selected in period *t*, whether to do only process, only product, or both process and product development.

4. Empirical Estimations.

The empirical studie saim to explore the factors affecting the firms' decision to conduct technological investment, R&D and innovation activities. Related decisions in carrying out such activities, these are the amount of expenditures and effort allocation of investment, are to be included in the study.

4.1. Model Specification.

Logistic regression is introduced for testinghypotheses about the factor affecting firms' decision on conducting R&D or innovation activities. Referred to the results summarized at the end of section 3.2 that firms decide to allocated resources to R&D activities with the amount of $r_t a_{Kt} K_t + w_t a_{Lt} L_t$, where a_{Kt} and a_{Lt} are described with equation 6.1 – 6.2, we adapt for analyses in case that firms decide to conduct R&D activities when a_{Kt} or a_{Lt} is positive and decide not to do when both of them are zero, where there is no resources allocated. Then, the outcome whether firms decide to do, or not to do, R&D or innovation activities are considered as a binary variable. In the basic logit model, the dependent or binary outcome variable, y, will be 1 if firms decided to carryout R&D or innovation activities, with probability, p, and be 0 if firms decided not to carry out R&D or innovation activities, with probability (1 - p). The probability mass function for the observed outcome, y, is $p^y(1-p)^{1-y}$, with $E(y) = p$, and $Var(y) = p(1-p)$.A regression model is formed by parameterizing p to depend on an index function of $X'\beta$, where X is a K x 1

regressors vector and β is a vector of unknown parameters (Cameron and Trivedi, 2009: 446). The Logit model and variables are defined as per the following,

$$P_i \equiv \Pr(y_i = 1 \mid x) = F(X_i'\beta) = \frac{e^{X'\beta_i}}{(1+e^{X'\beta})}, \qquad (9)$$

The study will test the hypothesis with another model,of which the alternative distribution for the disturbances to the normal or logistic distribution. The estimator called the scobit estimator, or "skewed-logit", allowing for a skewed response curve, was introduced by Nagler (1994). The model, relaxing assumption that individuals are with an initial probability of .5 of choosing either of two dichotomous alternatives, 0 or 1, and shown to be appropriate where individuals with any initial probability of choosing either of two alternatives are most sensitive to changes in independent variables (Nagler, 1994: 230). Cumulative Distribution for Scobit is shown in Figure 4.1, the model will be the same as another logit model when α, measure of skewness, is equal to one. By adding a parameter to the definition of the distribution, we may attempt to describe a set of distributions with the above criteria (Nagler, 1994: 234).The scobit or skewed logit model can be written here as,

$$P_i \equiv \Pr(y_i = 1 \mid x) = F(X_i'\beta, \alpha) = (\frac{e^{X'\beta_i}}{1+e^{X'\beta}})^{\alpha}, \qquad (10)$$

List of variables used in this and following models are described in Appendix A. The estimation for the binary model will be done by the maximum likelihood estimator (MLE) method. As indicated in Cameron and Trivedi (2009: 447), for a sample of N independent observations, the MLE, $\hat{\beta}$, maximizes the associated log-likelihood function

$$Q(\beta) = \sum_{i=1}^{N} [y_i \ln F(X_i'\beta) + (1-y_i)\ln\{1-F(X_i'\beta)\}], \qquad (11)$$

The MLE is obtained by iterative methods and asymptotically normally distributed.

For estimating firms' expenditures in R&D and innovation activities, referred to the the oretical summarized in section 3.2 that the cost or expenditure of the activities is $r_t a_{Kt} K_t + w_t a_{Lt} L_t$, where a_{Kt} and a_{Lt} are described with the equation 6.1 – 6.2, we use linear instrumental-variables or IV regression model, which provide a solution for that we have both exogenous and endogenous independent variables in the model. The independent endogenous variable mentioned is firms' revenue which is influenced directly by the main resources of a company, labor, which also is the important part of dependent variables R&D or innovation activities. The model called a structural equation can be written as

$$y_i = X_i'\beta + u_i \ , \qquad (12)$$

where the regressors vector $X_i' = [y_{2i}' \quad X_{1i}']$ consists of both endogenous and exogenous variables. By combining instruments for these variables, then we get the vector of IV, $z_i' = [X_{1i}' \quad X_{2i}']$, where X_1 serves as the instrument for itself and X_2 is the instrument for

y_2 and the instruments z satisfy the conditional moment restriction, $E(u_i \mid z_i) = 0$, (Cameron and Trivedi, 2009: 173 - 174).

The samples used for estimation in this and the next R&D or innovations related parts, are only firms those carried out R&D and innovation activities in Thailand, in 2008, and so, variables representing institution of firms' activities are included in the estimation models, those are the limitations, information sources, funding sources and external coordination in carrying out the activities. Variables that reflect government support here are included in the institutional ones, here we refer to the universities and public research institutes as the government agents supporting firms in carrying out their tasks of R&D and innovations.

In the study, the estimator for IV estimation to be used is the two-stage least-squares (2SLS) estimator, which is one the most efficient estimators, when u_i are independent and homoskedastic. The 2SLS estimator can be written as

$$\hat{\beta}_{2SLS} = \{X'Z(Z'Z)^{-1}Z'X\}^{-1}X'Z(Z'Z)^{-1}Z'y, \qquad (13)$$

For testing the hypothesis about the factors affecting firms' decision on allocation efforts of R&D and innovation activities, we referred to the the oretical models described by equations 8.1 – 8.2 in section 3.3, with some modifications adapting for empirical analyses. We use the unordered multinomial logit (MNL) model introduced by McFadden (1973), a widely used choice model due to its simple mathematical structure and ease of estimation for regressors specific case. In the MNL here, outcome y_i is one of alternatives, among m choices, that firms choose or decide. The model specified probability that the outcome for individual i is alternative j, conditional on the regressors X_i, is

$$P_{ij} \equiv \Pr(y_i = j \mid X_i) = F_j(X_i'\beta) = \frac{e^{X_i'\beta_i}}{\sum_{l=1}^{m} e^{X_i'\beta_l}}, \quad j = 1,...,m, \quad i = 1,...,N \qquad (14)$$

where X_i are case-specific regressors. Only m - 1 of probability can be freely specified because probabilities sum to one. The model ensures that $0 < p_{ij} < 1$ and $\sum_{j=1}^{m} p_{ij} = 1$. To ensure model identification, we set β_j to zero for one the category, called the base category, and coefficients are interpreted with respect to that category (Cameron and Trivedi, 2009: 484, and Greene, 2009: 721).

The estimation for MNLisalso by maximum likelihood (ML). The density for the ith individual is written as

$$f(y_i) = p_{i1}^{yi1} \times ... \times p_{im}^{yim} = \prod_{j=1}^{m} p_{ij}^{yij}, \qquad (15)$$

where $y_{i1},...,y_{im}$ are m indicator variables with $y_{ij} = 1$ if $y_i = j$ and otherwise $y_{ij} = 0$. For each individual, one of $y_1,...,y_{im}$ will be non-zero. As indicated in Cameron and Trivedi

(2009: 447) and Greene (2009: 721), for a sample of N independent observations, the MLE, $\hat{\beta}$, maximizes the associated log-likelihood function

$$\ln L(\beta) = \sum_{i=1}^{N}\sum_{j=1}^{m} y_{ij} \ln F_j(X_i'\beta), \qquad (16)$$

The hypotheses to be tested, using MNL, are factors explaining the firms' decision to choose alternative efforts of R&D or innovation activities, whether to do R&D or innovate only in process[17], or only product[18], or both process and product[19].

4.2. Data

The study uses the firm-level data from Thailand R&D and Innovation activities survey in Industrial sector 2009, carried out by the National Science Technology and Innovation Policy Office (STI, 2009). The survey, using standard definitions of the R&D activities referring to Frascati Manual (OECD, 2002) and Innovation activities referring to Oslo Manual (OECD, 1997), had statistically sampling selected a total of 8,174 firms from 27,022 firms of 23 manufacturing sectors and 6 services sectors, whose revenues were greater than 12 million Baht in 2008 (STI, 2009: 11- 12). Of the 8,174 sampled, a total of 3,230 completed questionnaires or approximately 40% are used for analyses. The list of variables description is attached in Appendix A.

A summary of sample profiles are presented here. Of the total 3,230 samples from different industries, we categorize, by ISIC code (International Standard Industrial Classification of All Economic Activities), into 5 groups,ISIC group 1–3 consist of a total of 2,613 firms from manufacturing industries and, ISIC group 6-7 consist of 617 firms fromthe services industries. Most of the samples or a total of 2,218 firms are wholly locally owned companies, where 425 are wholly foreign-owned and the rest of the 587companies are joint-ventures between local and foreign share holders. The overall average experiences of firms, years from establishment, are around 17 years. The highest value of 18.50 years is the firms in ISIC group no. 6 and the lowest value of 12.37 years is of the firms in ISIC group no.7.

The average of firms' total employees is 429 persons. The highest number is of firms in ISIC group no.6, with the value of 1,308 persons and the lowest are of firms in ISIC group no.2, with the value of 275 persons. The average sales of sample firms are 2,558 million THB. The highest value of 5,003 million THB is of firms in ISIC group no.6 and the lowest value of 278 million THB of firms in ISIC group no.7. We notice that the sales amount of firms is not a normal distribution.

[17] In the study, firms carried out "R&D in process" are those distributed more than 60% of R&D expenditure to improve existing or develop new working process. Firms which carried out "process innovation" are those which introduced new or significantly improved process; such as methods of manufacturing, logistics, delivery, or distribution methods, or supporting activities of processes e.g. maintenance systems, operations for purchasing, accounting or computing.

[18] In the study, firms which carried out "R&D in product" are those which distributed more than 60 percent of R&D expenditure to improve existing or to develop new product. Firms carried out "product innovation" are those which introduced new or significantly improved their products.

[19] In the study, firms which carried out "R&D in process and process" are those which distributed more than 40 percent of R&D expenditure for each alternative. Firms which carried out "process and product innovation" are those which innovated both process and product.

In a summary of firms which carried out R&D (either in Thailand or foreign) or innovation activities (in Thailand) (RDI) in year 2008, we have a total of 707 firms or 22 percent of samples pursued such activities. Firms in manufacturing industries (ISIC group no.1-3), averaged 23-29 percent, carried out the activities more than those in the service industries (ISIC group no.6 -7), averaged 11-14 percent. And when categorized by owner status, the wholly foreign-owned companies, averaged 41 percent, carried out RDI activities more than those of joint-venture, averaged 29-37 percent, and those of wholly locally owned companies, averaged 15 percent.

5. Results

A summary of the estimated results of related firms' decisions, the expenditures and allocation efforts of such activities are described here. Likewise R&D activities, studies of innovation activities were carried out but we skipped discussion in detail, the empirical results of innovation activities are presented in Appendix B.

Table 1 reports the estimates of the firms' decision to carry out R&D in Thailand in the year 2008, using the scobit model as equation (15). The coefficients of the model are exponentiated so that we can interpret them as oddsratios, which are easier for interpretation. The odds ratios indicate how one unit change of each independent variable would affect, increase or decrease by a certain factor, the odds that the outcome variable of being "1" versus "0", here is that odds of firms which decided to carry out R&D in Thailand (*rdlocal* = 1) versus not to carry out (*rdlocal* = 0).

Variable measuring skewness α ,isto be tested. The likelihood-ratio test at the bottom of the table, rejects H_a: $\alpha = 1$, indicates that the model is significantly, at 1%, different from a normal logit model. The variables *total_sale (in log)*and*wholly foreign-owned*, significance at 1%, *techact* and*1-50% locally owned,* significant at 5%, affect the odds of firms decided to carry out R&D versus not to carry out. Holding other variables at a fixed value, odds ratio of variable *total_sale (in log)* indicates that a 1% increase in sale increases the odds of firms' deciding to carry out R&D (versus not to carry out) increased by factor of 1.48. Having other technological activities in Thailand (*techact* = 1), the odds increase by a factor of 5.74 or 474% higher.

Five other variables which significantly increases the odds, but with lower effect or less than 10%, are *employee*, *experience*, *salese,sodm* and,*sobm*. The results can be interpreted as per the following, holding other variables at a fixed value, one unit change inthe total number of employees, experiences of firms, export portion of firms' revenue, portions of sales to parent company, sales as ODM, and sales OBM, increase the odds of firms' deciding to carry out R&D (versus not to carry out) by factors of 1.0006, 1.0902, 1.0094, 1.0155 and 1.0196 respectively.

The other variables significantly, but decreasingly, affecting the odds are two firms with group ownership status of 1-50% locally owned and wholly foreign-owned. Holding other variables with a fixed value, odds of firms' with ownership status of 1-50 percent locally owned and wholly foreign-owned decided to carry out R&D (versus not to carry out) decrease from those of firms with wholly locally-owned (the reference group) by factors of 0.25and 0.24, or 75% and 76% lower, respectively.

The estimated results of firms' expenditure in R&D activities are presented in Table 2. The percentage difference of R&D expenditures among the firms can be significantly explained by four variables, those are *total_sale (in log)*, *rdstaff*, *exco1* and*exco2*. We can interpret that a percentage difference of firms' total sales resulted in a 34 percent difference of R&D expenditures. The expenditures increase by 2 percent when firms acquire one more R&D staff, and also increased by 24 percent if firms cooperate intensely with business partners or universities or public research institutes in carrying out R&D or innovation activities. The information sources of firms' R&D or innovations, either from within the company or associate companies, business partners, and universities or public research institutes, do not affect the difference in the R&D expenditures.

Table 3 reports the estimated coefficients of the firms' decision on the allocation effort (*rdallot*) of carrying out R&D in Thailand in the year 2008, by using multinomial logit model as presented in equation (19). The coefficients of the estimation are exponentiated so that we can interpret them as relative risk ratios, which indicate the factor ratio, for one-unit increase of predictor variable for being a certain outcome versus the base outcome. The outcomes include carrying R&D only process, only product, or both process and product.The decision to carry out R&D only in product (*rd_prod*) is assigned to be the base outcome, since most firms selected this alternative. The likelihood ratio chi-square of 87.33 with a P-value less than 0.001 indicates that model as a whole fits significantly better than an empty model.

Five predictors which significantly affect the odds of firms deciding to carry out only R&D in process (*rd_process*) versus only R&D in product (base outcome) are 3.*isic1*, *sobm*, *info1*,*info2* and *urco*. The relative risk ratio switching from ISIC group no.1 (reference group) to no.3 (*3.isic1*) is 3.74 for carrying only R&D in process versus only in product. The ratios of having their own company or associated (*info1*), business partners (*info2*) as the important sources of information, and having engagement frequently in R&D or innovation activities with universities/public research institutes (*urco*) are 3.51, 2.84 and 0.46 respectively, for carrying only R&D in process versus only in product. For a one-unit increase in portion of OBM sales (*sobm*), the relative risk ratio is 0.98 for carrying only R&D in process versus only in product.

The odds of firms deciding to carry out both R&D in process and product (*rd_product _process*) versus only R&D in product (base outcome) are significantly affected by seven predictors, those are *2.isic1*,*3.isic1*, *4.owner, sobm*, *rdfund1*, *info3* and *exco3.*The relative risk ratio switching from ISIC group no.1 (reference group) to no.2 (*2.isic1*), to no.3 (*3.isic1*), and from wholly locally-owned (reference group) to 1-50% locally owned (*4.owner*) are2.15, 2.92and 0.13 respectively, for carrying both R&D in process and product versus only in product.For a one-unit increase in the portion of OBM sales (*sobm*) and the portion of own funds used in R&D (*rdfund1*), the relative risk ratios are both 0.99 for carrying both types of R&D. The ratios of having universities, other higher educational institutes as important sources of information for R&D (*info3*), and cooperating intensely with institutes other than business partners and universities or public research institutes (*exco*3) are 0.46 and 2.26 respectively, for carrying both types of R&D in process and product versus only in product.

Table 1: Estimation of R&D Activities in Thailand(Skewed Logistic Regression) (N = 2,609)

rdlocal	Odds Ratio	Std. Err.	P-value
isic1			
2 : (201 - 293)	1.1333	0.3819	0.7100
3 : (300 - 372)	0.5946	0.2259	0.1710
Owner			
71-99% locally owned	2.4968	1.8423	0.2150
51-70% locally owned	1.9978	1.1411	0.2260
1-50% locally owned	0.2518**	0.1438	0.0160
Wholly foreign-owned	0.2368***	0.1163	0.0030
employee	1.0006*	0.0003	0.0650
techact	5.7386**	3.8955	0.0100
experience	1.0902***	0.0258	0.0000
total_sale (in log)	1.4842***	0.1781	0.0010
salese	1.0094**	0.0043	0.0280
sparent	1.013	0.0084	0.1200
soem	0.9888	0.0075	0.1390
sodm	1.0155*	0.0083	0.0600
sobm	1.0196**	0.0084	0.0190
Constant	0.0001***	0.0001	0.0000
/lnalpha	-2.3684***	0.3770	0.0000
alpha	0.0936	0.0353	-

Notes : 1.) * significant at 10% ; ** significant at 5% ; ***significant at 1%

Table 2: Estimation of R&D expenditures (Instrumental variables (2SLS) regression)(N=369)

lnrdexp	Coefficient	t-ratio	P-value
total sale (in log)	0.3450***	3.9300	0.0000
experience	-0.0032	-0.6300	0.5300
salese	-0.0029	-1.4800	0.1390
rdfund1	-0.0055	-1.6300	0.1040
rdstaff	0.0212***	6.4500	0.0000
info1	0.0383	0.2900	0.7710
info2	-0.0686	-0.4300	0.6660
info3	-0.2134	-1.4400	0.1500
info4	1.3728	1.2900	0.1990
exco1	0.2404*	1.6800	0.0940
exco2	0.2462*	1.6600	0.0980
exco3	0.0312	0.2300	0.8170
urco	-0.0462	-0.3300	0.7390
Constant	6.7759***	3.5800	0.0000

Notes : 1.) * significant at 10% ; ** significant at 5% ; ***significant at 1%

Table 3: Estimation of Firms' allocation efforts of R&D activities (Multinomial logistic regression) (N = 331)

	Rdallot	RRR	Std. error	P-Value
rd_process				
	isic1			
	2 : (201 - 293)	1.0500	0.5437	0.9250
	3 : (300 - 372)	3.7366**	2.0783	0.0180
	owner			
	71-99% locally owned	1.0142	0.8679	0.9870
	51-70% locally owned	1.2234	0.7907	0.7550
	1-50% locally owned	0.6351	0.5224	0.5810
	Wholly foreign-owned	0.6045	0.4204	0.4690
	employee	1.0000	0.0002	0.9520
	techact	833,610	685,000,000	0.9870
	experience	1.0211	0.0151	0.1580
	sobm	0.9789***	0.01	0.0000
	total_sale (in log)	1.00	0.14	0.9920
	salese	1.00	0.01	0.4960
	rdfund1	0.9875	0.0100	0.2150
	rdstaff	0.9960	0.0104	0.7010
	info1	3.5144**	1.8441	0.0170
	info2	2.8413*	1.7510	0.0900
	info3	0.8932	0.4761	0.8320
	exco1	0.5413	0.2674	0.2140
	exco2	0.6232	0.3587	0.4110
	exco3	0.9963	0.4859	0.9940
	urco	0.4605*	0.2033	0.0790
	_cons	0.0000	0.0004	0.9860
rd_product		(base outcome)		
rd_product_process				
	isic1			
	2 : (201 - 293)	2.1459*	0.8564	0.0560
	3 : (300 - 372)	2.9248**	1.4229	0.0270
	owner			
	71-99% locally owned	0.8744	0.5093	0.8180
	51-70% locally owned	0.9899	0.4904	0.9840
	1-50% locally owned	0.1318**	0.1173	0.0230
	Wholly foreign-owned	0.5647	0.2911	0.2680
	employee	1.0001	0.0001	0.3180
	techact	2.7968	3.1998	0.3690
	experience	0.9803	0.0137	0.1550
	sobm	0.9911**	0.0037	0.0170
	total_sale (in log)	1.0677	0.1085	0.5190
	salese	1.0067	0.0048	0.1580
	rdfund1	0.9858*	0.0079	0.0730
	rdstaff	1.0038	0.0066	0.5650
	info1	1.5069	0.5480	0.2590
	info2	1.3659	0.5892	0.4700
	info3	0.4558*	0.1933	0.0640
	exco1	0.9438	0.3749	0.8840
	exco2	0.7891	0.3263	0.5670
	exco3	2.2622**	0.7883	0.0190
	urco	0.8169	0.2982	0.5800
	Constant	0.0856	0.2009	0.2950

Notes : 1.) * significant at 10% ; ** significant at 5% ; ***significant at 1%

6. Conclusion and Discussions

The study examines three hypotheses according to theoretical models; those are the variables of socioeconomic, business environment and institutional factors which significantly explain the firms' decisions on carrying out R&D and innovation activities, the expenditures andallocation efforts of such activities.

The results show that most of the firms' characteristic and business environment variables; including ownership status, number of employees, experience in business, total sales and categories of sales, are significantly related to the probabilities to carry out R&D or innovation activities. Locally-owned firms tend to carry out R&D and innovation more than foreign majority firms. Firms having higher sales or carrying other technological activities are also highly tentative to carry out such activities.

The expenditures for R&D can be explained significantly by total sales, number of R&D staff, and external cooperation with business partners and universities or public research institutes, all of which are in a positive direction. For innovations activities, the expenditures are significantly related to total sales, export portion, experiences, and results of former activities in recent years.

Decisions on effort allocation of firms' R&D and innovations activities are different. For R&D, firms tend to do product research more than process or carry out both of them. The factors that significantly relate to the firms' decision to carry out process or both product and process are industry group, information from parent and associate companies,information from business partner, and intense cooperation with other institutes. For innovation activities, firmstend to carry out both product and process, except for some industry groups that tend to carry out more on product only. The reason may be they have to commercializequickly, so they have to plan and develop their production or service process to be ready oncethe product development is finished.

In general, the institutional factors can explain some behavior of firms in carrying out R&D or innovation activities as described above, of which some are in the part of government roles. From the evidence, government support that significantly relates todecisions on R&D and innovation activities are information from universities, or public research institutes which affect the allocation effortsof R&D activities, cooperation with universities or public research institutes which affect the expenditure, and frequently engagement with universities or public research institutes which affect the allocation effort of R&D activities.

From the study, there are policy implications which are proposed to be implemented. Firstly, as information is the important factor for firms in making decisions on R&D and innovation activities, government should provide, or make firms to be able to access enough information or proper knowledge for industries, the services or supporting mechanisms of government, and contacts of supporting agentsusing integrated communication to target firms or industries. Events such as public events for intellectual property marketing or R&D fairs should be arranged periodically. This would givemore chances for firms to explore, plan and decide to invest in proper technological development.

Secondly, as the results show that external cooperation influences the decision onR&D and innovation, since cooperation or technology alliances can reduce R&D costs by dropping out redundant activities, sharing knowledgeand enhancing more outcomes effectively,

government must continually support and play a more active role in facilitating the network and cooperation of both public and private,and among private industrial firms.

The co-operation could be contracting or conducting joint research projects or other activities such as hiring academic consultants, technology licensing, using analytical and testing services or other technical infrastructure, training and personnel exchanges, meeting or conference, and even informal personal contacts. Government should also support firms to have more chances for asoft-loan, grantedin a specific field of technology, or having a tax rebate program for R&D and facilitate matching funds for technology investment. The available funds or cost reduction should make firms comfortable in making a decision on their choices of R&D and innovations.

The important thing to be done is matching required technology or development of industrial firms to the researchers of universities or public research institutes. These will be the best answer to research problems for researchers since, if it succeeds, it will be fully used and commercialized in the real economic sectors. The public research institutes should also be enthusiastic to acquire research topics from outside-in or industries (users) oriented approach, instead of just following their interests or having competence without any requests from users. The government must play this important role of promoting and subsidizing the institu tionalization of joint R&D or innovation activities between public and private firms, setting its policy to target the real commercialization outcomes to the research institutes, and having effective control and monitoring procedures.In terms of individual joint R&D project, the government may have to subsidize or realize some loss in knowledge creation, but it will eventually have more benefit to the economy when fully considered in the long run.

Finally, the government should encourage technological activities other than R&D, such as acquisition or adaptation of external technology, reverse engineering, basic and detail design, testing and quality control of products or processes, since they are significantly lead to the firms' decision to carry out more R&D and innovations.

Not with standing, there are some new development by public research institutes in Thailand in cooperation at more concrete levels than in the past. National Research Administration Network (NRAN), consisting of leading public research institutes relating to scientific fields[20], was founded in 2012 according to the national research strategy to bring research outputs to solve problems and increase the competitiveness of the country. The NRAN members work together in national research project management, focusing on the same target issues and thoroughly supporting each other to bring the outputs to commercialization.At present, the five issues they focus onare rice,cassava, rubber, logistic and tourism. This is a good evolution in Thailand R&D society, but it has to be done continually and it will take length of time to see the effectiveness and sustainability of the operation. Related parties must support this for future success, not just be initiated by politics and to fade away in the later.

There are two recommendations for further studies. Firstly, the next phase of study should be done by panel data analyses, since many R&D or innovation activities cannot be finished completely in one year and decisions are more proper to be considered as a dynamic model. It

[20] The group consists of seven related public research institutes; National Research Council of Thailand, The Thailand Research Fund, Agricultural Research Development Agency (Public Organization), Office of the Higher Education Commission, Health Systems Research Institute, National Science Technology and Innovation Policy Office, and National Science and Technology Development Agency.

is also required that data collection and recording are systematic and suitable for such analyses. Secondly, more institutional issues; socioeconomic conditions, political and business environment,specifically to industries or geographic region concerning firms' decision on R&D and innovation activities should be explored to help handle the problems of institutionalization.

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APPENDIX A.

Variables Description

Table A.1 Variables Description

Variables	Description	Obs.	Means	Std.
rdlocal	firms'decisionto carry R&D (dummy variable)	3230	0.1160991	0.3203933
inv	firms'decisionto carryinnovation (dummy variable)	3230	0.1362229	0.3430782
techact	firms carried out other technological activities in Thailand in 2008(dummy variable) *(such as acquisition or adaptation of external technology, reverse engineering, basic design, detail design, testing and quality control)*	3230	0.8668731	0.3397645
info1	important information for R&D are within the company or from parent and associate companies (dummy variable)	707	0.4144272	0.4929716
info2	important information for R&D are from clients, or locally- or foreign-owned suppliers (dummy variable)	707	0.4554455	0.4983635
info3	important information for R&D are from universities, other higher education institutes or public research institutes (dummy variable)	707	0.1683168	0.3744123
exco1	cooperation intensely with "business partners", including customers, buyers, suppliers, or parent or associate company overseas, in R&D or innovation activities (dummy variable)	707	0.4059406	0.4914208
exco2	cooperation intensely with "universities or public research institutes" in R&D or innovation activities (dummy variable)	707	0.1881188	0.3910837
exco3	cooperation intensely with "other institutes" in R&D or innovation activities (dummy variable)	707	0.1838755	0.3876569
urco	engagement frequently in R&D or innovation activities with universities/public research institutes (dummy variable)	707	0.4002829	0.4903025
limf1	"lack of funds" was an important limitation factors for innovation activities (dummy variable)	440	0.4090909	0.4922257
limf2	"lack of human capital" was an important limitation factors for innovation activities (dummy variable)	440	0.4590909	0.4988909
limf3	"lack of information" was an important limitation factors for innovation activities (dummy variable)	440	0.5613636	0.4967851
limf4	"other external difficulties" was an important limitation factors for innovation activities (dummy variable)	440	0.4909091	0.5004864
lnrdexp	log of R&D expenditure (THB)	371	14.92588	1.434033
lninvexp	log of innovation expenditure (THB)	307	15.15484	1.725243
employee	number of firms' total employees (persons)	3229	429.3809	1533.494
experience	experiences of firms measured by years from established (years)	3230	17.03746	10.69363
total_sale (in log)	log of firms' total sales in 2008 (thousand THB)	3230	19.10132	1.965741
salese	export portion of firms' total sales in 2008 (%)	3230	25.30879	35.6069
soem	portion of sales as original equipment manufacturing or OEM (%)	2610	43.63897	45.94782
sodm	portion of sales as own design manufacturing or ODM(%)	2610	13.01226	29.70785
sobm	portion of sales as own brand manufacturing or OBM(%)	2610	27.98123	41.81531
rdfund1	portion of company's own fund used for R&D expenditures (%)	3227	10.79421	30.53398
rdstaff	number of firms' R&D staffs (persons)	3230	1.939628	10.44052
salenew	portion of sales from improved products introduced in 2006 - 2008 (%)	3211	5.639069	19.81895

Table A.2 Variables Description (Category Variables)

Variable	Description	Freq.	Percent
rdallot	alternatives that firms carried out R&D activities choose their	356	100
	1 : only in process	43	12.08
	2 : only product	231	64.89
	3 : both process and product	82	23.03
invallot	alternatives that firms carried out innovation activities choose	440	100
	1 : only in process	77	17.5
	2 : only product	127	28.86
	3 : both process and product	236	53.64
isic1	ISIC group	3,230	100
	1: group of firms with ISIC code 151 - 192	701	21.7
	2 : group of firms with ISIC code 201 - 293	1,215	37.62
	3 : group of firms with ISIC code 300 - 372	697	21.58
	6 : group of firms with ISIC code 641 - 660	141	4.37
	7 : group of firms with ISIC code 721 - 749	476	14.74
owner	Ownership status of firms	3,230	100
	1 : Wholly locally owned	2,218	68.67
	2 : 71-99% locally owned	143	4.43
	3 : 51-70% locally owned	225	6.97
	4 : 1-50% locally owned	219	6.78
	5 : Wholly foreign-owned	425	13.16

APPENDIX B

Empirical Results of Innovation Activities

Table B.1: Estimation of innovation activities in Thailand (Skewed Logistic Regression)

inv	Odds Ratio	Std. Err.	P-value
isic1			
2 : (201 - 293)	1.8876	0.9555	0.2090
3 : (300 - 372)	1.613	0.8116	0.3420
owner			
71-99% locally owned	3.8334	4.2915	0.2300
51-70% locally owned	3.9979	3.8354	0.1490
1-50% locally owned	0.1585*	0.1524	0.0550
Wholly foreign-owned	0.1115***	0.0935	0.0090
employee	1.0009	0.0006	0.1280
techact	26.1863***	30.8463	0.0060
experience	1.0899**	0.0429	0.0290
total_sale (in log)	1.6616**	0.3822	0.0270
salese	1.0118*	0.0066	0.0720
sparent	1.0248*	0.0147	0.0880
soem	0.9828*	0.0099	0.0850
sodm	1.0082	0.0098	0.4000
sobm	1.0176	0.0115	0.1230
_cons	0.0000***	0.0000	0.0060
/lnalpha	-2.7899***	0.5444	0.0000
Alpha	0.0614	0.0334	
Likelihood-ratio test of alpha=1: chi2(1) = 17.60 Prob > chi2 = 0.0000			
Number of obs	2609		
Zero outcomes	2199		
Non-zero outcomes	410		
Log likelihood	-977.9375		

Table B.2 Estimation of Expenditures of Innovation Activities (Instrumental variables (2SLS) regression)

lninvexp	Coefficient	t-ratio	P-value
total sale (in log)	0.5593***	5.9100	0.0000
experience	-0.0142*	-1.6900	0.0910
salese	-0.007**	-2.4800	0.0140
salenew	0.0003	0.1300	0.8960
invreslt	-0.9636**	-2.2000	0.0280
limf1	0.0673	0.3300	0.7390
limf2	0.2785	1.3000	0.1950
limf3	-0.3304	-1.4600	0.1460
limf4	0.1787	0.9100	0.3660
info1	0.1429	0.6600	0.5120
info2	-0.183	-0.7000	0.4830
info3	-0.1452	-0.6400	0.5230
exco1	0.349	1.4900	0.1370
exco2	-0.0987	-0.4200	0.6740
exco3	0.1396	0.6500	0.5190
urco	-0.1979	-0.8700	0.3870
_cons	5.2717***	3.0100	0.0030
Number of obs	292		
F(16, 277)	2.96		
Prob > F	0.0002		
R-squared	0.3012		
Adj R-squared	0.2606		
Root MSE	1.4916		

Table B.3: Estimation of Firms' Allocation of Innovation Efforts(Multinomial logistic Regression)

invallot	RRR	Std. error	P-Value
inv_process			
isic1			
2 : (201 - 293)	0.7600	0.3105	0.5020
3 : (300 - 372)	1.9126	0.8691	0.1540
6 : (641 - 660)	2.3633	3,742.0250	1.0000
7 : (721 - 749)	0.0000	0.0020	0.9880
owner			
71-99% locally owned	1.4220	0.8635	0.5620
51-70% locally owned	0.7412	0.4027	0.5810
1-50% locally owned	1.4657	0.9424	0.5520
Wholly foreign-owned	1.5263	0.8327	0.4380
total_sale (in log)	1.1358	0.1028	0.1590
experience	0.9553***	0.0164	0.0080
techact	1.6389	2.1399	0.7050
salese	0.9964	0.0047	0.4540
salenew	0.9677***	0.0055	0.0000
invreslt	0.4030	0.2243	0.1020
info1	1.0491	0.4352	0.9080
info2	0.5181	0.2362	0.1490
info3	0.7907	0.3855	0.6300
exco1	0.4715*	0.2042	0.0830
exco2	0.5969	0.2924	0.2920
exco3	1.0292	0.4276	0.9450
urco	0.8814	0.3491	0.7500
_cons	0.6487	1.4079	0.8420
inv_product			
isic1			
2 : (201 - 293)	1.4635	0.5010	0.2660
3 : (300 - 372)	2.3221**	0.9195	0.0330
6 : (641 - 660)	6.90E+07	5.91E+10	0.9830
7 : (721 - 749)	32.7894***	27.7907	0.0000
owner			
71-99% locally owned	1.4159	0.7395	0.5060
51-70% locally owned	0.6100	0.2936	0.3050
1-50% locally owned	1.4592	0.8617	0.5220
Wholly foreign-owned	1.3237	0.6344	0.5580
total_sale (in log)	0.9035	0.0683	0.1790
experience	1.0025	0.0111	0.8230
techact	1.5899	1.5664	0.6380
salese	1.00	0.0040	0.9270
salenew	1.00	0.0036	0.4150
invreslt	1.50	0.7536	0.4250
info1	0.5815*	0.1778	0.0760
info2	0.6726	0.2475	0.2810
info3	1.1449	0.4219	0.7130
exco1	0.3449***	0.1153	0.0010
exco2	1.3260	0.5173	0.4690
exco3	0.9591	0.3350	0.9050
urco	0.6810	0.2241	0.2430
_cons	2.8303	4.8672	0.5450
inv_process___product	(base outcome)		
Number of obs	438		
Log likelihood	-325.3568		
LR chi2(46)	223.62		
Prob > chi2	0.0000		
Pseudo R2	0.2558		