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R&D and non-R&D in the innovation process among firms in ASEAN countries

Based on firm-level survey data

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Abstract

Purpose – The purpose of this paper is to identify factors promoting innovation in the framework of R&D based on surveys conducted on firms in five ASEAN countries, Indonesia, Laos, Thailand, the Philippines, and Vietnam.

Design/methodology/approach – The analytical method divided sample firms into two categories, namely, "the R&D group" and "non-R&D group." The analysis attempts to identify which of the internal capabilities, consisting of technology, human factors and organization factors, promote innovation. Ordered probit analysis is employed.

Findings – Findings from the estimations indicate that the two groups pursue product innovation differently. The R&D group promotes innovation by cross-functional teams of production, engineering, and marketing and IT use, whereas the non-R&D group promote product innovation by HRD programs for workers, group awards for suggestions or QC, and ISO9000 series.

Research limitations/implications – The number of samples related to the non-R&D group is too small to conduct statistical analysis. External linkages played an important role in the authors' previous studies. The introduction of external linkages into the model may yield different results, though the analysis would become more complex.

Practical implications – The results of this paper provide the solid basis of policy to promote innovation and upgrading SMEs in the region.

Social implications – Many ASEAN SMEs successfully achieve innovation without owning specified in-house departments or sections to conduct R&D.

Originality/value – The features of this paper lie in the original firm-level survey data and rigorous estimation method using ordered probit analysis, which are new to this literature.

Keywords MNCs, HRD, Learning process, Cross-functional team, Ordered probit analysis, QC

Paper type Research paper

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1. Introduction

For further economic development in ASEAN economies, transformation from simple production bases, known by terms such as the "factory of the world," to "knowledge economies" is mandatory. In addition to so-called national innovation initiatives for this transformation, sector-specific or firm-specific policy is also required for industry or firms to upgrade their production and management. Particularly, the transformation of SMEs in these regions is an urgent prerequisite for overall macroeconomic development. In the innovation process, there is another important basis, which is R&D. Some SMEs in Europe and the USA take on the role of inducing such transformation by R&D themselves. Venture companies in the IT and biotech industries, which are strongly oriented toward R&D, are representative of these SMEs. These companies are deconstructing existing industrial structures and creating new products, services, and business models, a phenomenon aptly called creative destruction. SMEs in ASEAN economies, on the other hand, can be said to be victims of this process rather than innovators. In the midst of such rapid and turbulent change, it goes without saying that sustained R&D and the resulting innovation are required to regain vitality and, furthermore, to grow.

In this regard, in order to postulate the basic behavior of firms in these regions toward innovation, the innovation process and internal capability for innovation inside the firm must be clarified. In doing so, this paper studies innovation by focusing on R&D. R&D is thought to be the other side of the coin, and the above innovation process can be viewed from the standpoint of R&D. Similar to the above four sub-processes, the R&D process can be decomposed into the following sub-processes: idea generation; screening business analysis; development; testing; and commercialization (Booz *et al.*, 1982). In this R&D process, the internal innovation capability of firms plays an essential role in achieving innovation. Internal capability includes the technological level, such as the number of patents, production facilities, human resources, such as the number of engineers with higher degrees or skills, the level of craftsmanship and work ethics, and organizational aspects, such as communication between workers and top management, speed of decision making, and top management leadership. To achieve innovation, firms are required to nurture and strengthen their internal innovation capability. The innovation and R&D processes are considered to be the processes by which firms organize their internal innovation capability to achieve objectives. This paper categorizes R&D into two types: traditional R&D and non-R&D. The former is R&D conducted by specific R&D sections or units, whereas the latter is implemented without explicit or formal units. Jensen *et al.* (2007) defines the former as the science, technology and innovation (STI) mode and the latter as the doing, using, and interacting (DUI) mode. The authors' previous paper terms these as formal and informal R&D (Tsuji *et al.*, 2017). This paper aims to examine the innovation and R&D processes of SMEs in the ASEAN countries, which are less STI-type due to the current level of technology and size of firms in terms of employees and assets. That is, they are too small to own specific sections or units for R&D. Accordingly, the research questions in this paper are whether there are differences in the performance and conduct of innovation between two types of R&D, and if so, what they are. To solve these questions, this paper employs rigorous statistical analysis, ordered probit analysis, which examines the process by which firms come to achieve innovation under different R&D processes.

The remainder of this paper is organized as follows. The next section presents a brief survey of R&D and HRD followed by a summary of the data obtained in the five ASEAN countries. The methodology and models to be estimated are then discussed, after which the estimation results and their implications are presented. Brief conclusions and directions for further research are provided in the final section.

2. Literature review

The innovation process was defined and studied by Cohen and Levinthal (1990), Zahra and George (2002), and Christensen and Kaufman (2009), for example. Cohen and Levinthal (1990) also recognize the innovation process as a learning process consisting of four dimensions; acquisition, assimilation, transformation, and exploitation. Firms must elevate their abilities in all four dimensions to promote innovation, which is referred to as an internal capability for innovation. This internal capability includes the integrated ability of a firm to create innovation, consisting of the integration of all resources, core competences, and competitiveness, as noted by Lawson and Samson (2001), Mariano and Pilar (2005), and Perdomo-Ortiza *et al.* (2008). R&D is, on the other hand, thought to be the other side of the coin, and the above innovation process can be viewed from the standpoint of R&D. Similar to the above four sub-processes, the R&D process can be decomposed into the following sub-processes, idea generation; screening business analysis; development; testing; commercialization (Booz *et al.*, 1982). In this R&D process, the internal innovation capability of firms plays an essential role in achieving innovation.

R&D is one of the riskiest elements for businesses (Booz *et al.*, 1982; Crawford, 1987/1997; Cooper, 2001; Nadia, 2011). This nature of R&D has motivated the publication of numerous textbooks and handbooks for firms, including Crawford (1987/1997), Smith and Reinertsen (1998), Cooper (2001), and Kahn (2013). Similarly, various papers analyze R&D from the viewpoints of autonomy (Argyres and Silverman, 2004; Lerner and Wulf, 2007), of managing R&D teams (Leven and Cross, 2004; Colquitt and Rodell, 2011), of leadership (Hirst and Mann, 2004; Berson and Linton, 2005; Zheng *et al.*, 2010; Wong and Tong, 2012), of reward and incentive schemes (Lerner and Wulf, 2007), and so on. On the other hand, there also various studies of innovation through non-R&D, hidden innovation, or informal R&D, which characterize a different pattern or mode of innovation and R&D. The difference between the two is well summarized by Jensen *et al.* (2007) as the STI mode and the DUI mode. The former is dominated by scientific and technical knowledge, which is related to the formal process of R&D, whereas the latter is characterized as the informal process of learning and experienced-based skills and know-how (Thomä, 2017). The two notions are not dichotomous, but rather ambiguous. Even high-technology firms, which are perfect examples of STI, conduct non-R&D-type R&D (Barge-Gil *et al.*, 2011; Hervas-Oliver *et al.*, 2015).

3. Nature of R&D and non-R&D in ASEAN firms

3.1 Factors promoting innovation under non-R&D

3.1.1 R&D structure. R&D does not simply create something new in terms of technology or engineering, but is related to various aspects of manufacturing. R&D therefore also has related sections or functions attached to it, such as production technology, manufacturing technology, quality assurance, design, and so on. These sections are well organized so as to conduct R&D in a coherent manner.

On the other hand, in SMEs which do not own an R&D section, each engineer is trained to fulfill customer needs. Since the firms manufacture simple parts such as gears, they receive all kinds of requests regarding gears, and are required to satisfy customer needs by cultivating their skills and technologies. In firms that do not own an R&D center, each craftsman plays this role and other workers are assigned to roles that perform the functions that are similar to sections in R&D centers. In this sense, whether the R&D is formal or informal, a certain number of related functions require the conduct of R&D. The role of the ISO9000 series is important, since some SMEs (nearly 50 percent of our sample) obtained ISO9001 certification, which forms the basis of their standardized structure and R&D function.

3.1.2 R&D execution. R&D practice differs in R&D and non-R&D groups. The first step is to find ideas or a seed for innovation. An R&D group discovers these seeds by themselves or

by collaborating with business partners, mainly multi-national corporations (MNCs). Once they find a research theme, they conduct R&D either on their own or by collaborating with business partners. Most of the seeds of innovation come from buyers or suppliers in the form of either claims for better products or changes in the models or specs of final products.

Some SMEs have been invited to joint research consortia organized by MNCs and university laboratories. The reason why small SMEs are invited to participate in high-tech projects is that they have superior technology in specific parts. Without these parts, the final products would never be realized. Superior technology in a niche area is a source of further enhancement and widening of technology for these firms. Enhancing and maintaining their own high-technology level attracts innovation seeds.

ISO9001 postulates a standardized process regarding how R&D is to be conducted once an idea has been identified. One feature of SMEs is the speed of decision making. This is another reason why they are selected to be partners of MNCs.

3.1.3 HRD. HRD takes different forms in SMEs according to the technology, product, size of the firm, and other factors. The similarity in HRD is that OJT is the main practice. New employees are assigned to specific sections and receive OJT to achieve required skills from senior colleagues. Even smaller SMEs have their skill-raising process. Workers are required to achieve certain skills; failure to do so will mean that they are not promoted to higher positions. They also have skill assessment systems, which evaluate employee ability according to a scale. After attaining a passing level, employees can be registered as trainee designers and participate in design as assistants, for example. One example of more intensive OJT is observed as follows. Since most of their new employees are graduates of regular high schools, not technical high schools, they are trained thoroughly on a man-to-man basis and are required to master CAD/CAM as the first step. The employees are then required to master each machine in order, and their performance with each machine is marked up on a skill map. A glance at this map makes it apparent who is able to operate a particular machine and perform a particular function. These skills are reflected in the employees' salaries, providing them with an incentive to work seriously.

3.2 Research questions

Based on the above discussion on the ways of conducting R&D activities, the research questions of this paper are summarized as follows:

RQ1. Do informal and formal R&D groups have different innovation processes?

RQ2. What are the factors of production innovation in formal and informal R&D groups: Are there any differences between them?

3.3 Summary of data and estimation model

In this section, the sources of data, the procedure of estimation, and the construction of variables are presented.

This study is based on mail surveys and phone interviews conducted with firms in four ASEAN economies, such as Vietnam, Indonesia, Laos, the Philippines, and Thailand from 2013 to 2014, amounting to 152 in the Hanoi area and 161 in the Ho Chi Minh City area, Vietnam; 200 in the Batangas and other areas in the Philippines; 181 in the Jabodetbek area, Indonesia; and 160 in Greater Bangkok, Thailand. The surveys were conducted from November 2013 to January 2014. The total number of valid responses from these areas was 1,061.

As explained earlier, this study categorizes R&D activities into two types, R&D and non-R&D, the firms also being divided into these two groups. The firms that replied "no" to the two questions about whether they have an R&D budget (Q19.1. What is the ratio between R&D expenditure and sales at present?) and whether they have specific personnel

who are engaged only in R&D activities (Q19.3. Does your establishment develop personnel in charge of R&D at present?) were classified as non-R&D. The rationale of this lies in (i) the difficulty of devising questions to ask regarding SME R&D and (ii) the ambiguity of the definition of R&D and non-R&D. As stated in the introduction, regarding (i), questions have to be simple enough for the CEO or person in charge of R&D or innovation to understand and reply properly. Due to (ii), the concept of non-R&D activity may inseparable from those of R&D. Thus questions to identify the type of R&D are limited to the above two only. Thomä (2017) and Lee and Walsh (2016) utilize official data from the EU and USA, respectively. The former categorizes R&D expenditures into R&D and non-R&D, whereas the latter employs questions that ask "one (question) about the creative process that led to their invention and one about the type of unit to which they belonged at the time of the invention (p. 350, word in brackets added by authors)." Although our definition appears to be rough, it is convenient for the questionnaire survey. Accurate but complicated questions are hard for respondents to understand. Since the areas and firms targeted by this study are less developed countries and SMEs, simplified definitions are useful in practice.

The number of firms analyzed in this study sample was 608 in the R&D group and 441 in the non-R&D group to give 1,049 in total, as shown in Table I. 58.0 percent of the respondent firms belong to the formal R&D group. Vietnam had the largest number of firms in the R&D group, amounting to 83.7 percent of the total, followed by Indonesia at 61.9 percent. The percentage of firms in the R&D group was the lowest in the Philippines at 37.3 percent. These figures imply that the number of firms with informal R&D was larger than that with formal R&D.

Regarding the size of the firms, 50 percent of formal R&D firms have smaller than 200 employees, while that of informal R&D has smaller than 50 employees. In terms of assets, two thirds of Formal R&D are larger than 1 million-5 million USD, whereas two thirds of Formal R&D own less than those amounts. The informal R&D firms have much smaller than the formal group.

3.4 Construction of variables: product innovation as outcome variable

The construction of variables related to product innovation is based on the following four categories of innovation:

(1) Product innovation Type I: introduction of a new product, redesigning packaging or significantly changing the appearance design of your existing products (Nascia and Perani, 2002).

(2) Product innovation Type II: introduction of a new product, significantly improving your existing products with respect to their capabilities, user friendliness, components, subsystems, etc.

(3) Product innovation Type III: development of a totally new product based on the existing technologies at your establishment.

(4) Product innovation Type IV: development of a totally new product based on new technologies at your establishment.

	Vietnam		Indonesia		Thailand		Philippines		Laos		Total	
Type of R&D	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
R&D	262	83.7	112	61.9	83	53.5	72	37.3	79	38.2	608	58.0
Non-R&D	51	16.3	69	38.1	72	46.5	121	62.7	128	61.8	441	42.0
Total	313	100.0	181	100.0	155	100.0	193	100.0	207	100.0	1,049	100.0

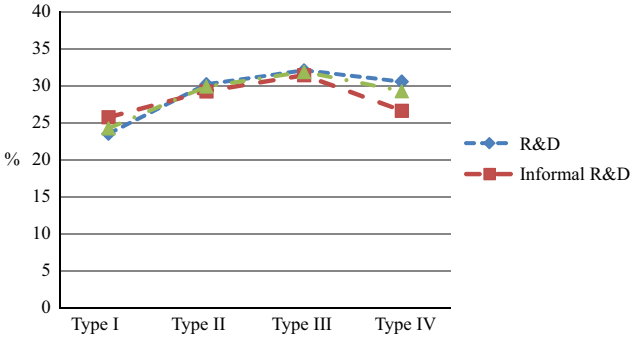
Source: Authors

Table I.
Types of R&D group by countries

These are based on "Q13. Have you tried to introduce a new product in the last two years (2013-2014)?" This categorization is based on the OECD Oslo Manual. For each category, the respondents were asked whether they had achieved, attempted, or not attempted the innovation. If respondents had achieved the innovation, two points are given; if they had attempted the innovation, one point is given; and those who had not yet attempted the innovation are indicated by zero. Figure 1 shows the distributions of product innovation by two groups for whole regions, while Figure 2 indicates product innovation by countries without making difference between two groups. The vertical axis of both figures indicates the percent of forms responded to achieved. As shown in Figure 1, in the pooled data, no difference is found in the three groups of firms, but innovation by countries shows that Thailand has the largest percentages of the four types, whereas Indonesia shows the smallest in all types. The other three countries have almost similar figures, except for Type I (Figure 2).

3.5 Selection of explanatory variables

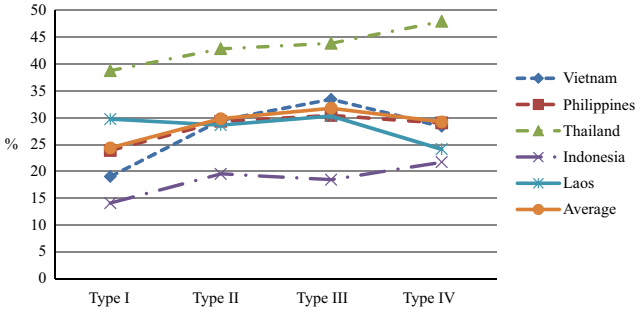
This paper employs ordered probit model and the explanatory variables used in the estimation are discussed. All variables play important roles in the promotion of innovation. The most of the previous papers were concerned with the specific research question and did



Notes: Type I, redesigning packaging or significantly changing appearance design. Type II, significantly improving existing products. Type III, new product based on the existing technologies. Type IV, new product based on new technologies

Source: Authors

Figure 1.
Product innovation: whole regions



Source: Authors

Figure 2.
Product innovation by countries

not cover the all related variables which might affect R&D. The authors' previous study which employed Structural equation modeling used the categories of explanatory variables such as cross-functional team, QC, human factors such working experience's for MNCs, and so on (Tsuji *et al.*, 2016). This paper also basically follows those variables.

3.5.1 ISO9000 series. ISO9000 series cover wide activities related to quality management, training, R&D structure and implementation, and so on. The technological level of a firm can be indexed by the number of patents obtained, the amount of R&D investment made, or the quality of equipment used in the manufacturing process. This study focuses only on the ISO9000 series and ISO14000 series, since the number of explanatory variables is large and there are other variables which we wish to highlight in this paper. In the actual estimation, only ISO9000 series were employed, since variables related to technology are not significant. This will be discussed in more detail in what follows.

3.5.2 Human factors. In the previous papers, human factors are discussed from the various aspects which include labor mobility (Kesidou and Szirmai, 2008), spillovers (Görg and Strobl, 2005; Balsvik, 2011; Poole, 2013) or leadership of R&D team (Sarin and McDermott 2003; Wong and Tong, 2012) in the high-tech industries. The questions related to human factors in this paper confine to those related manager classes and aim obtain the abilities of employees, but these are not in general observable. The questions thus asked subjects to focus on their career backgrounds, or current positions. The variables employed for estimation are based on the following questions: Q30.1. Does your establishment have a factory manager?

3.5.3 Organizational factors. Since innovation or R&D are conducted with various teams, groups, or units, conflicts among them are easily occurred, and to avoid such conflicts managerial arrangements or organizations are required for conducting R&D coherently. Daniel (1961) and Rockart (1979), for example, asserted that related organizations need to clarify factors that are critical to the success of the R&D process, since failure to achieve coherency would result in organizational failure. The questions related to organizational factors in this paper thus aim to obtain information on whether firms as a whole are systematically and coherently conducting R&D or innovation activities. This factor contains activities which are summarized as follows.

3.6 Top management leadership

This is an important factor particularly for the informal R&D group, as already mentioned. Innovation in SMEs is mainly led by the owners of firms, particularly SMEs with top-down type. The top management leadership contains ability to establish D&R strategy, to encourage related teams or personnel, to avoid conflicts among related groups, to evaluate their performance, etc. Greenleaf (1977) referred their ability to avoid conflicts and coordination failure to as Servant Leadership. Since the top management leadership is unobservable, it is obtained from the following questions, which are also related to top management backgrounds, such as education or past experience: Q29.8. Does the top manager have experience of working for MNCs?

3.7 Cross-functional team

This is an organizational arrangement for the exchange, dissimulation and sharing of different views or opinions from different sections of a firm that are related to innovation and which become a basis for creating new ideas. The heterogeneity of ideas or thought tends to create something new through communication. The role of cross-functional teams has been recognized not only in the context of innovation but also solving problems in general. Besides previous studies discussed the conditions on which cross-functional teams work. There were empirical studies; Blindenbach-Driessen (2015) demonstrated the positive relationship between the cross-functional team and innovation by saying that

the existence of cross-functional team is not sufficient for successful innovation. Hirunyawipada *et al.* (2010) identified the conditions for teams to works such as task cohesion, interpersonal cohesion, and transformational leadership and the qualification of team members such as common knowledge, functional expertise, and their positions in the network. Again, this factor is unobservable, and the following question is used as a proxy: Q21.5. Production Engineering, Q21.6. Manufacturing, and Q21.11. sales and marketing From the survey data, the percentages of firms which practice following three cross-functional teams are shown in Table II.

The above questions investigate whether the firm has this characteristic. In the estimation, "no team" and "cross-functional team (production engineers, manufacturing, and sales and marketing)" are used, and the latter consists of personnel who are "production engineers, manufacturing, and sales and marketing." The role of marketing section was emphasized by De Luca, Atuahene-Gima (2007) which obtained the conclusion such that market knowledge and cross-functional collaboration are two fundamental resources for successful product innovation. They identified the mechanisms which combine these two.

3.8 Quality control (QC)

Although QC does not directly contribute to innovation, new ideas related to innovation, particularly related to process innovation, can be obtained through small group activities. Since the improvement of product quality is a part of process innovation, the outcome of QC is equal to innovation itself. The questions used for this factor are as follows: Q22.2. Does your establishment operate a QC circle? Q22.7. Group rewards for suggestions or QC. From the data, actual practices are shown in Table III.

3.9 Learning process

This role of the learning process is to share the success experiences among related personnel engaged in R&D activities, and consists of the following questions: Q33. HRD program for blue-collar workers, such as cross-training or job rotation.

3.10 IT use

IT use is now popular and necessary among SMEs in these areas, and it is important to examine whether or not IT promotes R&D activities, since IT supports employees in dissimulating their experiences and sharing them with others (Idota *et al.*, 2015a, b, c). IT use was asked in Q28.2. Has your establishment introduced the following IT systems?, which consists of the following two IT use.

	Non-R&D(%)	R&D(%)
Research	2.7	26.0
Development	6.3	38.8
Sales and marketing	25.4	40.3

Source: Authors

Table II. Cross-functional teams

	Non-R&D (%)	R&D (%)
QC	53.7	73.4
Group rewards for QC	42.5	56.5

Source: Authors

Table III. QC

3.10.1 Internal use of IT. This variable consists of the number of items of questions which are true to the firm: 5. Enterprise Resources Planning (ERP), 6. Customer Relationship Management (CRM), 7. CAD/CAM, 8. Groupware, 9. Intra-Social Networking Services (SNS).

3.10.2 External use of IT. This variable consists of the number of items of questions which are true to the firm: 1. Business-to-Business e-commerce (B2B), 2. Business to Consumer e-commerce, 3. Electronic Data Interchange (EDI), 4. Supply Chain Management (SCM), 10. Public SNS.

3.10.3 IT all. The variable "IT all" includes all of the internal and external uses of IT. In estimation, we use IT all as a variable.

The summary statistics of the above variables are shown in Table IV.

R&D/non-R&D	Variable	Obs. 951	Mean 0.40	SD 0.49	Min. 0	Max. 1
Dependent variables						
Product innovation	Type I: introduced a new product, redesigning packaging or significantly changing appear	951	0.98	0.92	0	2
	Type II: introduced a new product, significantly improving your existing products	951	0.93	0.89	0	2
	Type III: development of a totally new product based on the existing technologies	951	0.77	0.86	0	2
	Type IV: development of a totally new product based on new technologies	951	0.55	0.78	0	2
Indedendent variables						
Technology factor	ISO9000 series	951	0.43	0.50	0	1
Human factor	Appointing factory manager	951	0.69	0.46	0	1
Leadership of top management	CEO has experiences working for MNCs	951	0.41	0.49	0	1
Cross-functional team	Cross-functional team (engineering, manufacturing, sale and marketing)	951	0.93	0.97	0	3
Quality control	Practicing QC	951	0.65	0.48	0	1
	Statistical QC	951	0.54	0.50	0	1
	Group rewards for suggestion or QC	951	0.50	0.50	0	1
Learning process	HRD program for blue-collar workers such as cross-training or job rotation	951	0.59	0.49	0	1
IT	IT all	951	1.99	1.90	0	10
Control variables						
Firm characteristics	ln (operation years)	951	4.68	0.11	4.50	5.35
	Total Assets	951	7.26	2.26	1	10
	100% locally owned	951	0.67	0.47	0	1
	Food	951	0.11	0.31	0	1
	Wear	951	0.15	0.36	0	1
	Wood and paper	951	0.11	0.31	0	1
	Chemical & plastic	951	0.17	0.37	0	1
	Iron and metal	951	0.12	0.32	0	1
	Parts and machine	951	0.21	0.40	0	1
	Other industries	951	0.66	0.48	0	1
Country dummy	Philippines dummy	951	0.18	0.38	0	1
	Indonesia dummy	951	0.19	0.39	0	1
	Laos dummy	951	0.22	0.41	0	1
	Thailand dummy	951	0.09	0.29	0	1
	Vietnam dummy	951	0.32	0.47	0	1

Table IV.
Summary statistics

Source: Authors

3.11 Result of estimation

By using the questions explained previously, ordered probit analysis is employed to identify factors promoting innovation. The results are presented through two models, product and process innovation, in what follows. For the sake of simple and clear discussion, summaries of the estimation results shown in Table V are utilized and detailed estimation results are shown in the Table AI.

First, ordered probit estimation on product innovation is conducted for each type of innovation to identify factors to achieve particular type innovation, and second estimation is conducted through four type innovations which aim to identify factors which elevate firms to higher degree of innovation. For both estimation, explained variables are relies such as 2 for "achieved," 1 for "attempted," and 0 for "not attempted." The rationale of this methodology lies in the category of innovation. We assume that upgrading innovation from Types I to II, from Types II to III, and so on are so drastic changes for local firms in ASEAN countries that ordered probit analysis might not capture essential factors for innovation. Actually the estimation in this way did not bring reasonable results. Thus upgrading from "not attempted" to "attempted," or from "attempted" to "achieved" seems not difficult for SMEs and can capture the desired results. Accordingly, this method is adopted. Estimation result for each type of innovation.

3.12 Common factors of two groups

The results of the estimation are summarized in Table V, in which firm characteristics are omitted for simplicity (for detailed estimation results, see Table AI). The significant variables differ according to the types of innovation and groups, and it is therefore difficult to obtain a clear and unified explanation. It can be said, however, that the R&D and non-R&D groups have different innovation patterns, since the only significant variables common to both groups are: "Q22.2. Does your establishment operate a QC circle?" for Type III and IV and "IT all" for Type I.

Variables	Type I		Type II		Type III		Type IV	
	Non-R&D	R&D	Non-R&D	R&D	Non-R&D	R&D	Non-R&D	R&D
ISO9000 series	**		**			**	*	
Factory manager								**
CEO has experiences working for MNCs or JVs								
CFT (engineering manufacturing sale and marketing)		***		***		***		***
QC					*	*	**	**
Statistical QC						**		
Group rewards for suggestion or QC	***		**		*			
HRD program for blue-collar workers such as cross-training or job rotation	**		**		***		***	
IT all	**	***		***		***		***
Observations	383	568	383	568	383	568	383	568
Pseudo R^2	0.091	0.080	0.070	0.065	0.094	0.070	0.113	0.104
Log likelihood	−305.3	−525.5	−316.6	−561.2	−292.5	−570.8	−251.6	−510.7

Note: *,**,***Indicate levels of significance of 10, 5 and 1 percent, respectively
Source: Authors

Table V.
Estimation result of product innovation

Both groups enhance innovation by practicing QC for higher innovation, but the difference is not a matter of measurement. Thus the first conclusion obtained from the estimation is that the R&D and non-R&D groups operate under almost totally different processes for product innovation, which answers *RQ1* for product innovation.

3.13 R&D group

Next, let us focus on the R&D group in more detail. This group has the following significant variables:

(1) cross-functional team consisting of "production engineering, manufacturing, and sales and marketing" for all types of innovation; and

(2) IT all for all types.

From these observations, factors such as cross-functional team and IT all are the same variables that were identified as promoting innovation obtained in the authors' previous studies (Machikita *et al*., 2016; Tsuji *et al*., 2016, for example), implying that the previous studies appeared to be focused on firms conducting formal R&D activities. Moreover, since there are no significant variables related to top management, innovation in this group is mainly enhanced by employee participation. This is different from the conclusion obtained in our previous studies. As discussed in the previous sections, the R&D group consists of larger SMEs and has active QC and R&D (improvement activities, more precisely) conducted by cross-functional teams covering different sections. These results tend to coincide with the results of in-depth interviews.

3.14 Non-R&D group

What then are the results for the non-R&D group? The only common factor in this group for different types of innovation is:

(1) ISO9000 series for Types I, II, and IV;

(2) group awards for suggestions or QC for Types I, II, and, III;

(3) HRD program for workers for all Types; and

(4) IT all for Type I.

HRD is the most important factor in this group since HRD is positively significant for all types. This is different from the R&D group. This group achieves innovation through the skills and know-how of workers, as seen from the in-depth interviews. Group awards for suggestions, which provide incentives for suggestions or QC practice, is significant for Types I, II, and III. The ISO9000 series also contributes to innovation in all types except IV. Since the ISO9000 series covers a wide range of activities related to quality management, training and education, and R&D structure and implementation, further study will be required to identify the exact factors.

3.14.1 Comparison with the results of field surveys. Let us compare the above results with what we learned from field surveys. In our past studies, we did not stress the STI-type of innovation for ASEAN SMEs. These SMEs obtain new information on innovation mainly from MNCs, and concentrate on producing parts and components for MNCs. In the case of manufacturing final products, SMEs supply to local markets. Thus, in the same innovation type, firms in the two R&D groups are not so different from each other, and therefore factors of innovation identified are either cross-functional teams or HRD, which belong to the category of DUI (Jensen *et al*., 2007). Even if their innovation is of the DUI type, there must be some reasons for the difference, these deriving from innovation or knowledge environment (Thomä, 2017), or from the types of products, e.g. simple parts and material, or complete parts

and final products. Innovation for the former requires the skills of workers accumulated by the learning process at the workplace or job shop. In case of the latter, products are more complex due to the number of parts or the need for higher quality. In addition, customer requests for quality tend to be higher. Not only do SMEs have to cope with these issues, they must also engage in marketing to sell their products. Accordingly, the number of employees participating in these activities increases. The success of these activities depends on the coordinators or supporting sections that manage these activities. In this sense, firms in the R&D group in ASEAN countries are more advanced than those in the non-R&D group.

4. Discussion

The estimation results identify the factors of innovation in R&D and non-R&D groups, which have received less discussion in the literature thus far. Here, let us compare our results with those of other studies.

The merit of this paper is in the analysis of R&D and innovation in firms in ASEAN economies. Previous empirical studies employed large public data from the EU and the USA, whereas this paper uses original data collected by each of the country teams. The US data, such as NSF's Business R&D and Innovation Survey (BRDIS) 2011, shows that "out of all US firms only 5 percent conduct R&D. Furthermore, out of all US product innovating firms, about 72 percent are non-R&D innovators. At the same time, R&D-active firms do have a higher probability of generating a product innovation than non-R&D-active firms (58 vs 7 percent) (NSF, 2014)" The data in this study show that the ratio between R&D and non-R&D is 52 vs 48 percent (Table I), but the performance in terms of product innovation appears not to be large (Figure 1).

Another merit of this research is that an original questionnaire was devised. As a result, concrete factors such as cross-functional teams and HRD have been obtained. Thomä (2017) used data from the 2011 survey wave of the Mannheim Innovation Panel (MIP), which covers the period 2008 to 2010. He emphasizes vocational education and training (VET) in Germany as an innovative factor in the DUI mode of learning. The higher ability of German workers is based on VET. In ASEAN economies, there is a severe shortage of such workers and engineers, making it necessary for firms to nurture these human resources through HRD.

5. Conclusion

The objectives of this study are to examine whether two groups of ASEAN firms have different R&D activities for achieving innovation. The firms are categorized into two groups depending on whether or not they own specific R&D sections or units. The underlying hypotheses are that the R&D group is characterized by the same process as obtained in the authors' previous studies, namely innovations are promoted by technology, human factors, and organizational arrangements. On the other hand, the non-R&D group has a different innovation process due to shortages in human resources, investment funds, or a low level of technology. Based on field research, these firms conduct innovation through the leadership of owners who dominate the firm in terms of technology, ideas, experience, and so on. In addition to this, a cross-functional team of employees discussing, disseminating, and sharing their ideas, experiences and skills among the members is another factor promoting innovation. Since the firm size is small, top management can participate in the team and the joint effort of employer and employees in the whole firm promotes innovation.

To examine the above hypotheses, this study employs a model using the same variables for both groups. This examines whether the two groups have the same innovation processes or not. The results of the first estimation procedure indicate that the two groups pursue product innovation differently. The formal R&D group promotes innovation by

cross-functional teams consisting of marketing personnel as well as technological and manufacturing engineers, QC, a learning process such as HRD and worker training. These factors coincide with those obtained in the authors' previous studies. The informal R&D group, on the other hand, does not yield clear results. An estimation model only applicable to this group is therefore employed. As a result, top management leadership, reflecting top management experience and study abroad, is identified. Accordingly, the RQs related to product innovation are partly demonstrated.

Although the roles of top management in the innovation process were recognized, they were not emphasized in the authors' previous studies. The study on connectivity conducted last year identified these roles in the context of the information transmission channel, that is, the route of information flow between MNCs and top management who formerly worked at MNCs. On the other hand, the role of top management in the innovation process in small SMEs is extracted for the first time in this study. The cross-functional team, training of workers, and QC practices were found to be three major factors prompting innovation in the authors' previous studies. These are also confirmed by this study.

This paper successfully identifies concrete factors promoting innovation for R&D and non-R&D groups in ASEAN economies, a region that has received less analytical attention in comparison with the EU and the USA The limitations of this study that require solution in further studies are as follows: number of samples, estimation method; concrete channels as to how factors affect innovation; and external linkages. The number of samples related to the non-R&D group is too small to conduct statistical analysis. Further efforts regarding the survey method for focusing on small SMEs are required. The estimation method also requires improvement. The estimation method in this study aims rather to find factors which make a difference in the innovation process, but more suitable methods are required to test the hypotheses. The identification of how different factors affect innovation is also important. For example, how a cross-functional team disseminating ideas and experiences affects innovation is yet to be solved. Can the group reward system, for example, stimulate cross-functional activities? This can be examined by the cross term of two variables. What kind of organizational arrangements can elevate employee ability for innovation is a similar kind of problem that needs to be analyzed. This study focuses on the internal innovation process and is less concerned with external linkages, which played an important role in the authors' previous studies. The introduction of external linkages into the model may yield different results, though the analysis would become much more difficult and complex.

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Appendix

Table AI. Detailed estimation result of product innovation

Variables	(1) Type I Non-R&D	(2) Type I R&D	(3) Type II Non-R&D	(4) Type II R&D	(5) Type III Non-R&D	(6) Type III R&D	(7) Type IV Non-R&D	(8) Type IV R&D
ISO9000 series	0.370** (0.182)	−0.045 (0.123)	0.437** (0.178)	−0.032 (0.118)	0.249 (0.181)	0.271** (0.116)	0.355* (0.190)	0.043 (0.121)
Factory manager	0.066 (0.164)	−0.017 (0.129)	0.168 (0.162)	0.010 (0.125)	0.044 (0.167)	−0.067 (0.125)	0.026 (0.181)	−0.280** (0.133)
CEO has experiences working for MNCs or JVs	−0.119 (0.164)	−0.018 (0.116)	−0.017 (0.160)	−0.083 (0.112)	0.198 (0.163)	0.023 (0.111)	0.244 (0.172)	0.107 (0.115)
Cross-functional team (engineering manufacturing sale and marketing)	0.014 (0.091)	0.275*** (0.059)	0.004 (0.090)	0.285*** (0.057)	−0.045 (0.093)	0.195*** (0.057)	0.037 (0.096)	0.159*** (0.059)
QC	−0.049 (0.163)	0.015 (0.130)	0.171 (0.161)	−0.076 (0.127)	0.315* (0.167)	0.246* (0.127)	0.440** (0.181)	0.294**(0.136)
Statistical QC	−0.270 (0.181)	0.195 (0.136)	−0.245 (0.178)	0.118 (0.131)	−0.178 (0.183)	0.259** (0.129)	−0.206 (0.199)	0.053 (0.135)
Group rewards for suggestion or QC	0.549*** (0.176)	0.071 (0.127)	0.353** (0.172)	0.165 (0.123)	0.300* (0.176)	−0.013 (0.122)	0.284 (0.188)	0.127 (0.126)
HRD program for blue-collar workers such as cross-training or job rotation	0.313** (0.153)	−0.084 (0.118)	0.331** (0.150)	−0.024 (0.114)	0.413*** (0.155)	−0.034 (0.113)	0.614*** (0.169)	0.106 (0.119)
IT all	0.110** (0.050)	0.104*** (0.028)	0.043 (0.050)	0.120*** (0.028)	0.044 (0.051)	0.081*** (0.027)	−0.043 (0.054)	0.076*** (0.028)
Observations	383	568	383	568	383	568	383	568
Pseudo R^2	0.091	0.080	0.070	0.065	0.094	0.070	0.113	0.104
Log likelihood	−305.3	−525.5	−316.6	−561.2	−292.5	−570.8	−251.6	−510.7

Note: *,**,***Indicate levels of significance of 10, 5 and 1 percent, respectively
Source: Authors

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