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Innovation in Linked and Non-linked Firms: Effects of Variety of Linkages in East Asia*

Tomohiro MACHIKITA†
Inter-Disciplinary Studies Center, Institute of Developing Economies, Japan

Yasushi UEKI‡
Bangkok Research Center-Japan External Trade Organization, Thailand

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Abstract: This paper proposes a new mechanism linking innovation and networks in developing economies to detect explicit production and information linkages. It investigates the testable implications of these linkages using survey data gathered from manufacturing firms in Indonesia, Thailand, the Philippines, and Vietnam. In-house R&D activities, internal resources, and linkages with local and foreign firms play a role in reducing the costs of product-and process innovation, and the search costs of finding new suppliers and customers. We found that firms with more variety of information linkages achieve more types of innovation. Complementarities between internal and external sources of knowledge are also found.

Keywords: Innovation; Linkages; Sources of Knowledge; Dissimilarity; Complementarities

JEL Classification: O31, O32, R12

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† Address: Institute of Developing Economies, Inter-disciplinary Studies Center, Japan External Trade Organization (IDE-JETRO), 3-2-2 Mihama Wakaba Chiba 2618545, Japan. Email: machi@ide.go.jp.
‡ Address: Institute of Developing Economies, Bangkok Research Center, Japan External Trade Organization, 14th of Nantawan Building, 161 Rajdamri Road, Bangkok 10330, Thailand. Email: yasushi_ueki@ide-jetro.org.

1. Introduction

This paper proposes a new mechanism linking innovations and networking activities in developing economies to identify explicit internal and external information sources. It also investigates the empirical implications of this new mechanism using survey data gathered from manufacturing firms in four megacities in East Asia: Indonesia, the Philippines, Thailand, and Vietnam. We collected firm-level evidence on innovations, linkages between production and information, and the respondent-firms' own characteristics using mail surveys and field interviews.

In a model consisting of heterogeneous firms with R&D activity and internal and external sources, the more productive firms introduce more innovations than less productive firms and are more successful in introducing new goods to market, with only the most productive firms able to introduce new goods and technologies in new markets. That is, being able to achieve multi-variety innovations. Linkages with local and foreign firms help reduce the cost of finding new suppliers and customers. Firms with more information linkages tend to innovate more, and are more likely to introduce new goods and technologies in new markets, as well as find new partners in remote areas. These findings support the hypothesis that the varieties of linkages stimulate product, process, procurement, and market creating innovation.

There is a dearth of empirical research that precisely captures the knowledge transmission mechanism through inter-firm communication. There is also a lack of quantitative evidence that rigorously identifies the effects on several types of innovation of different varieties of internal and external knowledge sources, except for Cassiman and Veugelers (2002, 2006), Vega Jurad *et al*. (2008), and Frenz and Ietto-Gilles (2009). This paper is closely related to the theoretical concept of Frenz and Ietto-Gilles (2009). They try to estimate the impact of different sources of knowledge on innovation performance using the UK CIS dataset. The present paper, however, tries to estimate the benefits of diversity within each source of knowledge on innovation performance. This is our first empirical test. Our second test is to examine complementarities between the degree of own knowledge creation (R&D activities) and internal and external sources, on innovation. The impacts of diverse linkages have not been fully

examined in the field of innovation performance in developing economies. Since we need to quantify the contribution of searching for internal sources and networking with external sources to innovation, this paper collects detailed information about varieties of linkage and varieties of innovation. This field survey-based information provides findings that are lacking in previous studies.

To examine the complementarities between the degree of own knowledge creation and internal and external sources of innovation, we need to identify the extent of companies' investment in R&D as the proxy of knowledge creation, the exact channels used to upgrade existing products, the geographic extent of new-market creation, and the emergence of local alliances to introduce a new product. We will build a simple model to explain the large variation of product innovation across firms with and without R&D activities or multiple production linkages or other information sources. This simple theoretical framework will be based on the reduced-form regression model and will provide some interpretations of the empirical estimates of the effect of two factors, i.e., R&D activities and the variety of linkages, on innovation. Estimating the empirical elasticity of each linkage would enable us to detect the exact channels of several types of innovation.

This paper will investigate the role of production networks in industry upgrading by documenting the spatial architecture of upstream and downstream firms in developing economies, and examining the network effects of innovation. Local network externalities are a mechanism for understanding the relationship between production networks and innovation. At the cross-country level, Lucas (1988) identified local knowledge spillovers as important sources of economic growth. Glaeser *et al.* (1992) showed city-level evidence of the role of knowledge spillovers. At the household or farm level, Conley and Udry (2008) studied the role of communication networks in determining the importance of learning from others.

The next section shows our framework and concept. Data will be described in Section 3. Empirical results are examined in Section 4. The discussion and conclusion are shown in Sections 5.

2. Variety of Linkages; Effects on Innovation Performance

Manufacturing industries in East Asia are primarily involved in exporting and importing, and receive benefit from agglomeration economies within each country. Since they not only need to satisfy domestic demand but also to compete internationally, the firms tend to adopt new technology, acquire new organizational forms in response to market changes, create new markets, find new inputs aimed at improving product quality and cost efficiency, and introduce new products. They utilize the external environment and local/international markets to upgrade themselves.

We test what happens to firms' innovations when they successfully attract or hold many types of production or information linkage. In particular, we ask (1) why firms with many types of internal and external sources achieve different types of innovation; (2) why different types of internal and external sources complement each other in the achievement of innovation.

2.1. The Benefit of Diversity within Major Source Categories

Table 1 provides a summary of the main characteristics of the different types of knowledge source examined in this paper. First, we have five types of internal and external sources: (1) internal resources; (2) linkages with local firms; (3) linkages with MNEs; (4) linkages with public organizations; (5) linkages with universities. These internal and external sources are characterized by a variety of sub-sources within each major type of source. The numbers and variety of sub-sources within each type would differ across the five categories. Internal resources are decomposed into nine sub-sources, from own R&D department to recruitment of personnel retired from MNCs and large firms, and reverse engineering. The varieties of internal resources are quite dissimilar and heterogeneous. The second and third categories of source are linkages with local firms and linkages with MNEs. These types of linkage may also be decomposed into six different varieties of sub-source respectively. These range from joint venture projects with other local firms and joint venture projects with other MNEs, to licensing technologies from other local firms and licensing technologies from other MNEs. The varieties of linkages with local firms and the varieties of linkages with

MNEs are also quite dissimilar. Public organizations usually provide some public information services: technical assistance and research- and business consortium. Linkages with universities provide technical cooperation.

One reason for the success of firms with many varieties of linkage is that each linkage provides unique information relating to upgrading business processes and changes in the market. We assume that these linkages do not cancel out each other's contributions. If combination of linkages is not a costly activity, the combination of two different sources of knowledge is valuable for innovation. In fact, Saxenian (1996, 2006) shows that Indian or Chinese technicians coming back from Silicon Valley combine their resource with local knowledge to create new businesses. Berliant and Fujita (2008) formalizes in detail the concept that knowledge creation needs appropriate diversity of knowledge between two persons.

Table 1. Types of Sources and Their Characteristics

Type of sources		Varieties of sources within each type	Similarities within types
Source 1:			
Internal resources	(1)	Own R&D department	
	(2)	Own sales department or sales agent	
	(3)	Own production or manufacturing department	
	(4)	Technological agreement with the headquarters or affiliated firm	
	(5)	Recruitment of mid-class personnel	Dissimilar
	(6)	Recruitment of personnel retired from MNCs and large firms	
	(7)	Technical information obtainable from patents	
	(8)	Introduction of "foreign-made" equipment and software	
	(9)	Reverse engineering	
Source 2:			
Linkages with local firms	(1)	Joint venture established by your firm with other local firms	
	(2)	Local supplier or customer (100% local capital)	
	(3)	Local competitor	Dissimilar
	(4)	Local firm in the different business	
	(5)	Licensing technologies from other local firms	
	(6)	Local consultant hired by your firm	
Source 3:			
Linkages with MNEs	(1)	Joint venture established by your firm with other multinationals	
	(2)	Multinational supplier or customer	
	(3)	Multinational competitor	Dissimilar
	(4)	Foreign-owned firm in the different business	
	(5)	Licensing technologies from other MNCs	
	(6)	International consultant hired by your firm	
Sources 4:			
Linkages with public organization	(1)	Technical assistance financed/provided by government/public agency	
	(2)	Technical assistance financed/provided by local business organization	
	(3)	Research consortium organized with the support of government	
	(4)	Research consortium organized with the support of local business organization	Similar
	(5)	Business consortium organized with the support of government	
	(6)	Business consortium organized with the support of local business organizations	
Source 5:			
Linkages with universities	(1)	Technical cooperation with local university or R&D institute	Similar
	(2)	Technical cooperation with foreign university or R&D institute	
	(3)	Academic society and academic journal	

2.2. Accuracy Arising from Interactions

Product, production process, and organizational innovations are, by nature, processes of trial and error. One of the reasons why varieties of linkage within each type of source are beneficial to innovations is that the varieties of external source and internal resources are interpreted using instruments that help produce more accurate information, compared to trial and error. If firms have many varieties of production linkage with local firms or MNEs, the number and diversity of linkages would insure accuracy when firms invest in innovation trials. If firms do not already have an instrument for internal trial and error, they can learn about other firms' trials and errors through external linkages. On the other hand, firms with sufficient internal resources or with R&D activities could acquire this information by themselves. It is also true that firms with R&D activities could learn from more types of external resources than firms without R&D activities. That is, information accuracy increases when firms successfully attract external sources into their own internal resources, including R&D activities.

There is some literature focus on information accuracy from local interactions across different fields. In the setting of agricultural innovation, for example HYV (high-yield varieties), Foster and Rosezweig (1995) develops the Bayesian framework of learning by doing and learning from others in the village context and estimates the neighborhood impacts of introducing HYV, which is a risky project in the initial stage. They show the significant impacts of neighborhood experience in updating information on input volume at the optimal level. In the setting of labor mobility, Almeida and Kogut (1999) and Song *et al.* (2003) empirically investigate the level of labor mobility through new hiring across firms *within* regions. They also show that engineers cite patents from other engineers *within* the same region. These behaviors within a cluster stimulate to the creation of accurate information from local interactions.

2.3. The Role of Linkages with Multinational Enterprises

We should not forget the presence of multinational enterprises (hereafter, MNEs) in developing economies, especially in East Asia. Since Japanese MNEs have led the formation of production networks in the region, the relationship between production networks and innovation intensity and its type should vary according to the degree of

firms' capital tie-ups with MNEs. In Indonesia and Thailand, Ramstetter and Sjoholm (2006) try to answer the following three empirical questions: (1) why multinationals pay higher wages than host countries' counterparts, and whether the entry of multinationals raises wages for domestic workers; (2) why multinationals have higher productivity and whether multinationals affect the productivity of domestic enterprises; (3) whether multinationals have a greater tendency to export than local firms. Depending on the answers to these questions, linkages with MNEs could provide positive externalities especially for local firms.

In line with this framework, we examine the effects of variety of internal- and external sources on innovation performance through the following hypotheses:

- **Hypothesis 1.**
  The variety of internal and external sources increases the benefit from combinations of varieties within each type of sources, leading to higher innovation performance.
- **Hypothesis 2.**
  Research and development activities in-house and the different types of internal and external sources complement each other, leading to higher innovation performance.
- **Hypothesis 3.**
  The different types of external sources (linkages with local firms and linkages with MNEs) complement each other, leading to higher innovation performance.

3. Data

3.1. Sampling

We used the dataset from the Establishment Survey on Innovation and Production Networks for selected manufacturing firms in four countries in East Asia. We created this dataset in December 2008 in Indonesia, the Philippines, Thailand, and Vietnam. The sample population is restricted to selected manufacturing hubs in each country (JABODETABEK area, i.e., Jakarta, Bogor, Depok, Tangerang, and Bekasi for Indonesia, CALABARZON area, i.e., Cavite, Laguna, Batangas, Rizal, and Quezon for the Philippines, Greater Bangkok area for Thailand, and Hanoi area for Vietnam). A

total of 600 firms agreed to participate in the survey: (1) 149 firms in Indonesia; (2) 203 firms in the Philippines; (3) 112 firms in Thailand; and (4) 137 firms in Vietnam. For statistical purposes respondents with missing observations are excluded from the estimated sample. Number of observations is 578 firms.

3.2. Dependent Variables

We classified innovations into the following five categories based on the Schumpeterian view: (1) product innovations (introduction of new goods); (2) production process innovations, including adoption of new technology; (3) organizational innovations to improve product quality and cost efficiency; and (4) procurement innovations, securing new suppliers to produce existing products more efficiently or to produce new products; (5) market creating innovations, securing new customers to whom new or existing products may be sold. Product innovations, production process innovations, and organizational innovation have three types respectively. Table 2a shows summary statistics of the number of types of innovations. There is a large cross-sectional dispersion of innovations within a type. The variety of product innovations for each firm is the sum the number of innovations within product innovations. The sample average (standard deviations) of variety of product innovations for the pooled dataset is 0.671 (0.870). Production process and organizational innovations are more frequent than product innovations among firms: 1.752 (1.220) and 1.469 (1.198), respectively. Procurement and market creating innovations each have seven types. There is also a large cross-sectional dispersion of innovations within a type. Procurement innovations are less frequent than market creating innovations: 2.549 (2.061) and 2.742 (2.128), respectively. The detailed characteristics of each type of innovation are shown in Table 2b.

Table 2a. Summary Statistics of the Number of Types of Innovations

	Mean	Std. Dev.	Min	Max
Number of Types of Product Innovations	0.671	0.870	0	3
Number of Types of Production Process Innovations	1.752	1.220	0	3
Number of Types of Organizational Innovations	1.469	1.198	0	3
Number of Types of Procurement Innovations	2.549	2.061	0	7
Number of Types of Market Creating Innovations	2.742	2.128	0	7

Table 2b decomposes product, production process, and organizational innovations into three varieties each. While approximately 45 percent of the firms, on average, are able to make product innovations, it appears that more firms find it difficult to achieve certain kinds of product innovations. Only 9 percent said they were able to introduce new goods to new markets, while only 11 percent were able to introduce new goods using new technology. This situation may be due to the higher fixed costs of creating new markets and using new technology in addition to the typical costs associated with product innovations.

In contrast, more than 50 percent of the firms were able to introduce process innovations, such as (1) buying new machines; (2) improving existing machines; (3) introducing new know-how to production processes; (4) earning certification from the International Standards Organization (ISO); and (5) introducing internal activities to respond to changes in their markets.

Table 2b. Summary Statistics of Product, Process, and Organizational Innovations

	Mean	Std. Dev.	Min	Max
Product Innovations				
Introduction of New Good	0.458	0.499	0	1
Introduction of New Good to New Market	0.096	0.295	0	1
Introduction of New Good with New Technology	0.117	0.322	0	1
Production Process Innovations				
Bought New Machines	0.529	0.500	0	1
Improved Existing Machines	0.673	0.470	0	1
Introduced New Know-how on Production Methods	0.550	0.498	0	1
Organizational Innovations				
Adopted an international standard (ISO or others)?	0.531	0.499	0	1
Introduced ICT and reorganized business processes?	0.342	0.475	0	1
Introduced other internal activities to respond to changes in the market?	0.597	0.491	0	1

Table 2c decomposes procurement and market creating innovations into seven varieties each. Firms reported different experiences in the task of securing new customers and suppliers depending on the locations and characteristics of the customers and suppliers. The probability of securing a new local supplier or customer in a metropolitan area in which the respondent is also located is higher (63 percent for securing a new supplier and 65 percent for securing a new customer) than the probability of securing a new supplier or customer outside the metropolitan area (56

percent for securing a new supplier and 58 percent for securing a new customer). Securing a new supplier or customer in other ASEAN countries is more difficult for the four countries involved in the study (32 percent for securing a new supplier and 27 percent for securing a new customer). Sample firms also found it difficult to buy inputs from, or sell products to, MNEs. Only 17 percent of the firms successfully secured new multinational suppliers within a metropolitan area while only 16 percent were able to do so outside the metropolitan area. Between the two tasks, however, firms found it easier to sell products to MNEs than to buy inputs from them. Nearly 30 percent of the firms successfully secured new multinational customers within an agglomeration area, while 21 percent did so outside. Figure 2 summarizes the distribution of the number of innovations across firms in East Asia: the number of innovations across firms looks like a normal distribution with a fat-tail of zero innovation. The cross-country difference in the number of innovations across firms is shown in Figure 4. Panels in Figure 4 suggest that many firms in The Philippines achieve zero innovations while some firms in Thailand achieve many types of innovation.

Table 2c. Summary Statistics of Market-based Innovations

	Mean	Std. Dev.	Min	Max
Procurement Innovations				
Secured a new local supplier (100% local capital) in survey city	0.636	0.481	0	1
Secured a new local supplier (100% local capital) in the country outside survey city	0.567	0.496	0	1
Secured a new Multinational Company (MNC) (100% foreign capital) or joint venture (JV) supplier in survey city	0.174	0.379	0	1
Secured a new MNC or JV supplier in the country outside survey city	0.162	0.369	0	1
Secured a new supplier in other ASEAN countries	0.327	0.470	0	1
Secured a new supplier in other countries in East Asia (China, Japan, Korea, Taiwan)	0.380	0.486	0	1
Secured a new supplier in other foreign countries	0.302	0.460	0	1
Market Creating Innovations				
Secured a new local customer (100% local capital) in survey city	0.653	0.476	0	1
Secured a new local customer (100% local capital) in the country	0.580	0.494	0	1
Secured a new MNC or JV customer in survey city	0.307	0.462	0	1
Secured a new MNC or JV customer in the country	0.218	0.413	0	1
Secured a new customer in other ASEAN countries	0.271	0.445	0	1
Secured a new customer in other countries in East Asia (China, Japan, Korea, Taiwan)	0.347	0.476	0	1
Secured a new customer in other foreign countries	0.365	0.482	0	1

3.3. Independent Variables Explaining Innovation Performance

The independent variables are presented in Table 3. The main independent variables are types of sources and the variety of sub-sources within each main type of source as depicted in Table 1. Table 3 shows R&D activities, number of types of internal resource (nine different varieties of internal resource), number of types of linkage with local firms (six different varieties of linkage), number of types of linkage with MNEs (six different varieties of linkage), number of types of linkages with public organization (six different varieties of linkage), number of types of linkages with universities (three different varieties of linkage).

Rigorously speaking, we count the number of *varieties* of linkages. If the firm has a linkage to a local or foreign customer or supplier, we count that as *one* type of local or foreign production linkage. In addition, if the firm has a linkage to a local or foreign university, we also count that as another type of local or foreign intellectual linkage. This means that such a firm has two types of linkage.

R&D activities are carried out by twenty-two percent of firms. On first glance R&D activity is quite low among firms in East Asia. Notably, there is also a large cross-sectional dispersion of linkages among firms as well as dependent variables. Many firms have few internal or external sources and some firms are able to sustain many internal resources, and production- and intellectual linkages. The detailed variety of linkages is also quite different across types of linkage. The sample average (standard deviation) of the number of sources is 4.05 (3.20) types of internal resources. Firms with linkages with local firms only have 1.88 types of linkages on average while firms holding linkages with MNEs have an average of 1.89 types of linkage. Firms with public linkages have 1.50 types on average. As Table 3, suggests firms usually have less than two types of production and public linkage, though standard deviations are quite large. On average, firms holding linkages with universities only have 0.66 types of linkage.

Additionally, we can show that detailed evidence is excluded from Table 3. The most striking evidence of technical transfer is that production-related linkages are more cultivated than intellectual/information linkages. For example, collaboration with joint ventures established by a sample firm with other local firms and collaboration with a local supplier or customer were seen in 32 percent and 41 percent of the firms,

respectively. On the other hand, 27 percent of the firms accepted technical assistance financed or provided by a government or public agency while 23 percent engaged in technical cooperation projects with a local university. Technology transfer between firms is prevalent, and University-Industry Linkages (hereafter, UIL) do not play a key role in technology transfer in East Asia.

Furthermore, many firms also rely on internal sources for information on upgrading and innovation. Thirty-four percent of the surveyed firms depend on their own R&D departments as a source of information and R&D initiatives, while 38 percent utilize their own sales departments and sales agents as information sources. Fifty-one percent of surveyed firms use technological agreements with headquarters or affiliated firms; 62 percent look to their own production and manufacturing departments when undertaking upgrades.

Table 3. Summary Statistics and Correlations of Independent Variables (Sources and Controls)

		Mean	Std. Dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	R&D activities (1 if Yes, 0 otherwise)	0.221	0.416	0	1	1								
(2)	Number of types of internal resources	4.051	3.203	0	9	0.2726*	1							
(3)	Number of types of linkages with local firms	1.881	2.251	0	6	0.1858*	0.7887*	1						
(4)	Number of types of linkages with MNEs	1.878	2.282	0	6	0.1403*	0.7584*	0.7457*	1					
(5)	Number of types of linkages with public organizations	1.509	2.383	0	6	0.1768*	0.6494*	0.7894*	0.5804*	1				
(6)	Number of types of linkages with universities	0.663	1.175	0	3	0.1838*	0.6406*	0.7777*	0.6135*	0.8740*	1			
(7)	Multinational Enterprises	0.251	0.434	0	1	-0.1621*	0.0026*	-0.1117*	0.0695	-0.2406*	-0.2070*	1		
(8)	Age	14.202	12.392	1	80	0.2370*	-0.0112*	-0.0002	-0.056	0.1072*	0.1037	-0.2990*	1	
(9)	Full-time Employees	293.879	456.483	10	2000	0.1950*	0.0607	-0.0596	0.0426	-0.0644	-0.0351	0.1462*	0.2112*	1

Note: Correlations with asterisk ($p < 0.01$).

3.4. Other Control Variables

Table 3 also presents the summary statistics of the control variables. "Multinational Enterprises" is a dummy variable equal to one for a firm that is wholly funded by foreign capital. Multinationals can access global technology across frontiers and belong to international markets. This is not only a proxy of financial advantage for innovation but also a proxy of technology advantage compared with local firms. Age and employment size are also attributes of innovation. Long-established firms have a history of established production linkages and accumulated innovations. There is also a difference in the types of innovation and innovation investments that large and small/medium firms make. Cross-country differences can be attributed to fundamental differences in the causes and consequences of innovation in response to market conditions.

Average age of a firm is 14 years, with a standard deviation of 12 years. Firm size is also much dispersed. Average size is 293 employees, with a standard deviation of 456. Since our sampling strategy covers the whole of manufacturing in each country, some firms have more than 2,000 employees while some firms are very small, with fewer than 20 employees. Of the total number surveyed, approximately 60 percent are local firms; 13 percent joint-venture firms; and 25 percent, MNEs.

4. Results

4.1. The Varieties of Innovation within Each Type

To what extent are firms with and without linkages able to carry out innovation? In this section, we answer this question in order to present the effects of diversity of linkage on innovation performance. Innovation performance is measured by two ways: (1) how different varieties of innovation are achieved simultaneously within each main type of innovation; (2) how each variety of innovation is achieved. In order to answer the first empirical question, we have two assumptions. First, this paper simply assumes that each type of innovation and linkages are additive manner. Secondly, we also assume that firms which have many types of linkage have potentially several

directions from which they can source knowledge. This also could be information sources of innovation activities or upgrading. We set the estimated equation to explain the firm's achievement of several types of innovation as in the following ordered logit model:

$$Logit\ (y_{ic}) = \alpha R_{ic} + \beta VARIETY\_LINK_{ic} + \gamma x_{ic} + u_{ic},$$

where *y* means the number of types of innovation performed by each firm *i* located in each country *c*, the variable *R* signifies whether each firm has R&D activities or not, the variable *VARIETY_LINK* signifies the number of types of linkages, i.e., production linkages with local customers or suppliers, linkages with MNCs or Joint Ventures, linkages with public support institutions, and linkages with academics, *x* is other controls, i.e., age of firm, size, whether or not it engages in exporting goods to foreign countries, whether or not it imports intermediate goods from foreign countries, and country dummy variables. An error term follows logistic distribution and this is shown by *u*. We estimate this ordered logit model to simply regress the dependent variable (the number of types of innovation carried out) to independent variables and controls. We focus on the estimated coefficient of *VARIETY_LINK* as the degree of innovation management technology across firms, which transform several different types of linkages into different kinds of innovation achievement.

Table 4 presents the baseline results of the impacts of different types of linkage on different varieties of innovation within each type. The dependent variable is the number of varieties of innovation within each type, i.e., the sum of varieties within product innovations, the sum of varieties within production process innovations, the sum of varieties within organizational innovations, the sum of varieties within procurement innovations, and the sum of varieties within market creating innovations.

Column (1) of Table 4 shows that the coefficient for the R&D activities is .804 with standard error of .223 for product innovations; it is statistically significant at the 1 percent level. In other words, when a firm carries out R&D this raises the number of varieties within product innovation, through introducing new products to new markets or introducing new products using new technologies. The effects of R&D activity are quite pervasive and significant in explaining other types of innovation: production

process innovation, organizational innovation, procurement innovation, and market creating innovation as shown in column (2) to (5).

The coefficient for the number of types of internal resource is .180 with a standard error of .063 in explaining the number of varieties of product innovations; it is statistically significant at the 1 percent level. Firms with more varieties of internal resource could introduce significantly more new products than firms with fewer varieties of internal resource, even after controlling for firm and country characteristics. However, the impacts of internal resources disappear in explaining innovations in production process, organizational level, procurement, and market creation.

The impacts of linkages with local firms and with MNEs have different directions compared to the results for internal resources. As shown in column (4), the coefficient for the varieties of linkage with local firms is .168 with a standard error of .068 in explaining procurement innovations; it is statistically significant at the 5 percent level. As shown in column (5), the coefficient for the number of types of linkages with local firms is .139 with a standard error of .072 in explaining procurement innovations; it is statistically significant at the 10 percent level. These results suggest that the varieties of linkage with local firms promote procurement and market creating innovations.

The coefficient for the number of varieties of linkage with MNEs is -0.163 with a standard error of .067 in explaining product innovations; it is statistically significant at the 5 percent level. The coefficient for the number of varieties of linkage with MNEs is .10 with standard error of .055 in explaining market creating innovations; it is statistically significant at the 10 percent level. Firms with linkages with MNEs have a lower propensity to produce new products, while such firms have a higher propensity to find new markets. This result suggests that MNEs in East Asia focus on organizational, procurement and market-creating innovation, rather than product or production process innovation.

On the other hand, the impact of varieties of linkages with public organizations and universities is not significant. Cross-country differences in the variety of innovations are apparent: firms in Indonesia and the Philippines innovate less than those in Thailand. This sample also reflects the difference between less developed countries in East Asia such as Indonesia and the Philippines and more developed countries such as Thailand.

Table 4. Number of Linkages and Number of Innovations by Function

Ordered Logit Model	(1)	(2)	(3)	(4)	(5)
Dependent variables: Number of varieties of innovations within each type	Type: Product Innovations	Type: Process Innovations	Type: Organizational Innovations	Type: Procurement Innovations	Type: Market Creating Innovations
R&D activities	0.804**	0.920**	1.231**	0.705**	0.599*
	[0.223]	[0.224]	[0.218]	[0.249]	[0.243]
Number of varieties of internal resources	0.180**	0.005	0.053	0.021	0.059
	[0.063]	[0.054]	[0.054]	[0.055]	[0.048]
Number of varieties of linkages with local firms	-0.009	-0.043	0.082	0.168*	0.139+
	[0.083]	[0.072]	[0.103]	[0.068]	[0.072]
Number of varieties of linkages with MNEs	-0.163*	0.043	0.093	0.063	0.100+
	[0.067]	[0.069]	[0.071]	[0.057]	[0.055]
Number of varieties of linkages with public organizations	0.100	0.075	0.017	-0.011	-0.030
	[0.086]	[0.079]	[0.092]	[0.071]	[0.078]
Number of varieties of linkages with universities	-0.096	-0.118	-0.136	-0.006	0.050
	[0.178]	[0.160]	[0.187]	[0.111]	[0.124]
Multinational Enterprises	-0.422+	-0.645**	1.550**	1.160**	0.580*
	[0.248]	[0.235]	[0.236]	[0.223]	[0.227]
Age	0.003	0.009	-0.004	0.004	0.008
	[0.008]	[0.007]	[0.007]	[0.008]	[0.007]
Full-time Employees	0.001**	0.001**	0.001**	0.000*	0.000+
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Indonesia	-0.335	-0.497+	-1.963**	-0.773**	-1.373**
	[0.308]	[0.286]	[0.322]	[0.264]	[0.272]
Philippines	0.496	-0.090	-1.059**	-0.189	-1.360**
	[0.334]	[0.324]	[0.334]	[0.278]	[0.285]
Vietnam	-0.567	-1.320**	-1.324**	0.947*	0.237
	[0.440]	[0.383]	[0.422]	[0.377]	[0.353]
Observations	587	587	587	587	587

Notes: Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%. Reference country is Thailand.

4.2. Complementarities between R&D and Linkages: Production Process Innovations

To what extent are firms with R&D able to make innovations when they have a variety of internal and external sources? We test this question here to focus on production process innovation: that is, on introducing new machines. Table 5 reports the interaction terms of R&D and several types of internal and external sources, as well as the effects of R&D and several types of internal and external sources. We use a Probit model to estimate the marginal impacts of complementarities between R&D and linkages, on investment in new machines. First of all, the marginal impacts of R&D activities and each type of internal- and external source are not significant by themselves with respect to the introduction of new machines. Several specifications of R&D and linkages do not strongly suggest their own impacts. What have to be noticed are interaction terms between R&D activities and linkages.

Column (1) of Table 5 suggests that the coefficient for interaction terms between R&D activities and number of varieties of internal resources is .056 with a standard error of .017; it is statistically significant at the 1 percent level. Column (2) of Table 5 suggests that the coefficient for interaction terms between R&D activities and number of varieties of linkages with local firms is .064 with a standard error of .023; it is also statistically significant at the 1 percent level. Column (3) of Table 5 suggests that the coefficient for interaction terms between R&D activities and number of varieties of linkages with MNEs is .049 with a standard error of .023; it is statistically significant at the 5 percent level. Column (4) of Table 5 suggests that the coefficient for interaction terms between R&D activities and number of varieties of linkages with public organizations is .058 with a standard error of .022; it is also statistically significant at the 1 percent level. Finally, Column (5) of Table 5 suggests that the coefficient for interaction terms between R&D activities and number of varieties of linkages with universities is .085 with a standard error of .044; it is statistically significant at the 10 percent level. These results show the apparent evidence of complementarities between R&D activities and internal- and external sources.

Table 5. Number ofVarieties of Linkages Explains Introducing New Machines

Probit Model (Marginal Effects)	(1)	(2)	(3)	(4)	(5)
Dependent variables: Probability of Introducing New Machines					
R&D activities	-0.113	0.013	0.065	0.048	0.090
	[0.103]	[0.083]	[0.076]	[0.078]	[0.074]
Number of varieties of internal resources	-0.021	-0.006	-0.011	-0.006	-0.008
	[0.016]	[0.016]	[0.016]	[0.016]	[0.016]
Number of varieties of linkages with local firms	-0.023	-0.041+	-0.022	-0.028	-0.024
	[0.021]	[0.023]	[0.021]	[0.021]	[0.021]
Number of varieties linkages with MNEs	-0.018	-0.016	-0.029	-0.015	-0.016
	[0.018]	[0.018]	[0.019]	[0.018]	[0.018]
Number of varieties of linkages with public organizations	0.011	0.008	0.011	-0.003	0.010
	[0.021]	[0.022]	[0.022]	[0.022]	[0.022]
Number of varieties of linkages with universities	0.033	0.033	0.031	0.032	0.015
	[0.042]	[0.042]	[0.042]	[0.042]	[0.044]
R&D activities x Number of varieties of internal resources	0.056**				
	[0.017]				
R&D activities x Number of varieties of linkages with local firms		0.064**			
		[0.023]			
R&D activities x Number of varieties of linkages with MNEs			0.049*		
			[0.023]		
R&D activities x Number of varieties of linkages with public organizations				0.058**	
				[0.022]	
R&D activities x Number of varieties of linkages with universities					0.085+
					[0.044]
Multinational Enterprises	-0.181**	-0.183**	-0.175**	-0.190**	-0.182**
	[0.060]	[0.059]	[0.060]	[0.059]	[0.059]
Age	0.000	0.000	-0.001	0.000	0.000
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Full-time Employees	0.000**	0.000**	0.000**	0.000**	0.000**
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Indonesia	-0.133	-0.134	-0.137+	-0.117	-0.120
	[0.082]	[0.083]	[0.082]	[0.082]	[0.082]
Philippines	-0.078	-0.071	-0.080	-0.062	-0.067
	[0.091]	[0.092]	[0.091]	[0.092]	[0.091]
Vietnam	-0.041	-0.057	-0.047	-0.055	-0.053
	[0.114]	[0.113]	[0.113]	[0.113]	[0.113]
Observations	587	587	587	587	587

Notes: Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%. Reference country is Thailand.

4.3. Complementarities between Two Types of External Sources: Procurement Innovations

Finally, we can approach following question: to what extent are firms with local firms able to do innovations when they have linkages with MNEs? We test this question here to focus on inside the procurement innovations: securing new supplier. Table 6 reports the interaction terms of linkages with local firms and linkages with MNEs as well as the effects of linkages with local firms and linkages with MNEs. We also use a Probit model to estimate the marginal impacts of complementarities between the above two types of linkages on finding new suppliers. Columns (1) to (4) of Table 6 show the results for finding a new supplier within domestic areas while columns (5) to (7) of Table 6 show the results for international evidence.

First of all, the interaction terms are not significant in columns (1) to (4), which present the results of finding a new supplier within domestic areas. These results do not show any evidence of complementarities between two types of external sources. In column (5), the interaction term (number of varieties of linkages with local firms and number of varieties of linkages with MNEs) is significant in explaining the finding of a new supplier in other ASEAN countries. In column (7), the interaction term is also significant in explaining the finding of a new supplier in other foreign countries (EU or US). These results show evidence of complementarities between two types of external sources.

Table 6. Number of Varieties of Linkages Explains Securing New Supplier

Probit Model (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables: Probability of Securing New Supplier	New Local Supplier in Near Area	New Local Supplier outside Area	New MNEs or JVs Supplier in Near Area	New MNEs or JVs Supplier outside Areas	New Supplier in other ASEAN	New Supplier in East Asia	New Supplier in other Foreign Countries
R&D activities	0.051	0.041	0.077+	0.087+	0.088	0.125+	0.110+
	[0.057]	[0.060]	[0.046]	[0.046]	[0.061]	[0.066]	[0.061]
Number of varieties of internal resources	-0.003	0.034*	-0.001	0.003	-0.006	-0.003	0.012
	[0.015]	[0.016]	[0.010]	[0.010]	[0.016]	[0.017]	[0.015]
Number of varieties of linkages with local firms	0.072**	0.037+	-0.028	0.009	0.025	0.023	-0.030
	[0.024]	[0.022]	[0.017]	[0.018]	[0.025]	[0.026]	[0.024]
Number of varieties linkages with MNEs	-0.036	-0.040	0.0010	0.000	-0.031	0.029	-0.051+
	[0.028]	[0.032]	[0.019]	[0.018]	[0.027]	[0.033]	[0.029]
Number of varieties of linkages with public organizations	-0.020	-0.049*	0.026+	0.002	0.030	0.000	0.048*
	[0.021]	[0.022]	[0.015]	[0.015]	[0.026]	[0.027]	[0.022]
Number of varieties of linkages with universities	-0.012	-0.035	0.000	-0.006	-0.045	0.001	-0.023
	[0.039]	[0.042]	[0.032]	[0.029]	[0.048]	[0.046]	[0.042]
Number of varieties of linkages with local firms x Number of varieties of linkages with MNEs	-0.002	0.009	0.005	0.004	0.013*	0.003	0.016**
	[0.006]	[0.006]	[0.004]	[0.004]	[0.006]	[0.007]	[0.006]
Multinational Enterprises	0.102+	-0.130*	0.012	0.053	0.325**	0.498**	0.328**
	[0.057]	[0.061]	[0.041]	[0.044]	[0.057]	[0.053]	[0.057]
Age	-0.003+	0.000	0.000	0.003*	0.002	0.003	0.002
	[0.002]	[0.002]	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]
Full-time Employees	0.000	0.000	0.000**	0.000*	0.000*	0.000	0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Indonesia	-0.159+	-0.313**	-0.051	-0.071	-0.134+	-0.107	-0.059
	[0.082]	[0.076]	[0.050]	[0.045]	[0.074]	[0.080]	[0.082]
Philippines	-0.321**	-0.092	-0.028	0.046	0.144	0.112	0.189+
	[0.084]	[0.090]	[0.060]	[0.064]	[0.097]	[0.101]	[0.107]
Vietnam	0.203*	0.127	0.158	0.037	0.398**	0.233+	0.460**
	[0.098]	[0.121]	[0.111]	[0.088]	[0.127]	[0.132]	[0.138]
Observations	587	587	587	587	587	587	587

Notes: Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%. Reference country is Thailand.

5. Summary and Discussion

The findings here can be summarized as follows: in-house R&D activities raise the number of varieties within product innovation. The effects of R&D activities are pervasive and significant for production process innovations, organizational innovations, procurement innovations, and market creating innovations. Secondly, firms with more varieties of internal resource could introduce significantly more new products than firms with fewer varieties of internal resources. Thirdly, the varieties of linkage with local firms foster procurement and market creating innovations. Fourthly, firms with linkages to MNEs have a lower propensity to introduce new products, but a higher propensity to find new markets. Fifthly, the impacts of varieties of linkages with public organizations and universities are not significant. This could be due to a similarity of sources within public or university linkages. The benefits of diversity will not be shown for these linkages. Sixthly, there is evidence of complementarities between R&D activities and internal and external sources. Finally, complementarities between linkages with local firms and linkages with MNEs do not aid procurement innovation in terms of the domestic market. On the other hand, complementarities between linkages with local firms and linkages with MNEs do assist procurement innovation in the international market. Linkages with MNEs play an important role in providing knowledge for international procurement.

What is the policy implication of this network-based theory of innovation? Policy resources should be allocated to the reduction of obstacles to research and development activities, and to the establishment of internal and external sources. Since information exchanges with different sources happen at the local and international levels, (1) the innovation impact of research and development activities is stimulated both at the local and the international level, and (2) business matching within and across regions could stimulate the upgrading of firms and industries through intra-regional or international knowledge exchanges at the different stages of innovation.

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