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Interactive Learning-driven Innovation in Upstream-Downstream Relations: Evidence from Mutual Exchanges of Engineers in Developing Economies[*]

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Abstract. This paper presents a simple model of the innovations that result from face-to-face communication and mutual learning in upstream-downstream relations. To examine the framework, we empirically investigate the impact of mutual knowledge exchanges on product and process innovation using a survey of manufacturing firms in Indonesia, the Philippines, Thailand and Vietnam. Evidence from interconnected firms in developing economies suggests that firms with mutual exchanges between engineers and customers achieved product innovations with new technologies and new markets. However, this is not true for simple improvement of products or process innovation. Mutual exchanges with engineers can be expected to play an important role in the case of costly innovation and in situations unknown situation to the firms.

Keywords: Interactive learning, innovation, mutual exchanges of engineer, production chain

JEL Classification: O31, O32, R12

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1. Introduction

This paper constructs a new framework that links product and process innovations with explicit knowledge exchanges between firms in developing economies. We assume that detailed evidence of production linkages provides the information on knowledge exchanges between a company's own firms and their partners (customers and suppliers). Identifying detailed evidence of linkages opens a black-box of knowledge creation and the learning process among firms that deeply involves internal and international production chains. A canonical model of knowledge exchanges among engineers between their own firms and partners has been identified. This paper also investigates the empirical implications of this mechanism using the data gathered from manufacturing firms in five megacities in East Asia where there has been vertical specialization and fragmentation of production processes. The five cities are located in Indonesia, the Philippines, Thailand and Vietnam. Data collection through in-depth field surveys and interviews includes product and process innovations, mutual knowledge exchanges between upstream-downstream firms, detailed information on technology transfer of linkages between production and information, and respondent firms' own characteristics.

Based on the fact that most production processes are sequential, knowledge should be exchanged in upstream and downstream relations within a production chain. The cause and consequences of interdependence between firms in ASEAN and East Asia has been investigated in a framework of vertical specialization and fragmentation of production processes such as Kimura (2006), Kimura and Ando (2003, 2005), Kimura and Obashi (2009, 2010, and 2011), and Obashi (2009). Most recent theoretical contributions are Costinot, *et al.* (2011) and Antras and Chor (2011) which focus how sequential nature of production processes could shape specialization patterns of countries or boundaries of firm and allocation of control rights, but there is a huge lack of empirical study about how production chains upgrade themselves and how information spillovers in upstream and downstream relations within a chain.

There are several important findings on technology transfer from Multinational enterprises (here after MNEs) to local firms using firm-level data. Aitken and Harrison (1999) show positive impacts of foreign equity participation on plant productivity for small enterprises among Venezuelan plants. They also find foreign investment negatively affects the domestic plant's productivity. They conclude that the net gain from foreign direct investment is quite small if we take into account the two offsetting effects. Javorcik (2004) and Blalock and Gertler (2008) find backward linkage impacts in terms of productivity growth for local suppliers from MNEs customers by using the share of MNEs in downstream sectors as an explanatory variable. Blalock and Gertler (2008) interpret there is a sizable technology transfer to upstream firms from downstream MNEs behind empirical estimates of the relationship between the share of MNEs in downstream firms and productivity growth.

Contrary to these previous work, this paper surveys direct evidence that precisely captures the knowledge transmission mechanism through interaction among local producers and MNEs or Joint Venture firms. Since this paper has collected the information who exchanges information with whom through engineer exchanges, we can fill the gap utilizing firm's self-reported data on customer-supplier relationships. There are also a few empirical papers that test if interfirm learning is relation-specific (Kellogg 2011, Machikita and Ueki 2011a and 2011b).

The concept of interactive learning and innovation has been developed by study of user/producer interactions, most notably by Lundvall (1985, 1988), and seminal works on user-driven innovation by von Hippel (1986, 1988, 2005) over the course of two decades. These existing works on interactive learning also have played an important role by re-highlighting Polanyi's classical and very important argument on the extent of the tradability of knowledge and the tacit dimension of knowledge exchanges (see Polanyi 1958, 1966). This paper utilizes the theoretical framework of interactive learning and innovation to understand how firms and their production partners may interact in the face of a firm's upgrading in developing economies. In the context of firms and information transactions in developing economies, we try to provide a modern empirical treatment of interactive learning and innovation based on new contributions from economic geography, for example Berliant and Fujita (2008, 2009) and Fujita (2007). In this paper, we try to interpret our empirical results by using the implications of classic management research and the recent economic contributions on interactive learning. Next, we combine our empirical results with findings from Teece (2009) to obtain deeper insight into absorptive and desorptive capacity in technology transfers across firms in developing economies.

What is the recent economic research on interactive learning and innovation? How should we use it when we consider the industrial development among firms in the interconnected world? To pin down the effect of interactive learning and innovation, this paper focuses on face-to-face communications between engineers in upstream and downstream firms. Now we will outline a theoretical framework for determining the linkage impact of innovation and mutual knowledge exchanges between upstream and downstream relations in industrial development. Econometric evidence suggests that mutual knowledge exchanges drive innovation. Some evidence is robust in support of the conclusion that mutual knowledge exchanges matter in innovation. The theoretical background of this paper consists of several model of learning and knowledge creation through face-to-face communication among different types of agents as developed by Berliant and Fujita (2008, 2009). The central concern of these models is how diversity of knowledge among members could affect decisions on collaboration and its outcome. In that sense, diversity of knowledge among firms and exchange of knowledge between firms could have aggregate implications like a city system as well as agglomerations of firms.

However, it has been difficult to capture and quantify the information flow between agents—one of the growing fields in development, labor and industrial organization—specifically in the study of network impact on productivity growth. The following research studies have been successful in identifying the exact information flows among agents. Conley and Udry (2009) study the impact of input use of informational neighbors for pineapple farmers in Ghana on their own input use and productivity. Goyal (2007), Jackson (2008) and Easley and Kleinberg (2010) showed the measurement and theoretical framework of information diffusion through a network. Firm-level productivity growth depends on the types of production or intellectual linkages that they have. It is also true that productivity affects entry or exit, especially when the hub-firm is located centrally to the production network. Given this situation, the dense network in East Asia could provide new insight into the causes and consequences of information diffusion among local firms. This paper aims to study the impact on innovation of mutual knowledge exchanges among interconnected firms in the field of industrial development. This paper is also related to the fields of international technology diffusion and international knowledge production. Keller (2004) presented an overview of the causes and consequences of technology diffusion across countries. Kerr (2008, 2010) and Kerr and Lincoln (2010) studied the role of ethnic scientific communities in technology diffusion by matching ethnic scientists' names with individual patent records.

A testable hypothesis considers the impacts of mutual exchange on product and process innovations using firms' self-reported customer and supplier data. With this, we can establish inter-firm connectivity network data. The data reveals not only the impact on innovation of mutual exchanges between connected firms but also the motivation from direct information flow upstream to downstream or vice versa. The findings also show that manufacturing firms are more likely to achieve product innovations when they have engineers engaged in mutual exchanges with specific customers, especially for new product development using technologies for a new market. Mutual knowledge exchanges with customers do not have any significant impact on production process innovation, except for changing cost controls which are affected by customers' requirements more than other types of organizational improvements. This entails close collaboration with the primary customer in the stage of costly innovation, for example product innovation based on new technologies and new markets. On the other hand, suppliers are less likely to have impact on improvement of existing machines and development of new products after the mutual exchange. The next section demonstrates an empirical hypothesis. Section 3 describes the data collected in Indonesia, the Philippines, Thailand and Vietnam. Section 4 shows the impact on innovation of mutual knowledge exchanges with engineers. Section 5 presents the interpretation of the results, and Section 6 states the conclusion.

2. Framework and Hypothesis

This section presents our testable hypothesis based on the theoretical framework of interactive learning and innovation. As we discussed in the Introduction, there is much literatures on interactive learning and innovation, for example Lundvall (1985, 1988) and von Hippel (1986, 1988, 2005). Interactive learning seems to be useful for considering the impact of the production network on industrial upgrading in East Asia where there is denser and wider transaction of intermediate goods within and across countries. So, what implications does the theory of interactive learning have if we apply the framework to industrial development? To understand the relationship between interactive learning and industry upgrading, the implications of interactive learning and innovation should be tested in the context of firms and economic transactions in developing and emerging economies.

This paper focuses on technology transfer between production partners and its impact on innovation. Technology transfer is a truly costly activity for two parties because the recipients are required by their production partners to have absorptive capacity, while donors always have significant opportunity costs of production when they transfer technologies to their production partners. It is natural for both parties to exchange their personnel when the benefits from interactive learning are higher for both parties, for example in the period when both parties introduce a product which is new to the firms.

Before presenting our testable hypothesis, we summarize the main, key assumptions of this paper as follow. Firstly, introduction of new products based on new technologies seems to be more unfamiliar to the firm; it is more costly than introduction of new products based on existing technologies. Secondly, mutual exchanges of engineers between customers and suppliers are more costly for two parties than unidirectional information flows achieved by dispatching or accepting engineers. Thirdly, the benefit from the propensity to upgrade through innovations to the firm could be higher if both parties were to choose face-to-face communications by exchanging engineers. The hypothesis to be tested in this paper is as follows.

Testable Hypothesis: Introduction of new products based on new technologies is more likely to occur if two parties choose *both* to dispatch engineers to *and* accept engineers from each other (that is, mutual exchanges of knowledge). Conversely, if two parties choose *either* to dispatch engineers to production partners *or* accept engineers from their counterparts (that is, unidirectional information flows), then easy innovation based on existing technologies is more likely to occur.

We tested this hypothesis by using a questionnaire-based firm-level survey of companies in Indonesia, the Philippines, Thailand and Vietnam.

3. Data on Firms' Self-reported Customers and Suppliers

3.1. Sampling

The sample industries are currently operating in East Asia and are primarily involved in the manufacturing sector (and in exporting for some firms). The dataset used is from the Establishment Survey on Innovation and Production Networks of selected manufacturing firms in four countries in East Asia. In December 2009, a dataset was created for Indonesia, Philippines, Thailand and Vietnam. The sample population is restricted to 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 and Ho Chi Minh area for Vietnam). A total of 864 firms agreed to participate in the survey, as follow: (1) 183 firms in Indonesia, (2) 203 firms in the Philippines, (3) 178 firms in Thailand, and (4) 300 firms in Vietnam. The sample industries consist of 17 manufacturers for each country.

3.2. Firm characteristics

Table 1 presents a summary of firm characteristics. The average term of existence of a firm is 16.8 years with a standard deviation of 13.9 years. Firm size varies widely, averaging 340 employees with a standard deviation of 499. Since the sampling strategy covers the whole of manufacturing in each country, some firms have more than 2,000 employees while others are as small 20 employees or fewer. Of the total number surveyed, approximately 67.5% are local firms, 14.5% are joint-venture firms, and 17% are multinational enterprises (MNEs). Firm function is classified into one of nine categories. Seventeen percent of the firms produce raw materials. Forty-two percent of the firms process raw materials. Thirty-six percent produce components and parts, while 63% produce final goods. In addition to Table 1, a total of 19% procure raw materials, while 24% carry out logistics. Only 2% of the firms have an information technologies department. Twenty percent of firms have sales, while 40% carry out marketing activities.

The average size of domestic sales is calculated by the average number of local customers (producers), i.e., on the average 27.8 customer firms with standard deviation of 25.7. There is a considerably larger dispersion in shipping across respondent firms. The average span of the product life cycle is 2.9 years with a standard error of 2.2 years. So, there is also a larger dispersion in the years of the product life cycle. The average number of product types is 6.9 with a standard error of 4.2. There are firms with many types of products, while others have only a single product.

Now, with regard to the characteristics of top management and worker characteristics within the firm, 28.4% of the employees hold a master's degree or higher. Almost 57.8% of top managers rise from the engineering ranks. Moreover, 45.9% of top management have multinational or joint venture experience. The percentage of high school graduates among blue-collar workers is 58.1%, while the percentage of technical college graduates among engineers is 50.4%.

Table 1: Summary Statistics of Firm Characteristics

	Mean	Std. Dev.
R&D activities (1 if Yes, 0 otherwise)	0.501	0.500
Age	16.796	13.922
Full-time Employees	340.198	514.347
Local Firms	0.675	0.469
Joint Venture Firms	0.145	0.352
Food	0.111	0.314
Textiles	0.053	0.225
Apparel	0.053	0.225
Wood	0.043	0.203
Paper	0.051	0.220
Chemical	0.049	0.215
Plastic	0.080	0.271
Nonmetal	0.015	0.122
Iron	0.047	0.213
Metal	0.063	0.242
Machinery	0.063	0.242
Computers	0.023	0.150

	Mean	Std. Dev.
Electronics	0.095	0.293
Precision	0.019	0.135
Auto	0.058	0.234
Transport	0.009	0.096
Production (raw material)	0.176	0.381
Production (processing)	0.427	0.495
Production (components and parts)	0.345	0.476
Production (final products)	0.589	0.492
Size of domestic sales	27.833	25.770
Years of product life cycle	2.973	2.254
Number of product types	6.962	4.234
Top management have a master degree	0.284	0.451
Top management was engineer	0.578	0.494
Top management have an experience for MNC/JV	0.459	0.499
Ratio of high school graduates among blue-collar workers	58.191	27.665
Ratio of technical college graduates among engineers	50.453	36.371

Source: ERIA Establishment Survey 2009.

3.3. Dependent variables

To keep pace with the domestic demand and stay on top of international competition, the firms adopt new technologies, acquire new organizational forms to adapt to market changes, create new markets, find new inputs to improve product quality and cost efficiency, and introduce new products. Table 2 shows that the companies' main interests are product and process innovations. Innovative activities reflect several dimensions of industry upgrading. There are large variations in firm's policies for industry upgrading. Three different groups of measures were identified: (1) introduction of new goods, (2) adoption of new technologies and facilities and (3) changes in organizational structures.

An approximately 64% of the sample firms are able to change the design of their existing products. More than 80% of the firms improve their existing products. Almost 70% of the firms develop new products based on existing technologies, while 57% utilized new technologies. These results suggest that it is more difficult to achieve product innovation combined with new technologies. Eighty-five percent of firms are able to sell new products to the existing market, while 71% of firms are able to sell new products to a new market. These results also imply that creation of a new market is difficult and costly.

How about process innovations? More than 83% of the firms are able to buy new machines. Seventy percent of firms improved their existing machines. Likewise, 71% of firms introduced new know-how in production methods by making several types of changes in the production process, for example in quality, production, cost controls in terms of plant operation, marketing, inventory, procurement and delivery controls through shipping. These firms tend to change production processes more than shipping processes. There are also several types of changes in management practices, that is, in accounting systems, human resource management practices (hereafter HRMP), environment management and adoption of International Standard (hereafter ISO). Changes in the accounting system and HRMP within a firm are more popular than complying with regulations and global standardization.

Table 2: Summary Statistics of Product and Process Innovations

	Mean	Std. Dev.
Product Innovations		
(1) Change Design	0.639	0.481
(2) Improvement of Existing Product	0.841	0.365
(3) Development of New Product based on Existing Technologies	0.692	0.462
(4) Development of New Product based on New Technologies	0.573	0.495
(5) New Product to Existing Market	0.845	0.362
(6) New Product to New Market	0.712	0.453
Process Innovations		
(1) Bought New Machines	0.656	0.475
(2) Improved Existing Machines	0.831	0.375
(3) Introduced New Know-how on Production Methods	0.704	0.457
(4) Change Quality Control	0.789	0.408
(5) Change Production Control	0.840	0.367
(6) Change Cost Control	0.801	0.400

Source: ERIA Establishment Survey 2009.

3.4. Connectivity variables

We present the forms of guidance, transferred technology, and partners' characteristics here. Firms utilize exchanges of knowledge among production partners (their own customers and suppliers) for upgrading purposes. Adaption of new technologies and improvement of organizational practices, particularly technology transfer, are more likely to happen in response to the demands of the external environment. What occurs in the knowledge flows among customers? There are three dimensions of technology transfer: (1) quality control, (2) cost control and (3) delivery control. Environment management is also important in technology transfer between customers and suppliers in East Asia, especially at exporting firms. Only 1% of the firms have received enquiries about environment management from their main customer.

Firstly, proxies exist in mutual knowledge flows between a company's own firm and a customer. Interactive learning consists of mutual knowledge flows. 'Knowledge flows' refers to the exchange of engineers from a customer to a company's own firm as well as engineers from a company's own firm to a customer. Thirty-seven percent of firms engage in mutual exchanges of engineers between their own firm and customers. Fifty-four percent of firms accept engineers from their main customer (i.e., customer-dispatched engineers). Forty-three percent of firms dispatch engineers to their main customer. Total quality management is one of the incentives for mutual knowledge flows between firms. Twenty-eight percent of firms are provided with quality control by their customers. Customers provide cost control for 7% of firms. Customers provide delivery control for 9% of firms. Forty-seven firms provide quality controls to customers. On the other hand, 4.6% of firms provide cost controls, and 14.6% of firms provide delivery control. Thirty percent of firms are granted license by their customers. Thirty-six percent of firms grant license to their customers. Forty-three percent firms are required by their customers to have ISO. Almost 35% of firms require customers to have ISO. Fifty-five percent of firms form JIT with their customers, while the average distance to a customer is 448 km with a standard deviation of 702 km.

Table 3: Summary Statistics of Relationship with Main Customer and Main Supplier

Relationship with Customer			*Relationship with Supplier*		
	Mean	Std. Dev.		Mean	Std. Dev.
Mutual exchanges of engineers with customer	0.372	0.483	Mutual exchanges of engineer with supplier	0.359	0.480
Customer dispatch engineers	0.541	0.499	Supplier dispatch engineers	0.476	0.500
Dispatch engineers to customer	0.432	0.496	Dispatch engineers to supplier	0.459	0.499
Customer provides quality control	0.278	0.448	Supplier provides quality control	0.358	0.480
Provide customer quality control	0.473	0.500	Provide supplier quality control	0.332	0.471
Customer provides cost control	0.074	0.262	Supplier provides cost control	0.079	0.269
Provide customer cost control	0.046	0.210	Provide supplier cost control	0.065	0.246
Customer provides delivery control	0.093	0.290	Supplier provides delivery control	0.182	0.386
Provide customer delivery control	0.146	0.353	Provide supplier delivery control	0.125	0.331
Customer grants license	0.299	0.458	Supplier grants license	0.314	0.464
Grants license to customer	0.365	0.482	Grants license to supplier	0.287	0.453
Customer requires ISO	0.433	0.496	Supplier requires ISO	0.328	0.470
Requires ISO to customer	0.348	0.477	Requires ISO to supplier	0.442	0.497
JIT with customer	0.553	0.497	JIT with supplier	0.507	0.500
Distance to customer	448.736	702.893	Distance to supplier	524.855	750.251
Same industry with customer	0.317	0.466	Same industry with supplier	0.361	0.481
Customer is local	0.600	0.490	Supplier is local	0.538	0.499
Customer is joint-venture	0.161	0.368	Supplier is joint-venture	0.193	0.395
Capital tie up with customer	0.406	0.491	Capital tie up with supplier	0.389	0.488
Years of duration with customer	6.699	3.605	Years of duration with supplier	6.485	3.541

Source: ERIA Establishment Survey 2009.

Secondly, the relationship with suppliers displays different numerical profile compared to the relationship with customers. Thirty-five percent of firms do mutual exchanges of engineers between their own firm and their suppliers. Forty-seven percent of firms accept engineers from their main supplier (i.e., supplier-dispatched engineers). Forty-five percent of firms dispatch engineers to their main supplier. Total quality management is also one incentive for mutual knowledge flows between firms and suppliers. Thirty-seven percent of firms are provided with quality control by their supplier. Thirty-five percent of firms received quality control from their supplier. Almost 8% of firms received cost control from their supplier, while 6.5% of firms provide delivery control to their suppliers. On the other hand, 18.2% of firms receive delivery controls from their suppliers, and 12.5% of firms provide delivery control to their supplier. Thirty percent of firms in the sample are granted license from their suppliers. Twenty-eight percent of firms grant license to their suppliers. Thirty-three percent of firms are required to have ISO by their suppliers. Almost 44% of firms require the supplier to have ISO. Fifty percent of firms form JIT with their supplier while the average distance to the customer is 524 km with a standard deviation of 750 km.

3.5 . Exchanges of engineers by firm and partners' characteristics

Table 4 presents the exchanges of engineers by type of respondent firm and their partners. Respondents are classified as local firms, joint venture (JV) firms or foreign-owned firms (multinational corporations or MNCs). Findings showed that, among the various types of firms, JVs and MNCs practiced more dispatching of engineers to their customers than did local firms.

With regard to dispatching engineers to their customers, fewer than half of local firms (49%) engage in this practice, while more than half of JVs (56%) and MNCs (71%) do. Similarly, when it comes to dispatching engineers to suppliers, more than 50% of JVs and MNCs engage in this practice. Overall, among the types of firms, dispatching engineers to customers is more often practiced than dispatching engineers to suppliers. This is another robust empirical finding.

Now, what about accepting engineers from their partners? Sixty percent of MNCs accept engineers from their main customer and supplier, compared to 52% of JVs and 37% of local firms. On the other hand, 52% of MNCs accept engineers from their main supplier, while the figure is 49% for JVs and 43% for local firms. At this point, it is the local firms which accept more engineers from suppliers than from their customers. Table 4 also shows the results of exchanges of engineers with their main partner. MNCs often engage in exchanges of engineers with partners, more so than JVs and local firms. Unlike JVs, local firms do not engage in mutual exchanges.

The internal patterns of dispatching and accepting differ from the above findings. As depicted in the middle of Table 4, the characteristics of dispatching engineers to main partners and accepting engineers from main partners are more complex. When MNCs have local customers, there are more MNCs than JVs or local firms that send their engineers to their local customers. For example, 80% of MNCs dispatch engineers to local customers, while 73% of MNCs dispatch their engineers to MNC customers. The situation of accepting engineers from a customer differs from dispatching engineers to them. If MNCs have local customers, then it is difficult for any other local customers to dispatch engineers to MNCs. It becomes the choice of the MNCs regarding from which customer they will take engineers, in contrast to the case when an MNCs' customers are MNCs. This is true not only for MNCs but also for local firms and JVs. It is difficult for a local customer to dispatch its engineers to local firms and JVs. For example, only one-third of the local firms accept engineers from local customers (33.7% of local customers dispatch engineers), and 48.6% of local customer dispatch engineers to JVs. Therefore, there is a strong connection between local customers and MNCs in terms of dispatching engineers from MNCs to upstream to downstream local customers. There is also significant connection between MNCs' customers and every type of firm. Downstream MNCs tend to dispatch engineers to upstream firms more than downstream JVs or local firms. As depicted in the third range of Table 4, 70% of MNCs dispatch engineers to MNCs' suppliers, and 65% of MNCs dispatch their engineers to local suppliers. On the other hand, 56% of MNCs accept engineers from local suppliers, and 52% of MNCs accept engineers from MNCs' suppliers.

These results suggest that (1) interconnection from downstream MNCs to upstream MNCs is stronger than from downstream MNCs to upstream local firms and (2) interconnection from upstream local firms to downstream MNCs is stronger than from upstream MNCs to downstream MNCs. These results also hold true for local firms.

Table 4: Summary Statistics of Exchange of Engineers by Firm and Partner's Type

Types of respondent firms	Local	JVs	MNCs
N	583	125	152
Dispatch engineers to customer	0.492	0.560	0.717
Dispatch engineers to supplier	0.413	0.544	0.664
Customer dispatch engineer	0.370	0.528	0.599
Supplier dispatch engineer	0.436	0.496	0.526
Exchange engineer with customer	0.317	0.408	0.559
Exchange engineer with supplier	0.328	0.376	0.474

Respondents' customer types	Local	JVs	MNCs	Local	JVs	MNCs	Local	JVs	MNCs
N	451	60	52	37	51	30	27	28	93
Dispatch engineers to customer	0.479	0.700	0.519	0.514	0.627	0.567	0.815	0.643	0.731
Dispatch engineers to supplier	0.410	0.583	0.385	0.595	0.588	0.467	0.667	0.679	0.677
Customer dispatch engineer	0.337	0.583	0.538	0.486	0.549	0.633	0.593	0.464	0.667
Supplier dispatch engineer	0.437	0.533	0.481	0.541	0.569	0.400	0.444	0.607	0.538
Exchange engineer with customer	0.293	0.517	0.404	0.351	0.471	0.467	0.593	0.393	0.624
Exchange engineer with supplier	0.333	0.417	0.308	0.432	0.412	0.333	0.370	0.500	0.505

Respondents' supplier types	Local	JVs	MNCs	Local	JVs	MNCs	Local	JVs	MNCs
N	411	76	59	29	60	30	23	30	92
Dispatch engineers to customer	0.479	0.671	0.610	0.448	0.583	0.667	0.826	0.633	0.750
Dispatch engineers to supplier	0.416	0.487	0.492	0.517	0.583	0.533	0.652	0.667	0.707
Customer dispatch engineer	0.377	0.395	0.492	0.517	0.517	0.600	0.652	0.500	0.641
Supplier dispatch engineer	0.440	0.539	0.525	0.483	0.533	0.467	0.565	0.600	0.522
Exchange engineer with customer	0.316	0.342	0.475	0.345	0.417	0.500	0.565	0.400	0.641
Exchange engineer with supplier	0.324	0.408	0.441	0.414	0.383	0.367	0.478	0.500	0.489

Source: ERIA Establishment Survey 2009.

4. Results

The effects of exchanges of workers and technology transfers on innovations are described in this section. The internal effects of the determinants of product and process innovations are discussed in order to understand the knowledge flow through upstream-downstream production linkages. Firstly, exchanging engineers, trainers and trainees could stimulate knowledge flow through face-to-face communication. Such an approach seems to be a 'vehicle' for knowledge flows. This experience validates the importance of face-to-face communication. On the other hand, the motivation for technology transfer remains unknown. Technology transfer could require an opportunity for face-to-face communication between suppliers and customers. Since this paper focuses on the impact of tacit knowledge exchange regarding product and process innovations, direct information flow through upstream-downstream linkages to product and process innovations is considered.

4.1. Product innovations

Table 5 shows the effects of exchanges of engineers between a company's own firm and partners (main customers and suppliers) regarding the introduction of new products. The dependent variable is equal to one if each firm achieves product innovations. We postulate six different types of product innovations, namely (1) change in design, (2) improvement of existing product, (3) development of new product based on existing technologies, (4) development of new product based on new technologies, (5) new product to existing market and (6) new product to new market. The independent variable, R&D activities incurring expenditure and country dummy variables are also shown. The variable 'customer (supplier) dispatches engineers' is equal to one if each firm accepts engineers from their main customer (supplier). The variable 'dispatches engineers and trainees to customer (supplier)' is equal to one if each firm dispatches engineers and trainees to their main customer (supplier). This paper focuses on the interaction of 'customer (supplier) dispatches engineers' and 'dispatches engineers to customer (supplier)' in terms of the impact of mutual knowledge exchanges. The theoretical framework suggests that such mutual knowledge exchanges with partners could stimulate learning and innovation processes for each firm, utilizing the production linkages. The marginal effects are presented in Table 5.

As reported in Table 5, the coefficient for the interaction between 'customer dispatches engineers' and 'dispatches engineers to customer,' development of a new product based on new technologies has a coefficient of 0.242 with a standard error of 0.128 (column 4) and is statistically significant at the 10% level. On the other hand, new product to new market is 0.202 with a standard error of 0.091 (column 6) and is statistically significant at the 5% level.

The second main result of Table 5 is the coefficient for the interaction term between 'supplier dispatches engineers' and 'dispatches engineers to supplier.' The coefficient of this interaction also shows the impacts of mutual knowledge exchange with the supplier. On development of new product based on new technologies, a coefficient of -0.240 with a standard error of 0.128 (column 4) is statistically significant at the 10% level. These results suggest that mutual knowledge exchanges with their main suppliers negatively affect product innovations, especially for improvement of existing products and introduction of new products based on existing technologies.

Table 5: The Impact of Mutual Knowledge Exchanges on Product Innovations

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables: Product Innovations (Yes/No)	Change Design	Improvement of Existing Product	New Product based on Existing Technologies	New Product based on New Technologies	New Product to Existing Market	New Product to New Market
Relationship with customer						
Mutual engineer exchanges with customer	0.201	0.029	0.050	0.242+	0.039	0.202*
	[0.123]	[0.062]	[0.124]	[0.128]	[0.048]	[0.091]
Customer dispatch engineers	-0.181*	0.033	0.063	-0.189*	-0.007	0.024
	[0.076]	[0.052]	[0.087]	[0.085]	[0.032]	[0.069]
Dispatch engineers to customer	-0.183+	-0.023	-0.147	-0.167	-0.019	-0.222**
	[0.109]	[0.049]	[0.103]	[0.115]	[0.040]	[0.076]
Relationship with supplier						
Mutual engineer exchanges with supplier	0.033	-0.144	-0.122	-0.240+	-0.053	-0.078
	[0.126]	[0.090]	[0.118]	[0.128]	[0.059]	[0.108]
Supplier dispatch engineers	0.106	0.096+	0.080	0.183+	0.023	0.064
	[0.091]	[0.057]	[0.089]	[0.097]	[0.035]	[0.074]
Dispatch engineers to supplier	0.008	0.078	0.088	0.262**	0.059	0.148+
	[0.097]	[0.058]	[0.091]	[0.100]	[0.044]	[0.080]
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Product characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Manager's characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Employee's characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Country characteristics	Yes	Yes	Yes	Yes	Yes	Yes
N	483	483	483	483	483	483

Source: ERIA Establishment Survey 2009. *Notes*: Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%. Firm characteristics include age, size, local firms, join venture, industry, function dummies, incidence of R&D, and size of domestic sales. Product characteristics includes years of product life cycle and number of product types. Manager's characteristics includes the variables whether top management has a master degree, whether top management was engineer, whether top management has an experience for MNC/JV. Employee characteristics include ratio of high school graduates among blue-collar workers and ratio of technical college graduates among engineers. Reference country is Thailand.

4.2. Process innovations

Process innovations are composed of six different types of changing production processes: (1) improvement of existing machines, (2) purchase of new machines, (3) introduction of new know-how for production methods, (4) changes in quality control, (5) changes in production control and (6) changes in cost control. The primary variables include R&D, mutual knowledge exchange with customer and mutual knowledge with supplier.

Table 6 shows the impacts of mutual knowledge exchanges with a company's main supplier. The coefficient for purchase of new machines is -0.374 with a standard error of 0.119 (column 2) and is statistically significant at the 1% level. On the other hand, the coefficient for accepting engineers from a supplier is 0.169 when purchasing new machines with a standard error of 0.094 and is statistically significant at the 10% level in this specification. The coefficient for accepting engineers from a supplier is 0.183 when changing production control with a standard error of 0.081 and is statistically significant at the 5% level. The coefficient for accepting engineers from a supplier (i.e., supplier dispatches engineers) has a positive impact on purchasing new machines (column 3) and changing production control (column 5). Dispatching engineers to a company's main supplier also has large and positively significant impacts on purchasing new machines (column 3) and changing production control (column 5).

Table 6: The Impact of Mutual Knowledge Exchanges on Process Innovations

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables: Process Innovations (Yes/No)	Improved Existing Machines	Bought New Machines	New-Know How on Production Methods	Change Quality Control	Change Production Control	Change Cost Control
Relationship with customer						
Mutual engineer exchanges with customer	0.077	0.043	0.066	0.106	0.150+	0.235*
	[0.059]	[0.111]	[0.099]	[0.074]	[0.079]	[0.096]
Customer dispatch engineers	0.003	-0.053	0.064	-0.071	-0.082	-0.079
	[0.048]	[0.073]	[0.076]	[0.051]	[0.059]	[0.066]
Dispatch engineers to customer	-0.030	0.115	-0.056	-0.069	-0.152*	-0.185*
	[0.047]	[0.096]	[0.084]	[0.065]	[0.070]	[0.087]
Relationship with supplier						
Mutual engineer exchanges with supplier	-0.017	-0.374**	-0.136	-0.004	-0.216*	-0.122
	[0.068]	[0.119]	[0.111]	[0.084]	[0.106]	[0.107]
Supplier dispatch engineers	0.024	0.169+	0.109	0.102	0.183*	0.098
	[0.053]	[0.094]	[0.086]	[0.076]	[0.081]	[0.083]
Dispatch engineers to supplier	0.030	0.186*	0.065	-0.007	0.128+	0.004
	[0.045]	[0.088]	[0.077]	[0.058]	[0.071]	[0.078]
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Product characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Manager's characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Employee's characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Country characteristics	Yes	Yes	Yes	Yes	Yes	Yes
N	483	483	483	483	483	483

Source: ERIA Establishment Survey 2009. *Notes*: Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%. Firm characteristics include age, size, local firms, join venture, industry, function dummies, incidence of R&D, and size of domestic sales. Product characteristics includes years of product life cycle and number of product types. Manager's characteristics includes the variables whether top management has a master degree, whether top management was engineer, whether top management has an experience for MNC/JV. Employee characteristics include ratio of high school graduates among blue-collar workers and ratio of technical college graduates among engineers. Reference country is Thailand.

5. Diagnostics and Discussion

It is time to discuss the implications of the empirical results for which clear evidence was presented in the above section. We have found that the probability of development of a new product based on new technologies and the probability of introduction of a new product to a new market are both higher when two parties have exchanged their engineers with each other. What mechanism is behind this? Our diagnostic method is simple and intuitive. These types of product innovations are rather costly and new to the firm. The marginal probability of innovation could become high if firms fully receive technology transfer from their production partners. Firms are likely to choose mutual learning with production partners in the stage of costly product innovation, especially product innovation accompanied by new technologies and seeking a new market. On the other hand, firms are not likely to choose mutual exchanges of engineers when they are in the stage of not-so-costly upgrading, for example process innovation and total quality of control. This mechanism is supported by the empirical results of information transactions among upstream and downstream firms in developing economies.

The concept of interactive learning has been enlightened by recent economic research (especially, Berliant and Fujita, 2008, 2009). In this line of research, the expected costs and benefits from mutual learning are explicitly modeled. Berliant and Fujita (2008, 2009) and others suggest that two parties (professionals) can create new knowledge with each other with commuting or communication costs. Then they can utilize the new knowledge for new projects. We use mutual exchanges of engineers as a main explanatory variable which has played an important role in personnel-to-personnel technology transfer. This paper combines the basic framework of classic research by Lundvall (1985, 1988) and von Hippel (1986, 1988, 2005) with recent economic research to pursue an econometric treatment of the relationship between innovation and interaction between upstream and downstream firms.

The empirical results may also be related to seminal work on dynamic capabilities of firms (Teece 2009). This paper has demonstrated and estimated how interactive learning affects innovation in the context of economic transactions between upstream and downstream firms in emerging economies such as Indonesia, the Philippines, Thailand and Vietnam. The mutual exchanges of engineers may require absorptive capacity on the part of the recipients, while donors have been required, conversely, to have desorptive capacity. In this sense, the estimated impacts of interactive learning on product and process innovation are useful for understanding absorptive and desorptive capacity in technology transfers which framework of dynamic capabilities has highlighted over last two or three decades.

Based on our foregoing diagnostics of the empirical results, the implications of this paper for industrial development are summarized as follow. Firstly, interactive learning is important for industrial development. This is derived from evidence that technology transfer between firms in the upstream and downstream has significant impact on the achievement of industrial upgrading. Secondly, interactive learning plays different roles in the direction of industrial upgrading depending on whether the innovation is incremental innovation within the production processes or product innovation with new technologies or new markets. This is derived from evidence that product innovation is explained by mutual exchanges of engineers while process innovation is not. Finally, interactive learning with downstream customers is more important for industrial development. This is also consistent with von Hippel (1986, 1988, 2005).

6. Conclusion

This paper presents evidence that mutual knowledge exchanges between engineers have an important connection with product and process innovation in manufacturing in developing economies. This paper takes advantage of data that combines information on product creation and quality upgrading with relationships between connected firms (i.e., upstream and downstream firms). Findings show that manufacturing firms are more likely to achieve product innovations when they exchange engineers mutually with their main customer for development of a new product based on new technologies and a new product to a new market. Using new technologies and creating a new market require close collaboration with the main customer. Mutual exchanges of engineers with a supplier are less likely to have impact on achievement of product and process innovations. Mutual knowledge exchanges with a customer play an important role in product innovation with new technologies and a new market. On the other hand, mutual knowledge exchanges with a customer do not have any significant impact on production process innovation, except for changing cost controls which are affected by the customer's requirements more than other types of organizational improvements.

Remaining issues and future tasks are threefold, as follow. Firstly, we should pay close attention to the question of how each firm chooses its intermediate goods based on customer firms' requests. If firms are sensitive to customer firms' requests, the choice of supplier could be endogenous to the firms. If this is true, we should not simply use a firm's self-reported supplier as a control variable. Secondly, we have to incorporate the duration of on-site knowledge exchanges into our empirical framework. It is natural to imagine that there is much heterogeneity within and across manufacturing industries. Thus, it is not easy to control for duration of mutual knowledge exchanges between two parties by using industry differences simply. Finally, our empirical framework can be also applied to the service or agricultural sectors. Testing how interactive learning affects industrial upgrading should be one of the most important research agendas when we consider the transition from manufacturing to service economies and resource-based economies.

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