Chapter 9

Learning and Innovation in Upstream-Downstream Relations: Mutual Knowledge Exchanges and Types of Transferred Technologies

Tomohiro Machikita
Institute of Developing Economies (IDE/JETRO), Japan

Yasushi Ueki
Bangkok Research Center-JETRO, Thailand

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Learning and Innovation in Upstream-Downstream Relations: Mutual Knowledge Exchanges and Types of Transferred Technologies*

Tomohiro Machikita and Yasushi Ueki

Abstract

This paper presents a simple model of knowledge creation as a result of face-to-face communication between upstream-downstream relations. This also serves to be an empirical investigation of mutual knowledge exchanges' impacts of knowledge production function in a survey of manufacturing firms in East Asia—Indonesia, Thailand, Philippines, and Vietnam. Evidence from inter-connected firms in developing economies suggests that firms which mutually exchange engineers with customers achieved more innovations than other firms. However, one-way flow of knowledge with supplier is effective for product innovation but not for mutual exchanges of engineers. We find that managerial experience with foreign firms is an important technology for knowledge creation. Technology transfer needs not only one-way face-to-face communication but also mutual exchanges of knowledge.

1. INTRODUCTION

This paper constructs a new framework linking product and process innovations and explicit knowledge exchanges between firms in developing economies. We assume that detailed evidences of production linkages provide the information of knowledge exchanges between own firms and their partners (customer and supplier). Identifying

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detailed evidences of linkages opens a black-box of knowledge creation and learning process among firms that deeply involves internal and international production chains. A canonical model of knowledge exchanges of engineers between own firms and partners has been identified. It also investigates the empirical implications of this mechanism using the data gathered from manufacturing firms in five megacities in East Asia. The five cities come from Indonesia, Philippines, Thailand and Vietnam. Data collection through mail surveys and field interviews include 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.

This paper was able to outline a methodology in determining linkage impact of innovation and mutual knowledge exchanges between upstream-downstream relations in industrial development. Microeconometric evidences suggest that mutual knowledge exchanges drives innovation as well as one-way flow of information from partners after controlling self-selection (i.e., "teachers" achieve more innovation than "students"). Some evidences are robust to conclude that mutual knowledge exchanges matter. The theoretical background of this paper explains a model of learning and knowledge creation through face-to-face communication among different types of agents as described by Berliant and Fujita (2008, 2009), Fujita (2007), and Berliant, Reed, and Wang (2006). The central concern of these models is how diversity of knowledge among members could affect the decision on collaboration and its outcome. Their fundamental modeling approach has been applied to the question how cultural background of members affects city system (Ottaviano and Prarolo 2009). In that sense, diversity of knowledge among firms and exchange of knowledge between firms could have aggregate implications like city system as well as agglomerations of firms.

However, it has been difficult to capture and quantify the information flow between agents—one of growing field in development, labor, and industrial organization—specifically the study of network impact of productivity growth. The following identified some factors that contribute to such difficulty like Conley and Udry (2010) study in development economics which associated input use of informational neighbors for pineapple farmers in Ghana as well as their geographic neighbors as affecting growth. Another is Bandiera, Barankay, and Rasul (2009) study in labor economics where the social and workplace level connections among fruit pickers affect the changing payment system on productivity. Goyal (2007), Jackson (2008), and Easley and Kleinberg (2010) showed the measuring and theoretical framework of information diffusion through network. Productivity growth could differ between firms depending on the types of production or intellectual linkages that they have. It is also true that productivity changes on entry or exit especially when the hub-firm is located central to the production network. Given this situation, the dense network in East Asia could provide a new insight on causes and consequences of information diffusion among local firms. This paper aims to study the innovation impacts of mutual knowledge exchanges among inter-connected firms in the field of industrial development. This paper is also related to the field of international technology diffusion and international knowledge production. Keller (2000) gave an overview of the cause and consequences of technology diffusion across countries. Kerr (2008, 2010) and Kerr and Lincoln (2010) studied the role of ethnic scientific communities on technology diffusion to match ethnic scientist name with individual patent records.

A testable hypothesis considers the mutual exchange impacts of product and process innovations using interfirm connectivity network data. The data uncovers not only innovation impacts of mutual exchange between connected firms, but also motivation from direct information flow of upstream to downstream or vice versa. Findings also show that manufacturing firms are more likely to achieve product innovations upon mutually exchanging engineers with specific customers, especially for new product development using technologies for a new market. This entails close collaboration with the primary existing customer. On the other hand, connected firms are less likely to achieve improvement of existing machines and development of new product after the mutual exchange with their main supplier. Mutual knowledge exchanges with the supplier do not seem to fit existing machines and technologies. Further, evidence shows that product and process innovations experienced by a manager with foreign firms (including joint venture firms) are an important technology of innovations. Experience of foreign firms plays a key role on new knowledge to local firms.

The next section provides the theoretical framework. Section 3 describes the data collected. Section 4 presents the results of innovation impacts of mutual knowledge exchanges. Robustness checks are also shown here. Section 5 explains the determinants of mutual knowledge exchanges. Section 6 is the conclusion.

2. THEORETICAL FRAMEWORK

2.1. Matching, Transfer of Technologies, and Mutual Knowledge Exchanges with Partners

Interfirm linkages take various forms of guidance and learning like the exchange of engineers. Interfirm guidance and learning may exist in controlling quality, costs, delivery, and environment management (QCDE) within the firm as well as within the (international) production chain. Total quality management plays an important role in knowledge exchanges between upstream-downstream firms. Not only the customer but also the supplier takes guidance from the partner firm. That is, firms learn about specific product demand from their customers. They also gain technical information from their suppliers faced with the new demand. It is assumed that each firm requires information spillovers through backward and forward linkages to meet the demand. Therefore, information exchanges between demand and technologies spillover within the (international) production chain. Information exchanges are not always in “encoded” form (Polanyi 1966, 1967). Communication between firms and their partners are not well-facilitated when demand and technologies become complicated. The same is with knowledge production in the academic field. First, team production achieves more cited research than individuals do (Wuchty, Jones, and Uzzi, 2007) across all fields of natural science, social science, and arts-humanities. Second, teamwork in science is done by not only multi-university collaborations but also stratified groups (Jones, Wuchty, and Uzzi, 2008). Rosenblat and Mobius (2004) studied the impacts of rising Internet on international collaboration the similar field.

This paper focuses on the dynamics of two-way information flow from downstream to upstream (backward linkage) and from upstream to downstream (forward linkage) instead of examining of a one-way process. If engineers are sent out to share their professional knowledge about the production process, then accepting engineers from partners is more of learning the activities for the respondent firms. Dispatching engineers to partners seem to be teaching the activities for the firms. If these firms were able to gain professional knowledge through partners, then aforementioned strategy is a better choice. To identify which flows become learning or teaching, direct information from the “teachers” and “students” are helpful. Due to the limitations of this paper, it was assumed that the “teacher” receives benefits from “students”. On the other hand, “students” learn new production processes, materials, and market from “teachers”. This has been tested to determine the implication to upstream-downstream relations.

2.2. Experiences of Foreign Firms as Technology of Innovations

Bloom and van Reenen (2007, 2010a, 2010b) emphasize that differences in management practices play a crucial role in productivity dispersion within a country and across countries. Bloom, Eifert, Mahajan, McKenzie, and Roberts (2010) also provides the experimental evidence of modern management practices on productivity upgrading among the Indian textile factories. Finding showed that treated factories achieve not only product upgrading but also profitability than control factories. It is difficult to identify the impact of adoption of modern management practices as well as changing managerial abilities of managers. This was subjected to further testing focus on the background of top management.

Hortacsu and Syverson (2009) suggested the importance of intangible inputs like managerial oversight within the firm to show vertical ownership is not usually used to facilitate transfers of goods in the production chain. They concluded that the central motivation of owning production chains is the more efficient transfer of knowledge of production and information on markets. This motivation is closely related to the concept of “adaptive organization” A la Dessein and Santos (2006) theoretically analyzes the complementarities between the level of adaptation to a changing environment, coordination, and the extent of specialization. Production chains within firms help the firm to collect information on market and use it for production and vice versa. Therefore, since managerial abilities have centralized local information, these abilities play a key role as a technology of product and process innovations within the firm.

One concrete example is that the industrial development impacts of immigrant technologist as shown in Kerr (2008, 2010) and Kerr and Lincoln (2010). Experiences in foreign firms or countries are as an important technology of innovations. Experience of foreign firms plays a key role of new knowledge to local firms. This implication is also directly derived from Berliant and Fujita (2008, 2009).

3. DATA

3.1. Sampling

The sample industries primarily involved in the manufacturing (and exporting for some firms) sector are currently operating in East Asia. The dataset used came from the Establishment Survey on Innovation and Production Network for selected manufacturing firms in four countries in East Asia. In December 2009, a dataset was created in Indonesia, 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 and Ho Chi Minh area for Vietnam). A total of 864 firms agreed to participate in the survey: (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 existence of a firm is 16.8 years, with a standard deviation of 13.9 years. Firm size is much dispersed 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 as having less than 20 employees. Of the total number surveyed, approximately 67.5 percent are local firms; 14.5 percent, joint-venture firms; and 17 percent, 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 percent produce final goods. In addition to

Table 1, a total of 19 percent procure raw materials while 24 percent carry out logistics. Only two percent of the firms has information technologies department. Twenty percent of firms have sales while 40 percent carry out marketing activities.

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
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
Indonesia	0.212	0.409
Philippines	0.235	0.424
Thailand	0.206	0.405
Hanoi	0.174	0.379
Ho Chi Minh City	0.174	0.379

The average size of domestic sales is calculated by the average number of local customers. That is, on the average 27.8 customer firms with standard deviation of 25.7

that respondent firm has. There is quite larger dispersion in shipping across respondent firms. The average years of product life cycle are 2.9 years with a standard error of 2.2 years. There is also a larger dispersion of years in 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 single product only.

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

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 the main interests—product and process innovation. Innovative activities reflect several dimensions of industry upgrading. There is large distinction on the firm's policy 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 percent of the sample firms are able to change the design of their existing products. More than 80 percent of the firms improve their existing products. Almost 70 percent of the firms develop new products based on existing technologies while 57 percent utilized new technologies. These 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 percent of firms are able to sell new products to new market. These also imply that creation of new market is difficult and costly.

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
Production 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
Change in Production Process		
(1) Change Quality Control	0.789	0.408
(2) Change Production Control	0.840	0.367
(3) Change Cost Control	0.801	0.400
(4) Change Marketing	0.745	0.436
(5) Change Inventory Control	0.699	0.459
(6) Change Domestic Procurement	0.495	0.500
(7) Change International Procurement	0.701	0.458
(8) Change Domestic Delivery	0.360	0.480
(9) Change International Delivery	0.635	0.482
Changes in Management Practices		
(1) Change Accounting System	0.780	0.414
(2) Change HRMP	0.753	0.431
(3) Change Environment Management	0.671	0.470
(4) Adopt New ISO	0.503	0.500
Upgrading Production Process		
(1) Decrease in Defection	0.727	0.446
(2) Decrease in Inventories	0.580	0.494
(3) Decrease in Materials	0.506	0.500
(4) Reduce Labor Inputs	0.334	0.472
(5) Improve Quality	0.838	0.369
(6) Reduce Lead-time	0.503	0.500
(7) Increase in Domestic Market	0.606	0.489
(8) Increase in Abroad Market	0.350	0.477
(9) Reduce Pollution	0.612	0.488
(10) Meet Regulation	0.825	0.380

How about process innovations? More than 83 percent of the firms are able to buy new machines. Seventy percent of firms improved their existing machines. Likewise, 71 percent of firms introduced new know-how in production methods. There are several types of changes in production process, for example, 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, accounting system, human resource management practices (HRMP), environment management, and adoption of International Organization for Standardization (ISO). Changes in accounting system and HRMP within firm is popular than meeting with regulation and global standardization.

Information collected are not only changes in production processes but also actual upgrading; (1) decrease in defection (72%); (2) decrease in inventories (58%); (3) decrease in materials (50%); (4) reduce the labor input (33%); (5) improve quality (84%); (6) reduce lead-time (50%); (7) increase in domestic market (60%); (8) increase in abroad market (35%); (9) reduce pollution (61%); (10) meet regulation (82%).

3.4. Independent Variables--Forms of Guidance, Transferred Technology, and Partner's Characteristics

Firms utilize knowledge exchange among production partners (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; (3) delivery control. Environment management is also important in technology transfer between customers and suppliers in East Asia especially in exporting firms. Only 1 percent of the firms have received environment management from the main customer.

First, proxies exist in mutual knowledge flows between own firm and customer. Learning and teaching create mutual knowledge flows. Knowledge flows refer to the exchange of engineers from customer to own firm as well as engineers from own firm to customer. Thirty-seven percent of firms do mutual exchange of engineers between own firm and customer. Fifty-four percent of firms adopt the engineers from their main customer (i.e., customer dispatch engineers). Forty-three percent of firms dispatch engineers to their main customer. Total quality management is one of the incentives of mutual knowledge flows between firms. Twenty-eight percent of firms are provided quality control by their customer. Customer provides cost control for 7 percent of firms. Customer provides delivery control for 9 percent of firms. Forty-seven firms provide quality controls to customer. On the other hand, 4.6 percent of firms provide cost controls as well as 14.6 percent of firms provide delivery control. Thirty percent of firms are granted license by their customer. Thirty-six percent of firms grant license to their customers. Forty-three percent firms are required to have ISO by their customers. Almost thirty-five percent of firms require ISO to customer. Fifty-five percent of firms form JIT with their customer while the average distance to customer is 448 km with a standard deviation of 702 km (Table 3a).

Second, relationship with supplier has different figures compared to the relationship with customer. Thirty-five percent of firms do mutual exchange of engineers between own firm and supplier. Forty-seven percent of firms adopt the engineers from their main supplier (i.e., supplier dispatch 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 quality control by their supplier. Thirty-five percent of firms received quality control from their supplier. Almost eight percent of firms received cost control from their supplier while 6.5 percent of firms provide delivery control to their suppliers. On the other hand, 18.2 percent of firms receive delivery controls from their suppliers as well as 12.5 percent of firms provide delivery control to their supplier. Thirty percent of firms in the sample are granted license from their supplier. Twenty-eight percent of firms grant license to their suppliers. Thirty-three percent of firms required to have ISO by their suppliers. Almost 44 percent of firms require ISO to supplier. Fifty percent of firms form JIT with their supplier while the average distance to customer is 524 km with a standard deviation of 750 km.

Table 3a Summary Statistics of Relationship with Customer

	Mean	Std. Dev.
Relationship with Customer		
Customer dispatch engineers*Dispatch engineers to customer	0.372	0.483
Customer dispatch engineers	0.541	0.499
Dispatch engineers to customer	0.432	0.496
Customer provides quality control	0.278	0.448
Provide customer quality control	0.473	0.500
Customer provides cost control	0.074	0.262
Provide customer cost control	0.046	0.210
Customer provides delivery control	0.093	0.290
Provide customer delivery control	0.146	0.353
Customer grants license	0.299	0.458
Grants license to customer	0.365	0.482
Customer requires ISO	0.433	0.496
Requires ISO to customer	0.348	0.477
JIT with customer	0.553	0.497
Distance to customer	448.736	702.893
Same industry with customer	0.317	0.466
Customer is local	0.600	0.490
Customer is joint-venture	0.161	0.368
Capital tie up with customer	0.406	0.491
Years of duration with customer	6.699	3.605
Customer's Production (raw material)	0.066	0.248
Customer's Production (processing)	0.054	0.227
Customer's Production (components and parts)	0.133	0.340
Customer's Production (final products)	0.433	0.496

Table 3b Summary Statistics of Relationship with Supplier

	Mean	Std. Dev.
Relationship with Supplier		
Supplier dispatch engineers*Dispatch engineers to supplier	0.359	0.480
Supplier dispatch engineers	0.476	0.500
Dispatch engineers to supplier	0.459	0.499
Supplier provides quality control	0.358	0.480
Provide supplier quality control	0.332	0.471
Supplier provides cost control	0.079	0.269
Provide supplier cost control	0.065	0.246
Supplier provides delivery control	0.182	0.386
Provide supplier delivery control	0.125	0.331
Supplier grants license	0.314	0.464
Grants license to supplier	0.287	0.453
Supplier requires ISO	0.328	0.470
Requires ISO to supplier	0.442	0.497
JIT with supplier	0.507	0.500
Distance to supplier	524.855	750.251
Same industry with supplier	0.361	0.481
Supplier is local	0.538	0.499
Supplier is joint-venture	0.193	0.395
Capital tie up with supplier	0.389	0.488
Years of duration with supplier	6.485	3.541
Supplier's Production (raw material)	0.454	0.498
Supplier's Production (processing)	0.134	0.341
Supplier's Production (components and parts)	0.156	0.363
Supplier's Production (final products)	0.115	0.319

3.5. Exchanges of Engineers by Firm and Partner's Characteristics

Table 4 presents the exchanges of engineers by types of respondent firms and their partners. Respondents are classified as: local firms; joint venture (JVs) firms; and foreign-owned firms (Multinational Corporations or MNCs). Findings showed that among the various types of firms, JVs and MNCs mostly practiced dispatching of engineers to their customers compared to local firms.

With regard to dispatching engineers to their customer, less than half (49%) are practiced by local firms and more than half are practiced by JVs (56%) and MNCs (71%). Similarly, in dispatching engineers to supplier, both JVs and MNCs are more than 50 percent. In the overall, among the types of firms, dispatching engineers to customer is more often the practice than dispatching engineers to supplier. This is another strong empirical finding.

Now, what about accepting engineers from their partners? MNCs (60%) accept engineers from their main customer and supplier compared to JVs (52%) and local firms (37%). On the other hand, 52 percent of MNCs accept engineers from their main supplier, 49 percent for JVs and 43 percent for local firms. At this point, it is the local firms which accept more engineers from supplier than accepting engineers from customer.

Table 4 also shows the results of exchanges of engineer with their main partner. MNCs often engage in exchanging engineers with partners more than JVs and local firms. Local firms do not engage in mutual exchanging, unlike JVs.

The inside patterns of dispatching and accepting are different from the above findings. As depicted in the middle of Table 4, there are more complex characteristics about dispatching engineers to main partners and accepting engineers from main partners. If MNCs had local customers, then there are more MNCs which send their engineers to their local customers than JVs or local firms. For example, 80 percent of MNCs dispatch engineers to local customers while 73 percent of MNCs dispatch their engineers to MNC customers. The situation of accepting engineers from a customer is different 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 on which customer they would take engineers compared to the case of MNCs' customer being MNCs. This is true not only for MNCs but also to local firms and JVs. It is difficult for a local customer to dispatch their 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) as well as 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 in upstream to downstream local customers. There is also significant connection between MNCs customer and every type of firms. Downstream MNCs tend to dispatch engineers to upstream firms compared to downstream JVs or local firms.

As depicted in the third range of Table 4, 70 percent of MNCs dispatch engineers to MNCs suppliers, and 65 percent of MNCs dispatch their engineers to local supplier. On the other hand, 56 percent of MNCs accept engineers from local suppliers as well as 52 percent 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; (2) interconnection from upstream local firms to downstream MNCs is stronger than from upstream MNCs to downstream MNCs. These results are 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	
No. observation		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	
No. observation of respondents		563			118			148	
Respondents' customer types	Local	JVs	MNCs	Local	JVs	MNCs	Local	JVs	MNCs
No. observation	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
No. observation of respondents		546			119			145	
Respondents' supplier types	Local	JVs	MNCs	Local	JVs	MNCs	Local	JVs	MNCs
No. observation	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

4. RESULTS

The results of exchanges of workers and technology transfer on innovations are described in this section. The internal effects of the determinant of product and process innovations are discussed in order to understand the knowledge flow through upstream-downstream production linkages. First, exchanging engineers, trainers, and trainees could stimulate knowledge flow based on face-to-face communication. Such approach seems to be a "vehicle" of knowledge flows. This experience validates the importance of face-to-face communication. On the other hand, motivation of technology transfer is silent. Technology transfer could require the opportunity for face-to-face communication between suppliers and customers. Since this paper aimed to focus on tacit knowledge exchange impacts of product and process innovations, direct information flow through upstream-downstream linkages to product and process innovations is considered. This paper also was able to detect the firm's knowledge production function using the estimated equation as follows:

$$\Pr(y_i = 1) = \alpha Exchange\_Engineer_i + \beta Manager_i + \gamma x_i + u_i ,$$

where y means the outcome of innovation and upgrading for each firm i located in each country c, the variable *Exchange_Engineer* serves as proxy for information and knowledge flows between firms (forms of guidance through exchanging engineers, trainers, trainees and incidence of receiving technical assistances), x for other controls (i.e., R&D, age, size, capital structure, industry, function of operation, years of product life cycle, number of product types, ratio of high school workers, ratio of college graduates engineer, and country dummy variables) as depicted in Table 1. A cross-sectional error term is shown by u. To simply regress innovation outcome to covariates, focus is given on the estimated coefficient of *Exchange_Engineer* as the degree of innovation management technology across firms.

4.1. Product Innovations

Table 5 shows the effects of exchanges of engineers between own firms 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 have six different types of product innovations, namely: (1) change 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 covering expenditure and country dummy variables are also shown. The variable of customer (supplier) dispatch engineers is equal to one if each firm accepts engineers from their main customer (supplier). The variable dispatch 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) dispatch engineers and dispatch engineers to customer (supplier) with the role of mutual knowledge exchanges impacts. The theoretical framework suggests that such mutual knowledge exchanges with their 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 R&D activities for development of new product based on existing technologies is .156 with a standard error of .048. This is statistically significant at 1 percent level (column 3). R&D activities dummy variable has also large impact on new product to new market (column 6), the coefficient being .137 with standard error of .066, also statistically significant at 5 percent level. Thus, firms doing R&D are likely to experience a significantly higher probability of product innovation than firms that do not engage in R&D at all.

With regard to the coefficient for the interaction between *customer dispatch engineers* and *dispatch engineers to customer,* development of new product based on new technologies has a coefficient of .230, with standard error of .129 (column 4), and statistically significant at 10 percent level. On the other hand, new product to new market is .271, with standard error of .129 (column 6), and statistically significant at 5 percent level.

The second main result of Table 4 is the coefficient for the interaction term between *supplier dispatch engineers* and *dispatch engineers to supplier*. The coefficient of this interaction also shows the impacts of mutual knowledge exchange with supplier. For improvement of existing product, a coefficient -.154 with standard error of .085 (column 2), is statistically significant at 10 percent level. On development of new product based on new technologies a coefficient -.267 with standard error of .127 (column 4), is statistically significant at 10 percent level. These results suggest that mutual knowledge exchanges with their main suppliers negatively affect product innovations especially on improvement of existing product and introducing new product based on existing technologies.

Table 5 Exchanges of Engineers and Product Innovations

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables: Product Innovations (Yes/No)	Change Design	Improvement of Existing Product	Development of New Product based on Existing Technologies	Development of New Product based on New Technologies	New Product to Existing Market	New Product to New Market
R&D dummy (Yes/No)	0.001	0.015	**0.156****	0.037	0.072	**0.137***
	[0.045]	[0.024]	**[0.048]**	[0.053]	[0.045]	**[0.066]**
Customer dispatch engineers*Dispatch engineers to customer	0.103	0.032	0.038	**0.230+**	0.084	**0.271***
	[0.104]	[0.052]	[0.125]	**[0.129]**	[0.097]	**[0.129]**
Customer dispatch engineers	**-0.161***	0.018	0.062	**-0.196***	-0.037	0.013
	[0.064]	[0.043]	[0.087]	**[0.085]**	[0.075]	[0.110]
Dispatch engineers to customer	-0.117	-0.016	-0.140	-0.162	-0.039	**-0.334****
	[0.084]	[0.040]	[0.102]	[0.116]	[0.091]	**[0.115]**
Supplier dispatch engineers*Dispatch engineers to supplier	0.030	**-0.154+**	-0.129	**-0.267***	-0.143	-0.145
	[0.113]	**[0.085]**	[0.118]	**[0.127]**	[0.132]	[0.170]
Supplier dispatch engineers	0.062	**0.091+**	0.076	**0.178+**	0.062	0.100
	[0.083]	**[0.052]**	[0.089]	**[0.099]**	[0.074]	[0.115]
Dispatch engineers to supplier	0.036	0.072	0.097	**0.288****	0.128	**0.237***
	[0.081]	[0.050]	[0.091]	**[0.099]**	[0.080]	**[0.110]**
Size of domestic sales	0.002*	0.000	-0.001	0.001	0.000	0.001
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.013	-0.009+	-0.003	-0.005	-0.008	0.020
	[0.010]	[0.005]	[0.011]	[0.013]	[0.009]	[0.014]
Number of product types	0.004	0.002	0.009	0.008	0.020**	0.017*
	[0.005]	[0.003]	[0.006]	[0.007]	[0.005]	[0.007]
Top management have a master degree	-0.057	-0.003	0.032	0.090	0.057	-0.143*
	[0.050]	[0.024]	[0.054]	[0.056]	[0.043]	[0.071]
Top management was engineer	0.100+	0.026	-0.004	0.061	-0.023	-0.010
	[0.055]	[0.030]	[0.058]	[0.065]	[0.050]	[0.074]
Top management have an experience for MNC/JV	0.076+	-0.033	0.015	0.149**	0.100*	0.057
	[0.046]	[0.024]	[0.051]	[0.056]	[0.047]	[0.071]
Ratio of high school graduates among blue-collar workers	0.001	0.001	0.000	0.000	0.001	0.000
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Ratio of technical college graduates among engineers	0.000	0.000	0.000	-0.002*	0.000	-0.002*
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Indonesia	0.095+	0.012	0.049	-0.041	0.156**	-0.053
	[0.054]	[0.033]	[0.086]	[0.104]	[0.032]	[0.102]
Philippines	0.042	-0.025	0.018	-0.028	0.039	-0.222*
	[0.061]	[0.038]	[0.080]	[0.089]	[0.058]	[0.090]
Hanoi	0.113+	0.028	0.035	-0.122	0.177**	0.188*
	[0.062]	[0.033]	[0.100]	[0.118]	[0.037]	[0.094]
Ho Chi Minh	0.514**	0.114**	0.141+	0.091		
	[0.041]	[0.030]	[0.084]	[0.101]		
Observations	483	483	483	483	338	338

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies.
Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%
Reference country is Thailand.

4.2. Process Innovations

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

As reported in Table 6, the coefficient of R&D activities on having bought new machines is .115 with a standard error of .045, and statistically significant at 5 percent level (column 2). The coefficient for R&D activities on introduction of new know-how on production methods is .179 with standard error of .044, and statistically significant at 1 percent level. Thus, firms that are involved in R&D are likely to experience a significantly higher probability of production process innovation than firms that no R&D expenditures. In addition to the contributions of R&D activities within the firm, Table 6 shows the impacts of mutual knowledge exchanges with their main supplier. The coefficient on buying new machines is -.390 with standard error of .119 (column 2), and statistically significant at 1 percent level. On the other hand, the coefficient for accepting engineers from supplier is .160 on buying new machines with a standard error of .055, and statistically significant at 10 percent level in this specification. The coefficient for accepting engineers from supplier is .162 on changing production control with standard error of .074, and statistically significant at 5 percent level. The coefficient for accepting engineers from supplier (i.e., supplier dispatch engineers) has positive impact on buying new machines (column 3) and changing production control (column 5). Dispatching engineers to their main supplier also have large and positively significant impacts on buying new machines (column 3) and changing production control (column 5).

Table 6 Exchanges of Engineers and Process Innovations

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables: Process Innovations (Yes/No)	Improved Existing Machines	Bought New Machines	Introduced New-Know How on Production Methods	Change Quality Control	Change Producti on Control	Change Cost Control
R&D dummy (Yes/No)	0.005	**0.115***	**0.179****	-0.004	0.051	0.019
	[0.026]	**[0.045]**	**[0.044]**	[0.029]	[0.034]	[0.040]
Customer dispatch engineers*Dispatch engineers to customer	0.067	0.030	0.044	0.067	0.101	0.205*
	[0.058]	[0.113]	[0.098]	[0.067]	[0.074]	[0.092]
Customer dispatch engineers	0.002	-0.051	0.059	-0.063	-0.077	-0.078
	[0.048]	[0.073]	[0.074]	[0.047]	[0.053]	[0.061]
Dispatch engineers to customer	-0.022	0.123	-0.042	-0.047	**-0.116+**	**-0.166***
	[0.046]	[0.098]	[0.083]	[0.056]	**[0.063]**	**[0.081]**
Supplier dispatch engineers*Dispatch engineers to supplier	-0.016	**-0.390****	-0.165	-0.025	**-0.216***	-0.150
	[0.067]	**[0.119]**	[0.111]	[0.078]	**[0.101]**	[0.105]
Supplier dispatch engineers	0.020	**0.160+**	0.102	0.091	**0.162***	0.092
	[0.052]	**[0.092]**	[0.084]	[0.069]	**[0.074]**	[0.078]
Dispatch engineers to supplier	0.029	**0.203***	0.085	0.012	**0.132***	0.025
	[0.044]	**[0.088]**	[0.075]	[0.051]	**[0.066]**	[0.075]
Size of domestic sales	0.000	0.001	0.001	0.001	0.001	0.001
	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.006	-0.002	-0.008	-0.008	-0.007	-0.010
	[0.006]	[0.011]	[0.010]	[0.007]	[0.008]	[0.009]
Number of product types	-0.001	0.006	0.005	-0.001	0.001	0.005
	[0.003]	[0.005]	[0.005]	[0.004]	[0.004]	[0.005]
Top management have a master degree	-0.002	0.082+	0.046	-0.003	0.050	0.045
	[0.026]	[0.044]	[0.042]	[0.035]	[0.033]	[0.040]
Top management was engineer	0.054	-0.013	0.006	0.043	0.060	0.057
	[0.034]	[0.053]	[0.049]	[0.037]	[0.045]	[0.048]
Top management have an experience for MNC/JV	0.004	0.026	0.129**	0.020	0.000	-0.016
	[0.029]	[0.049]	[0.045]	[0.032]	[0.035]	[0.043]
Ratio of high school graduates among blue-collar workers	0.000	-0.001	0.000	0.000	0.000	0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Ratio of technical college graduates among engineers	-0.001	0.000	-0.001	0.001	0.001	0.001*
	[0.000]	[0.001]	[0.001]	[0.000]	[0.000]	[0.001]
Indonesia	0.039	-0.016	-0.037	0.085**	0.064	0.110*
	[0.030]	[0.088]	[0.084]	[0.032]	[0.045]	[0.047]
Philippines	0.028	0.028	0.111+	-0.071	0.000	0.020
	[0.034]	[0.071]	[0.058]	[0.060]	[0.053]	[0.061]
Hanoi	0.074**	0.016	-0.002	-0.122	-0.048	-0.048
	[0.026]	[0.093]	[0.089]	[0.099]	[0.082]	[0.090]
Ho Chi Minh	0.123**	0.149*	0.239**	0.125**	0.193**	0.214**
	[0.032]	[0.075]	[0.054]	[0.044]	[0.044]	[0.050]
Observations	467	483	483	473	473	483

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies.
Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%
Reference country is Thailand.

4.3. Sales, Procurement, and Management Practices

Process innovation does not emerge from production processes alone but also in shipping phases (sales and procurement stages) and other managerial operation stages. Table 7 has 10 different organizational reforms within firms, namely: (1) change in marketing; (2) change in inventory control; (3) change in domestic procurement; (4) change in international procurement; (5) change in domestic delivery; (6) change in international delivery; (7) change in accounting system; (8) change in HRMP (human resource management practices); (9) change in environment management; and (10) adoption in ISO. The coefficients for the mutual knowledge exchanges on these organizational reforms could be interpreted as technologies of learning and teaching processes with upstream-downstream partners.

The coefficients for the R&D dummy variables are significantly effective for changing in international delivery (column 6), changing accounting system (column 7), and changing HRMP (column 8), being statistically significant at the 1 percent level. Since these organizational reforms have seemed to be costly activities, only firms with R&D activities can achieve the said reforms compared to firms without R&D activities. The coefficient for the mutual knowledge exchange with customer is .263 on changing environment management with standard error of .115, and statistically significant at 5 percent level. This suggests that firms which received the benefits of mutual knowledge flows from their main customer could have 26.3 percent larger probability of changing environment management than firms which no benefits from mutual knowledge flows. In addition to the mutual knowledge exchanges with customer, the coefficient is -.295 on changing inventory control (column 2) with standard error of .118, and statistically significant at 5 percent level. This is also true for changing international delivery (column 6) and changing HRMP (column 8). Since the coefficients for accepting engineers from supplier are always positive, firms accepting engineers naturally gain benefits.

Table 7 Exchanges of Engineers and Upgrading in Sales, Procurement, and Management Practices

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variables: Upgrading in Sales, Procurement, and Management Practices (Yes/No)	Change Marketing	Change Inventory Control	Change Domestic Procurement	Change International Procurement	Change Domestic Delivery	Change International Delivery	Change Accounting System	Change HRMP	Change Environment Management	Adopt New ISO
R&D dummy (Yes/No)	-0.044	0.007	0.048	0.066	0.053	0.148**	0.156**	0.152**	0.054	-0.002
	[0.038]	[0.038]	[0.049]	[0.057]	[0.047]	[0.050]	[0.054]	[0.043]	[0.051]	[0.055]
Customer dispatch engineers*Dispatch engineers to customer	0.027	0.114	-0.127	0.161	-0.027	0.142	0.116	0.065	0.263*	0.176
	[0.092]	[0.091]	[0.118]	[0.137]	[0.119]	[0.137]	[0.137]	[0.099]	[0.115]	[0.134]
Customer dispatch engineers	0.019	-0.079	0.162+	-0.133	0.038	-0.193*	-0.006	-0.083	-0.089	-0.071
	[0.066]	[0.061]	[0.087]	[0.087]	[0.081]	[0.097]	[0.095]	[0.064]	[0.082]	[0.090]
Dispatch engineers to customer	-0.104	-0.111	-0.013	-0.089	-0.059	-0.051	-0.131	-0.045	-0.068	0.02
	[0.076]	[0.078]	[0.093]	[0.118]	[0.099]	[0.119]	[0.116]	[0.083]	[0.108]	[0.122]
Supplier dispatch engineers*Dispatch engineers to supplier	-0.035	-0.295*	-0.110	-0.111	-0.094	-0.222+	0.018	-0.296*	-0.16	-0.007
	[0.091]	[0.118]	[0.113]	[0.132]	[0.111]	[0.119]	[0.129]	[0.117]	[0.118]	[0.128]
Supplier dispatch engineers	0.061	0.235*	0.027	0.209*	0.025	0.276**	0.099	0.163+	0.101	-0.067
	[0.072]	[0.092]	[0.086]	[0.101]	[0.081]	[0.090]	[0.099]	[0.087]	[0.092]	[0.098]
Dispatch engineers to supplier	0.033	0.098	0.075	0.009	0.040	0.146	-0.015	0.108	0.014	-0.03
	[0.069]	[0.072]	[0.084]	[0.094]	[0.084]	[0.101]	[0.102]	[0.079]	[0.093]	[0.102]
Size of domestic sales	0.000	0.001	0.001	0.001	0.004**	0.000	0.001	0.001	0.002+	-0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.015+	0.003	-0.019+	-0.022+	-0.015	-0.007	-0.021	-0.016+	-0.033**	-0.039**
	[0.009]	[0.009]	[0.011]	[0.013]	[0.010]	[0.012]	[0.013]	[0.009]	[0.012]	[0.013]
Number of product types	0.006	0.001	0.000	0.004	-0.002	-0.008	0.001	0.005	0.004	0.001
	[0.004]	[0.004]	[0.006]	[0.007]	[0.005]	[0.007]	[0.007]	[0.005]	[0.007]	[0.007]
Top management have a master degree	0.080*	0.012	0.015	0.156**	0.026	0.060	0.044	0.047	-0.004	0.143*
	[0.035]	[0.041]	[0.052]	[0.060]	[0.048]	[0.057]	[0.059]	[0.042]	[0.055]	[0.057]
Top management was engineer	0.002	0.062	-0.020	-0.016	0.064	0.114*	-0.048	0.03	0.093	0.136*
	[0.043]	[0.047]	[0.054]	[0.068]	[0.054]	[0.058]	[0.064]	[0.050]	[0.060]	[0.065]
Top management have an experience for MNC/JV	0.084*	0.069+	0.030	0.038	0.008	-0.015	-0.039	0.025	0.107*	0.144**
	[0.040]	[0.040]	[0.052]	[0.061]	[0.050]	[0.055]	[0.057]	[0.044]	[0.053]	[0.056]
Ratio of high school graduates among blue-collar workers	-0.001	-0.001	-0.002*	-0.002	-0.001	0.000	0	-0.001	0.001	0
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Ratio of technical college graduates among engineers	0.001	0.000	0.000	0.001	-0.001	-0.001	0	0.001	0	0.002**
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Indonesia	0.054	-0.092	0.034	-0.029	0.002	-0.106	0.181+	0.085	0.016	0.068
	[0.056]	[0.088]	[0.079]	[0.101]	[0.081]	[0.092]	[0.095]	[0.055]	[0.096]	[0.097]
Philippines	-0.041	-0.070	-0.056	0.045	-0.195*	-0.049	-0.049	0.031	0.011	-0.042
	[0.059]	[0.067]	[0.077]	[0.091]	[0.084]	[0.087]	[0.093]	[0.060]	[0.088]	[0.091]
Hanoi	0.146**	-0.195+	-0.021	0.199*	0.013	0.067	0.174+	0.049	-0.015	0.093
	[0.036]	[0.110]	[0.100]	[0.093]	[0.095]	[0.114]	[0.103]	[0.074]	[0.115]	[0.110]
Ho Chi Minh	0.272**	0.239**	0.322**	0.513**	0.287**	0.013	-0.273**	0.288**	-0.098	0.055
	[0.042]	[0.048]	[0.059]	[0.062]	[0.056]	[0.100]	[0.102]	[0.048]	[0.106]	[0.104]
Observations	483	483	483	483	483	483	483	483	483	483

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies. Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%. Reference country is Thailand.

4.4. Total Quality Management and Production Processes

Table 8 revealed ten different upgrading proxies, namely: (1) decrease in defection; (2) decrease in inventories; (3) decrease in materials; (4) decrease in labor inputs; (5) improve quality; (6) reduce lead time; (7) increase domestic market; (8) increase in abroad market; (9) reduce pollution; and (10) meet regulation. The coefficients for R&D is positively significant for estimating improved quality (column 5), reduce lead time (column 6), increase in domestic market (column 7), increase in abroad market (column 8), and meet regulation (column 10).

The coefficient for mutual knowledge exchange with customer on increasing abroad market is .234 with standard error of .133, and statistically significant at 10 percent level. The coefficients for one-way knowledge flows from customer where impacts of accepting engineers from customer are effective in reducing labor input (column 4), increase in domestic market (column 7), and reduced pollution (column 9). There is no significant effect of the mutual knowledge exchanges with supplier as well as the one-way knowledge flows to and from the supplier.

Table 8 Exchanges of Engineers and Upgrading in Total Quality of Management and Production Process

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variables: Upgrading Total Quality of Management and Production Process (Yes/No)	Decrease in Defection	Decrease in Inventories	Decrease in Materials	Reduce Labor Inputs	Improve Quality	Reduce Lead-time	Increase in Domestic Market	Increase in Abroad Market	Reduce Pollution	Meet Regulation
R&D dummy (Yes/No)	-0.017	0.007	0.064	0.038	**0.056+**	**0.094+**	**0.110***	**0.166****	0.064	**0.074***
	[0.044]	[0.054]	[0.054]	[0.049]	**[0.032]**	**[0.054]**	**[0.054]**	**[0.051]**	[0.052]	**[0.032]**
Customer dispatch engineers*Dispatch engineers to customer	0.061	0.282*	-0.070	-0.160	0.013	-0.092	-0.171	**0.234+**	-0.099	0.005
	[0.112]	[0.121]	[0.139]	[0.115]	[0.074]	[0.138]	[0.129]	**[0.133]**	[0.128]	[0.069]
Customer dispatch engineers	0.009	**-0.177***	-0.035	**0.144+**	0.001	-0.036	**0.274****	-0.041	**0.221***	-0.015
	[0.076]	**[0.083]**	[0.095]	**[0.077]**	[0.058]	[0.092]	**[0.089]**	[0.092]	**[0.093]**	[0.047]
Dispatch engineers to customer	-0.013	-0.095	0.034	0.135	-0.013	**0.211+**	0.11	-0.135	0.151	0.051
	[0.098]	[0.110]	[0.121]	[0.096]	[0.061]	**[0.118]**	[0.105]	[0.117]	[0.109]	[0.061]
Supplier dispatch engineers*Dispatch engineers to supplier	0.034	-0.131	0.008	-0.016	-0.076	0.126	-0.022	-0.016	0.012	-0.067
	[0.104]	[0.129]	[0.127]	[0.114]	[0.085]	[0.126]	[0.127]	[0.124]	[0.118]	[0.078]
Supplier dispatch engineers	0.012	-0.023	-0.077	-0.013	0.114+	-0.142	0.082	-0.022	-0.049	0.096
	[0.084]	[0.098]	[0.098]	[0.087]	[0.067]	[0.099]	[0.102]	[0.098]	[0.092]	[0.064]
Dispatch engineers to supplier	-0.073	0.141	0.147	0.021	0.035	-0.006	-0.069	0.088	0.023	-0.007
	[0.079]	[0.097]	[0.100]	[0.087]	[0.058]	[0.102]	[0.087]	[0.094]	[0.096]	[0.047]
Size of domestic sales	-0.001	-0.002+	-0.002+	-0.001	-0.001	-0.001	0.002*	-0.002*	0	-0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.022*	-0.010	-0.001	0.009	0.001	0.002	-0.023+	-0.038**	-0.013	-0.012+
	[0.011]	[0.012]	[0.013]	[0.011]	[0.008]	[0.013]	[0.013]	[0.013]	[0.012]	[0.007]
Number of product types	0.001	0.008	-0.001	-0.008	-0.006	0.017*	0.003	0.007	-0.002	-0.001
	[0.005]	[0.006]	[0.007]	[0.006]	[0.004]	[0.007]	[0.006]	[0.007]	[0.007]	[0.003]
Top management have a master degree	0.073	0.067	0.020	0.090	0.080*	0.085	-0.031	-0.018	0.079	0.009
	[0.047]	[0.057]	[0.058]	[0.055]	[0.032]	[0.060]	[0.058]	[0.058]	[0.055]	[0.035]
Top management was engineer	0.037	0.082	0.177**	0.037	0.037	0.165**	-0.055	0.065	0.058	0.036
	[0.053]	[0.063]	[0.062]	[0.058]	[0.039]	[0.063]	[0.063]	[0.061]	[0.061]	[0.037]
Top management have an experience for MNC/JV	-0.057	0.028	-0.035	0.036	-0.028	0.041	0.119*	0.055	0.078	0.046
	[0.049]	[0.056]	[0.058]	[0.053]	[0.034]	[0.059]	[0.056]	[0.055]	[0.058]	[0.033]
Ratio of high school graduates among blue-collar workers	0.001	-0.002*	-0.001	0.000	0.002**	0	0.002	-0.001	0	0
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Ratio of technical college graduates among engineers	0.001	0.001	0.002**	0.000	0.000	0.001	-0.001	0.001	0.001	0.001**
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.000]
Indonesia	0.206**	-0.054	-0.091	0.105	0.106**	0.476**	0.290**	0.107	0.178*	0.091**
	[0.041]	[0.099]	[0.106]	[0.097]	[0.029]	[0.050]	[0.049]	[0.107]	[0.078]	[0.025]
Philippines	0.218**	0.107	0.074	0.253**	0.085+	0.411**	0.167*	0.156	0.334**	0.082*
	[0.056]	[0.080]	[0.089]	[0.086]	[0.044]	[0.077]	[0.080]	[0.097]	[0.066]	[0.040]
Hanoi	0.215**	0.015	-0.024	-0.091	0.028	0.243*	0.203*	0.049	0.012	-0.107
	[0.049]	[0.110]	[0.118]	[0.090]	[0.058]	[0.105]	[0.079]	[0.120]	[0.110]	[0.094]
Ho Chi Minh	0.185**	0.364**	-0.184+	-0.285**	0.046	0.313**	0.462**	0.241*	-0.053	0.115*
	[0.066]	[0.073]	[0.101]	[0.068]	[0.058]	[0.097]	[0.058]	[0.108]	[0.101]	[0.046]
Observations	483	473	483	483	483	483	483	483	483	483

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies. Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%. Reference country is Thailand.

4.5. Robustness Checks

One concern arise regarding the above findings wherein engineer exchange with partner matters for product and process innovations. This means management practice with the main partner is the key reason for upgrading. If these findings simply reflect the *characteristics* of partners not the *practice* embedded with the partnership, then there may risk of misleading facts. The characteristics of partners—local firms, JVs, and MNCs—could affect the firm's upgrading through bypassing the exchange of engineers. Since Table 4 has suggested that MNCs dispatch engineers to their partners compared to JVs and local firms as well as there is more MNCs which accept engineers from their partners, MNCs could affect firm's upgrading through transactions without exchanges of engineers. To check the robustness of results, whether MNCs and JVs partnership do not simply affect product and process innovation compared to local firms was examined.

We regress product and process innovation outcome to the four dummy variables of types of partners—customer is MNCs, customer is JVs, supplier is MNCs, and supplier is JVs. The benchmark is the local firms. Since firms often send and accept engineers if they connect with MNCs customer, the expected coefficients of customers are MNCs and JVs are insignificant. Each column in Table 9 suggests that MNCs and JVs customer do not have significant impact on product innovations. On the other hand, the coefficient of JVs supplier means that firms achieve several types of product innovations in terms of development of new product based on existing technologies and new technologies as well as new product to existing market. Table 10 shows the process innovation impacts of MNCs and JVs partner. MNCs and JVs customer do not have significant impact on process innovations except for buying new machines as a process innovation.

On the other hand, MNCs and JVs partner solely affect the organizational reforms and changing of total quality of management. As shown in Table 11, if firms had connected with MNCs or JVs customer, then they achieve less change in marketing, domestic delivery, and account system compared to firms which sell to local customer. If firms had connected with MNCs or JVs supplier, they achieve more change in marketing, domestic delivery, international delivery, and adoption of ISO compared to firms which buy from local supplier. Table 12 shows that if firms had connected with MNCs customer, then inventories decreased. If firms had connected with MNCs or JVs customer, then they fail to reduce labor inputs or lead-time, to increase in domestic market, and to reduce pollution. If firms had connected with MNCs or JVs supplier, then they are able to increase domestic market, decrease inventories.

In summary, robustness in the main results is especially supported in terms of product innovations. Main results of process innovations, other organizational reforms, and changing of total quality of management are partially supported by above robustness check.

Table 9 Robustness Checks; Product Innovations Impacts of Partner's Types and Own Capabilities

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables: Product Innovations (Yes/No)	Change Design	Improvement of Existing Product	Development of New Product based on Existing Technologies	Development of New Product based on New Technologies	New Product to Existing Market	New Product to New Market
R&D dummy (Yes/No)	-0.027	0.001	**0.131****	0.006	0.070	**0.155***
	[0.047]	[0.024]	**[0.049]**	[0.056]	[0.046]	**[0.068]**
Main customer is MNCs	-0.099	0.024	-0.062	-0.005	0.032	-0.101
	[0.078]	[0.027]	[0.075]	[0.079]	[0.056]	[0.104]
Main customer is JVs	-0.020	-0.011	-0.099	0.072	-0.020	0.060
	[0.066]	[0.034]	[0.087]	[0.081]	[0.065]	[0.090]
Main supplier is MNCs	**0.102***	-0.009	0.015	0.101	0.012	0.091
	[0.051]	[0.031]	[0.062]	[0.070]	[0.052]	[0.079]
Main supplier is JVs	0.081	0.014	**0.216****	**0.128+**	**0.125****	0.034
	[0.049]	[0.027]	**[0.052]**	**[0.072]**	**[0.039]**	[0.090]
In-house design	0.053	0.006	-0.032	0.017	**-0.069+**	-0.071
	[0.058]	[0.027]	[0.056]	[0.066]	**[0.041]**	[0.073]
CAD, CAM, CAE	0.053	0.021	-0.056	0.088	0.005	0.041
	[0.053]	[0.028]	[0.057]	[0.065]	[0.045]	[0.070]
OEM	0.024	0.033	**0.143***	0.008	-0.013	0.059
	[0.046]	[0.025]	**[0.060]**	[0.065]	[0.046]	[0.066]
ODM	-0.054	0.040	0.050	-0.030	0.063	-0.077
	[0.053]	[0.026]	[0.057]	[0.064]	[0.046]	[0.086]
OBM	0.100*	0.041	0.068	0.098	0.034	0.078
	[0.051]	[0.027]	[0.058]	[0.063]	[0.048]	[0.073]
ISO9000, 14000, or other international standard	-0.032	-0.004	0.051	-0.068	0.009	0.016
	[0.049]	[0.024]	[0.056]	[0.062]	[0.048]	[0.071]
QM or QC circle	-0.010	-0.013	0.044	0.106	0.090	-0.018
	[0.056]	[0.024]	[0.073]	[0.083]	[0.066]	[0.082]
Adopted JIT	-0.068	0.020	-0.014	**0.135***	-0.024	0.081
	[0.050]	[0.026]	[0.056]	**[0.062]**	[0.045]	[0.074]
OJT	-0.003	0.004	-0.002	**-0.109+**	-0.030	-0.030
	[0.050]	[0.027]	[0.056]	**[0.062]**	[0.044]	[0.076]
OFFJT	-0.007	-0.003	0.086	0.069	0.077	0.061
	[0.049]	[0.026]	[0.052]	[0.059]	[0.048]	[0.073]
Size of domestic sales	0.002+	0.000	-0.001	0.001	0.000	0.001
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.018+	-0.009+	-0.001	-0.009	-0.009	0.016
	[0.010]	[0.005]	[0.012]	[0.013]	[0.009]	[0.014]
Number of product types	0.002	0.001	0.006	0.007	0.017**	0.017*
	[0.005]	[0.003]	[0.006]	[0.007]	[0.005]	[0.007]
Top management have a master degree	-0.053	-0.004	0.004	0.077	0.017	-0.137+
	[0.050]	[0.024]	[0.057]	[0.059]	[0.045]	[0.074]
Top management was engineer	0.086	0.038	-0.012	0.080	-0.002	0.019
	[0.054]	[0.030]	[0.057]	[0.065]	[0.047]	[0.072]
Top management have an experience for	0.065	-0.033	-0.017	0.110+	0.080	0.046
	[0.049]	[0.024]	[0.054]	[0.058]	[0.049]	[0.072]
Ratio of high school graduates among	0.001	0.001+	0.000	0.000	0.001	0.000
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Ratio of technical college graduates among	0.000	0.000	0.000	-0.002*	0.000	-0.001
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
Indonesia	0.099+	-0.002	0.064	-0.090	0.144**	-0.055
	[0.055]	[0.038]	[0.087]	[0.106]	[0.030]	[0.106]
Philippines	0.056	-0.034	0.070	-0.052	0.055	-0.203*
	[0.064]	[0.042]	[0.083]	[0.098]	[0.062]	[0.097]
Hanoi	0.041	0.035	0.038	-0.078	0.175**	0.189+
	[0.076]	[0.031]	[0.101]	[0.121]	[0.036]	[0.097]
Ho Chi Minh	0.470**	0.105**	0.080	0.061		
	[0.046]	[0.033]	[0.104]	[0.121]		
Observations	483	483	483	483	338	338

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies.
Robust standard errors in brackets.+ significant at 10%; * significant at 5%; ** significant at 1%
Reference country is Thailand.

Table 10 Robustness Checks; Process Innovations Impacts of Partner's Types and Own Capabilities

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables: Process Innovations (Yes/No)	Improved Existing Machines	Bought New Machines	Introduced New-Know How on Production Methods	Change Quality Control	Change Production Control	Change Cost Control
R&D dummy (Yes/No)	0.021	**0.122****	**0.183****	0.010	**0.058+**	0.012
	[0.026]	**[0.047]**	**[0.048]**	[0.028]	**[0.035]**	[0.042]
Main customer is MNCs	-0.013	-0.022	-0.001	0.027	-0.025	-0.094
	[0.040]	[0.067]	[0.062]	[0.039]	[0.052]	[0.068]
Main customer is JVs	0.023	**0.131****	-0.073	-0.012	0.004	0.039
	[0.030]	**[0.050]**	[0.081]	[0.045]	[0.051]	[0.053]
Main supplier is MNCs	-0.006	0.019	0.037	-0.041	-0.075	0.017
	[0.033]	[0.057]	[0.050]	[0.046]	[0.053]	[0.055]
Main supplier is JVs	-0.021	0.003	0.109*	-0.038	0.026	0.002
	[0.047]	[0.066]	[0.047]	[0.050]	[0.047]	[0.055]
In-house design	0.037	0.036	-0.053	**-0.088****	-0.025	-0.061
	[0.033]	[0.054]	[0.043]	**[0.024]**	[0.036]	[0.042]
CAD, CAM, CAE	-0.002	0.013	0.052	0.044	-0.013	0.047
	[0.027]	[0.054]	[0.052]	[0.035]	[0.036]	[0.050]
OEM	**0.066+**	**0.095+**	0.080	0.052	0.059	0.002
	[0.034]	**[0.056]**	[0.051]	[0.033]	[0.038]	[0.043]
ODM	**-0.077***	0.016	-0.019	-0.045	-0.038	0.054
	[0.034]	[0.054]	[0.051]	[0.036]	[0.041]	[0.045]
OBM	**-0.051+**	-0.068	-0.059	-0.001	-0.043	-0.046
	[0.026]	[0.052]	[0.048]	[0.032]	[0.038]	[0.043]
ISO9000, 14000, or other international standard	0.038	0.015	0.074	-0.001	0.028	-0.060
	[0.031]	[0.050]	[0.049]	[0.032]	[0.039]	[0.041]
QM or QC circle	0.047	0.097	0.073	**0.115***	0.081	**0.113+**
	[0.039]	[0.071]	[0.066]	**[0.054]**	[0.058]	**[0.065]**
Adopted JIT	**0.055***	**-0.082+**	**0.093***	0.055	-0.007	-0.025
	[0.026]	**[0.049]**	**[0.047]**	[0.034]	[0.038]	[0.044]
OJT	0.001	**-0.143****	0.011	0.036	0.038	0.072
	[0.027]	**[0.049]**	[0.048]	[0.033]	[0.040]	[0.046]
OFFJT	-0.015	0.076	0.032	0.052	0.040	0.026
	[0.026]	[0.050]	[0.048]	[0.032]	[0.039]	[0.044]
Size of domestic sales	0.000	0.001	0.001	0.001	0.001	0.001
	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.007	-0.006	-0.007	-0.008	-0.009	-0.010
	[0.005]	[0.011]	[0.010]	[0.007]	[0.007]	[0.009]
Number of product types	0.000	0.009	0.006	-0.002	0.000	0.006
	[0.003]	[0.006]	[0.005]	[0.004]	[0.004]	[0.005]
Top management have a master degree	0.014	0.046	0.045	-0.001	0.043	0.031
	[0.021]	[0.048]	[0.043]	[0.032]	[0.033]	[0.042]
Top management was engineer	0.059+	-0.013	0.002	0.021	0.04	0.025
	[0.032]	[0.052]	[0.050]	[0.032]	[0.040]	[0.045]
Top management have an experience for MNC/JV	0.000	0.002	0.097*	-0.007	-0.002	-0.027
	[0.027]	[0.050]	[0.047]	[0.033]	[0.037]	[0.047]
Ratio of high school graduates among blue-collar workers	0.000	0.000	0.000	0.000	0.000	0.000
	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Ratio of technical college graduates among engineers	0	0	-0.001	0	0	0.001
	[0.000]	[0.001]	[0.001]	[0.000]	[0.001]	[0.001]
Indonesia	0.027	-0.003	-0.074	0.071*	0.068+	0.110*
	[0.029]	[0.088]	[0.096]	[0.028]	[0.041]	[0.046]
Philippines	0.015	0.077	0.089	-0.064	0.023	0.04
	[0.034]	[0.072]	[0.064]	[0.056]	[0.050]	[0.060]
Hanoi	0.076**	0.037	0.085	-0.048	0.003	-0.025
	[0.020]	[0.089]	[0.066]	[0.076]	[0.065]	[0.084]
Ho Chi Minh	0.126**	0.065	0.255**	0.121**	0.206**	0.231**
	[0.030]	[0.090]	[0.056]	[0.041]	[0.045]	[0.054]
Observations	467	483	483	473	473	483

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies.
Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%.
Reference country is Thailand.

Table 11 Robustness Checks; Sales, Procurement, and Management Practices Innovation Impacts of Partner's Types and Own Capabilities

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variables: Upgrading in Sales, Procurement, and Management Practices (Yes/No)	Change Marketing	Change Inventory Control	Change Domestic Procurement	Change International Procurement	Change Domestic Delivery	Change International Delivery	Change Accounting System	Change HRMP	Change Environment Management	Adopt New ISO
R&D dummy (Yes/No)	-0.046	0.004	0.048	0.064	0.037	0.151**	0.152**	0.129**	0.036	0.002
	[0.039]	[0.039]	[0.050]	[0.060]	[0.050]	[0.052]	[0.056]	[0.044]	[0.052]	[0.062]
Main customer is MNCs	-0.150*	-0.11	-0.019	-0.074	-0.179*	-0.033	-0.204*	-0.002	0.055	0.016
	[0.073]	[0.070]	[0.071]	[0.087]	[0.080]	[0.072]	[0.083]	[0.059]	[0.067]	[0.082]
Main customer is JVs	-0.051	-0.017	-0.046	0.011	-0.140+	-0.022	-0.023	0.055	0.139*	-0.048
	[0.065]	[0.062]	[0.075]	[0.084]	[0.078]	[0.081]	[0.081]	[0.055]	[0.068]	[0.092]
Main supplier is MNCs	0.076+	-0.005	-0.092	0.096	0.075	0.217**	0.072	-0.075	0.067	0.275**
	[0.044]	[0.052]	[0.070]	[0.081]	[0.056]	[0.070]	[0.070]	[0.063]	[0.064]	[0.064]
Main supplier is JVs	0.069	0.06	0.039	0.087	0.105*	0.131	0.104	-0.011	-0.002	0.077
	[0.044]	[0.047]	[0.066]	[0.076]	[0.052]	[0.082]	[0.075]	[0.063]	[0.075]	[0.080]
In-house design	-0.035	-0.003	-0.031	0.012	-0.015	-0.089	0.123+	-0.014	-0.046	-0.255**
	[0.040]	[0.044]	[0.056]	[0.071]	[0.054]	[0.062]	[0.064]	[0.049]	[0.057]	[0.060]
CAD, CAM, CAE	0.031	-0.002	0.041	-0.034	-0.066	0.046	-0.045	0.015	-0.044	0.04
	[0.042]	[0.044]	[0.055]	[0.065]	[0.049]	[0.061]	[0.068]	[0.051]	[0.062]	[0.073]
OEM	0.019	0.039	0.028	0.062	0.06	0.143*	0.015	0.069	-0.059	0.084
	[0.040]	[0.044]	[0.054]	[0.065]	[0.052]	[0.061]	[0.068]	[0.049]	[0.064]	[0.072]
ODM	0.013	-0.038	0.042	-0.05	0.021	0.073	0.072	-0.009	0.062	0.015
	[0.045]	[0.046]	[0.059]	[0.069]	[0.055]	[0.062]	[0.064]	[0.050]	[0.057]	[0.070]
OBM	0.006	0.043	-0.065	0.049	-0.018	-0.105+	-0.111+	-0.032	0.023	-0.015
	[0.044]	[0.043]	[0.053]	[0.067]	[0.052]	[0.063]	[0.066]	[0.046]	[0.061]	[0.068]
ISO9000, 14000, or other international standard	0.029	0.047	0.023	0.014	0.055	0.001	0.007	0.054	0.073	0.493**
	[0.044]	[0.044]	[0.055]	[0.060]	[0.052]	[0.060]	[0.063]	[0.050]	[0.060]	[0.058]
QM or QC circle	-0.03	0.052	0.017	0.139+	0.114	0.11	0.101	0.057	0.076	-0.027
	[0.046]	[0.060]	[0.067]	[0.084]	[0.070]	[0.073]	[0.082]	[0.065]	[0.080]	[0.086]
Adopted JIT	0.026	0.02	0.065	-0.012	0.102+	0.011	0.043	-0.028	0.08	0.120+
	[0.043]	[0.043]	[0.054]	[0.064]	[0.054]	[0.059]	[0.060]	[0.047]	[0.056]	[0.064]
OJT	0.016	-0.047	-0.025	0.044	0.018	-0.026	0.075	-0.011	0.008	0.1
	[0.043]	[0.044]	[0.054]	[0.067]	[0.053]	[0.063]	[0.063]	[0.048]	[0.059]	[0.074]
OFFJT	0.065	0.05	0.071	-0.011	0.055	0.104+	0.127*	0.116*	0.063	0.110+
	[0.042]	[0.044]	[0.051]	[0.062]	[0.050]	[0.058]	[0.062]	[0.046]	[0.055]	[0.063]
Size of domestic sales	0	0	0.001	0	0.003**	0	0	0.001	0.002+	-0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.016*	0.002	-0.016	-0.024+	-0.012	-0.011	-0.023+	-0.018+	-0.033**	-0.039*
	[0.008]	[0.009]	[0.011]	[0.013]	[0.010]	[0.013]	[0.013]	[0.010]	[0.013]	[0.015]
Number of product types	0.007	0.001	0	0.003	-0.002	-0.009	0.003	0.004	0.003	0.002
	[0.004]	[0.005]	[0.006]	[0.007]	[0.005]	[0.007]	[0.007]	[0.005]	[0.007]	[0.007]
Top management have a master degree	0.069*	0.001	-0.003	0.153*	-0.003	0.032	0.043	0.031	-0.022	0.099
	[0.034]	[0.042]	[0.054]	[0.061]	[0.050]	[0.057]	[0.060]	[0.045]	[0.057]	[0.062]
Top management was engineer	-0.009	0.043	-0.025	-0.025	0.03	0.091	-0.053	-0.011	0.088	0.089
	[0.040]	[0.045]	[0.052]	[0.066]	[0.052]	[0.058]	[0.064]	[0.046]	[0.060]	[0.069]
Top management have an experience for MNC/JV	0.065	0.056	0.008	0.035	-0.013	-0.07	-0.048	-0.001	0.081	0.08
	[0.040]	[0.042]	[0.055]	[0.062]	[0.053]	[0.057]	[0.060]	[0.047]	[0.055]	[0.061]
Ratio of high school graduates among blue-collar workers	-0.001	-0.001	-0.002*	-0.001	-0.001	-0.001	0	0	0.001	-0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Ratio of technical college graduates among engineers	0.001	0	0	0.001	-0.001	-0.001	0	0	0	0.002+
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Indonesia	0.055	-0.094	0.005	-0.021	-0.01	-0.069	0.193*	0.110*	0.017	0.172+
	[0.055]	[0.090]	[0.087]	[0.105]	[0.084]	[0.098]	[0.096]	[0.050]	[0.100]	[0.091]
Philippines	-0.003	-0.042	-0.057	0.052	-0.188*	-0.011	0.027	0.088	0.007	0.004
	[0.057]	[0.068]	[0.085]	[0.096]	[0.088]	[0.094]	[0.098]	[0.058]	[0.090]	[0.096]
Hanoi	0.141**	-0.187+	0.035	0.208*	0.065	0.142	0.242*	0.08	0.063	0.217*
	[0.036]	[0.111]	[0.096]	[0.094]	[0.083]	[0.119]	[0.096]	[0.070]	[0.109]	[0.100]
Ho Chi Minh	0.274**	0.215**	0.331**	0.511**	0.291**	-0.017	-0.134	0.267**	-0.012	0.021
	[0.045]	[0.055]	[0.067]	[0.072]	[0.061]	[0.113]	[0.122]	[0.057]	[0.118]	[0.131]
Observations	483	483	483	483	483	483	483	483	483	483

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies.
Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%.
Reference country is Thailand.

Table 12 Robustness Checks; Total Quality of Management and Production Process Innovation Impacts of Partner's Types and Own Capabilities

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variables: Upgrading Total Quality of Management and Production Process (Yes/No)	Decrease in Defection	Decrease in Inventories	Decrease in Materials	Reduce Labor Inputs	Improve Quality	Reduce Lead-time	Increase in Domestic Market	Increase in Abroad Market	Reduce Pollution	Meet Regulation
R&D dummy (Yes/No)	-0.011	0.015	0.059	0.057	0.038	**0.111+**	**0.132***	**0.164****	0.083	**0.084****
	[0.046]	[0.054]	[0.056]	[0.050]	[0.031]	**[0.058]**	**[0.055]**	**[0.051]**	[0.055]	**[0.031]**
Main customer is MNCs	-0.035	**0.140***	0.084	-0.107	0.025	**-0.151+**	**-0.268****	-0.013	-0.1	-0.047
	[0.067]	**[0.071]**	[0.079]	[0.066]	[0.037]	**[0.079]**	**[0.084]**	[0.072]	[0.078]	[0.057]
Main customer is JVs	-0.002	0.036	-0.052	**-0.150***	-0.037	-0.051	**-0.186***	0.055	**-0.176+**	-0.037
	[0.071]	[0.078]	[0.084]	**[0.060]**	[0.053]	[0.086]	**[0.091]**	[0.082]	**[0.091]**	[0.048]
Main supplier is MNCs	-0.055	-0.096	0.054	-0.024	-0.089+	-0.056	**0.121+**	0.053	0.04	-0.037
	[0.062]	[0.075]	[0.072]	[0.065]	[0.049]	[0.073]	**[0.065]**	[0.071]	[0.068]	[0.045]
Main supplier is JVs	-0.025	**0.127+**	0.124	0.055	-0.077	-0.05	0.094	-0.024	0.065	**-0.107+**
	[0.071]	**[0.072]**	[0.077]	[0.080]	[0.056]	[0.083]	[0.068]	[0.077]	[0.079]	**[0.058]**
In-house design	0.002	-0.026	**-0.160****	0.01	-0.017	**-0.179****	0.056	0.014	**-0.184****	-0.018
	[0.051]	[0.060]	**[0.060]**	[0.055]	[0.034]	**[0.063]**	[0.065]	[0.062]	**[0.055]**	[0.031]
CAD, CAM, CAE	0.005	-0.062	-0.015	0.007	0.108*	0.064	0.022	-0.002	-0.016	0.024
	[0.055]	[0.062]	[0.067]	[0.058]	[0.044]	[0.068]	[0.062]	[0.062]	[0.064]	[0.036]
OEM	-0.064	-0.089	-0.024	0.063	-0.029	0.041	0.078	0.053	0.047	-0.021
	[0.053]	[0.062]	[0.066]	[0.056]	[0.036]	[0.070]	[0.061]	[0.065]	[0.066]	[0.031]
ODM	0.035	0.03	0.015	-0.026	0.053	0.048	0.003	-0.04	**0.136***	0.031
	[0.051]	[0.063]	[0.063]	[0.061]	[0.034]	[0.066]	[0.065]	[0.062]	**[0.060]**	[0.030]
OBM	-0.065	-0.092	-0.012	-0.031	0.014	-0.007	-0.01	0.047	-0.07	**-0.049+**
	[0.053]	[0.060]	[0.064]	[0.058]	[0.036]	[0.067]	[0.062]	[0.061]	[0.065]	**[0.029]**
ISO9000, 14000, or other international standard	**0.105+**	0.039	0.005	-0.098+	-0.019	0.002	-0.011	0.027	0.068	0.028
	[0.055]	[0.059]	[0.062]	[0.059]	[0.034]	[0.063]	[0.060]	[0.060]	[0.061]	[0.033]
QM or QC circle	0.05	-0.05	0.024	0.109+	0.06	0.019	-0.057	-0.01	0.160+	0.088
	[0.074]	[0.073]	[0.083]	[0.060]	[0.056]	[0.081]	[0.071]	[0.081]	[0.086]	[0.061]
Adopted JIT	0.06	**0.171****	**0.135***	0.038	0.052	0.067	0.02	0.007	**0.097+**	0.104**
	[0.052]	**[0.060]**	**[0.060]**	[0.053]	[0.034]	[0.061]	[0.061]	[0.060]	**[0.057]**	[0.033]
OJT	0.017	0.055	**0.137***	0.025	-0.029	0.038	**0.125***	0.021	**0.155****	0.038
	[0.051]	[0.061]	**[0.063]**	[0.056]	[0.034]	[0.065]	**[0.060]**	[0.062]	**[0.060]**	[0.034]
OFFJT	-0.011	-0.046	0.034	-0.035	**0.060+**	0.041	0.037	0.023	0.053	-0.032
	[0.051]	[0.061]	[0.061]	[0.056]	**[0.034]**	[0.062]	[0.059]	[0.058]	[0.060]	[0.032]
Size of domestic sales	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002*	0.001	-0.002*	0	-0.001*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Years of product life cycle	-0.018	-0.007	-0.001	0.01	0.004	0.004	-0.023+	-0.040**	-0.007	-0.007
	[0.011]	[0.013]	[0.014]	[0.011]	[0.007]	[0.013]	[0.013]	[0.013]	[0.013]	[0.007]
Number of product types	0.001	0.005	-0.004	-0.005	-0.005	0.018*	0.006	0.007	-0.001	0
	[0.005]	[0.006]	[0.007]	[0.006]	[0.004]	[0.007]	[0.007]	[0.007]	[0.007]	[0.003]
Top management have a master degree	0.078+	0.058	0.003	0.087	0.076*	0.072	-0.034	-0.02	0.055	0.027
	[0.045]	[0.059]	[0.059]	[0.057]	[0.029]	[0.060]	[0.060]	[0.058]	[0.057]	[0.031]
Top management was engineer	0.027	0.082	0.176**	0.062	0.045	0.149*	-0.035	0.088	0.072	0.032
	[0.053]	[0.062]	[0.062]	[0.055]	[0.038]	[0.063]	[0.060]	[0.059]	[0.061]	[0.034]
Top management have an experience for MNC/JV	-0.052	0.028	-0.075	0.057	-0.031	0.027	0.125*	0.043	0.058	0.049
	[0.050]	[0.059]	[0.060]	[0.054]	[0.034]	[0.061]	[0.058]	[0.057]	[0.059]	[0.031]
Ratio of high school graduates among blue-collar workers	0.001	-0.002*	-0.002	0	0.002**	0	0.001	-0.001	0	0
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.000]
Ratio of technical college graduates among engineers	0	0.002+	0.002*	0	0	0.001	-0.001	0.001	0	0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.000]
Indonesia	0.192**	-0.063	-0.062	0.063	0.081**	0.485**	0.286**	0.121	0.185*	0.066*
	[0.045]	[0.103]	[0.109]	[0.098]	[0.030]	[0.049]	[0.052]	[0.112]	[0.083]	[0.026]
Philippines	0.215**	0.073	0.074	0.238**	0.073+	0.483**	0.204*	0.172+	0.373**	0.064+
	[0.059]	[0.089]	[0.096]	[0.089]	[0.044]	[0.075]	[0.081]	[0.103]	[0.070]	[0.037]
Hanoi	0.234**	0.116	0.13	-0.048	0.047	0.301**	0.235**	0.068	0.210*	-0.014
	[0.044]	[0.098]	[0.112]	[0.098]	[0.045]	[0.100]	[0.073]	[0.125]	[0.089]	[0.060]
Ho Chi Minh	0.242**	0.506**	-0.024	-0.264**	0.028	0.338**	0.525**	0.247*	0.138	0.152**
	[0.067]	[0.062]	[0.121]	[0.081]	[0.059]	[0.111]	[0.058]	[0.123]	[0.109]	[0.039]
Observations	483	473	483	483	483	483	483	483	483	483

Notes: Other control variables are: age, size, local firms, joint venture, industry, and function dummies.
Robust standard errors in brackets. + significant at 10%; * significant at 5%; ** significant at 1%.
Reference country is Thailand.

5. THE DETERMINANTS OF THE FORM OF MUTUAL KNOWLEDGE EXCHANGES

5.1. The Impacts of Transferred Technologies from Partners

Table 13 suggests the concrete evidence of the technology transfer impacts of the determinants of mutual exchanges of engineers. As shown in column 1 to 5 of Table 13, the coefficient of R&D dummy variables play an important role of determinants of mutual knowledge flows with firm's main customer or main supplier. Findings revealed five main results to determine mutual knowledge exchanges in the margin of transferred technologies. First, result is related to the impact of quality controls especially when applied into own firm's characteristics rather than to the supplier's characteristics. Second, result is on the impact of cost controls. Third, result shows that delivery management system also determines the mutual exchanges of engineers. The coefficient for dummy variable that supplier provides delivery controls has significantly positive impacts on mutual exchanges in engineers with supplier. On the other hand, the coefficient for dummy variable that firm provides delivery controls to their main customer has significantly positive impact on mutual exchanges in engineers with customer. Fourth, licensing from supplier also determines the mutual exchanges of engineers. The coefficient for dummy variable that supplier grants licenses for mutual exchanges of engineers could be .250 with standard error of .079. Finally, ISO determines mutual exchanges of knowledge. The coefficient for dummy variable that customer requires ISO is .125 with standard error of .066.

In summary, if customer provides cost and delivery controls as well as providing licenses to customer, the propensity of mutual exchanges of engineers with customer increases. It is emphasized that if customer requires ISO, then the propensity of mutual exchanges of engineers with customer increases. If supplier provides quality, cost, delivery controls as well as licenses, then the propensity of mutual exchanges of engineers with supplier also increases.

5.2. The Impacts of Spacing

Table 13 also suggests that the JIT (Just-in-Time hereafter) does not have significant impact as one determinant of mutual exchanges of engineers. However, the coefficients of JIT with supplier are negative for the mutual exchanges of engineers in all specifications; standard errors are large. That is, JIT with supplier does not have significant impact on the two-way flow of engineers. Distances with customers also do not determine the mutual exchanges of engineers. Firms and their customers do not care about distance between them in terms of mutual exchanges of engineers. On the other hand, however the coefficient of distance with supplier is smaller than other explanatory variables like R&D and transferred technologies. It is significantly positive at the 1 percent level.

Table 13 The Determinants of Mutual Exchanges of Engineers

Probit (Marginal Effects)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables: Customer (Supplier) dispatch engineers*Dispatch engineers to customer (supplier)	Partner is Customer			Partner is Supplier		
R&D dummy (Yes/No)	**0.147****	**0.131****	**0.130***	**0.112****	**0.102****	0.087
	[0.036]	**[0.038]**	**[0.063]**	**[0.036]**	**[0.039]**	[0.058]
Partner Provides Quality Controls	**0.161****	**0.160****	0.092	**0.206****	**0.233****	**0.306****
	[0.048]	**[0.050]**	[0.076]	**[0.052]**	**[0.055]**	**[0.080]**
Provide Quality Controls to Partner	**0.099***	**0.099***	0.071	0.025	0.007	-0.039
	[0.044]	**[0.047]**	[0.078]	[0.048]	[0.051]	[0.072]
Partner Provides Cost Controls	**0.164***	0.132	**0.189+**	**0.212****	**0.233****	**0.320****
	[0.080]	[0.083]	**[0.112]**	**[0.081]**	**[0.084]**	**[0.113]**
Provide Cost Controls to Partner	-0.056	-0.055	**-0.255***	-0.025	-0.077	-0.162
	[0.094]	[0.103]	**[0.110]**	[0.081]	[0.083]	[0.103]
Partner Provides Delivery Controls	-0.027	-0.023	-0.027	**0.128***	**0.150***	**0.247****
	[0.063]	[0.067]	[0.108]	**[0.063]**	**[0.067]**	**[0.091]**
Provide Delivery Controls to Partner	**0.161***	**0.177***	**0.189+**	0.040	0.030	0.121
	[0.065]	**[0.071]**	**[0.101]**	[0.066]	[0.070]	[0.104]
Partner Grants Licenses	**0.213****	**0.209****	0.051	**0.313****	**0.324****	**0.250****
	[0.053]	**[0.056]**	[0.085]	**[0.055]**	**[0.055]**	**[0.079]**
Provide Licenses to Partner	0.070	0.065	**0.162+**	-0.034	-0.041	0.038
	[0.050]	[0.052]	**[0.090]**	[0.054]	[0.056]	[0.086]
Partner Requires ISO	**0.116****	**0.104***	**0.125+**	**0.199****	**0.226****	0.099
	[0.043]	**[0.045]**	**[0.066]**	**[0.057]**	**[0.061]**	[0.083]
Require ISO to Partner	**0.093+**	0.054	-0.013	-0.028	-0.048	-0.084
	[0.049]	[0.052]	[0.080]	[0.049]	[0.052]	[0.071]
JIT with Partner	0.026	0.014	0.058	-0.027	-0.033	-0.049
	[0.043]	[0.047]	[0.071]	[0.038]	[0.041]	[0.060]
Distance to Partner		0.000	0.000		0.000	-0.000**
		[0.000]	[0.000]		[0.000]	[0.000]
Partner belongs to same industry		0.044	0.048		-0.012	0.047
		[0.043]	[0.066]		[0.039]	[0.058]
Partner is local		-0.083	-0.012		-0.057	-0.190*
		[0.057]	[0.095]		[0.052]	[0.077]
Partner is joint venture		0.052	0.060		0.001	-0.115
		[0.065]	[0.098]		[0.059]	[0.080]
Capital tie-up with partner		0.044	0.049		-0.081+	-0.138*
		[0.044]	[0.064]		[0.046]	[0.067]
Years of duration with partner		0.008	0.012		-0.003	0.005
		[0.006]	[0.010]		[0.006]	[0.009]
Indonesia	-0.086	-0.111+	-0.129	-0.131*	-0.179**	-0.108
	[0.055]	[0.062]	[0.126]	[0.052]	[0.056]	[0.112]
Philippines	0.082	0.028	-0.023	0.087	0.020	0.065
	[0.058]	[0.066]	[0.110]	[0.055]	[0.061]	[0.109]
Hanoi	0.185**	0.208**	0.201	0.205**	0.154*	0.004
	[0.067]	[0.078]	[0.138]	[0.067]	[0.076]	[0.132]
Ho Chi Minh	0.631**	0.587**	0.470**	0.422**	0.399**	0.198
	[0.047]	[0.059]	[0.106]	[0.070]	[0.079]	[0.132]
Partner's control		ü	ü		ü	ü
Firm's control			ü			ü
Observations	864	813	470	864	794	468

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

6. CONCLUSION

This paper presents evidence that mutual knowledge exchanges through engineers is an important connection with the diffusion of knowledge regarding product and process innovation in manufacturing sector in developing economies. This paper takes advantage of data that combines information of product creation and quality upgrading with relationships between connected firms (i.e., upstream and downstream firms) on the impacts of tacit knowledge exchanges in an economy of dense production network. Findings showed that manufacturing firms are more likely to achieve product innovations upon the exchange of engineers mutually with their main specific customer, especially in terms of development of new product based on new technologies and new product to new market. Using new technologies and creating new market need close collaboration with main existing customer. Findings showed that such connected firms are less likely to achieve improvement of existing machines and development of new product to existing technologies upon the exchanging engineers mutually with their main supplier. Mutual knowledge exchanges with supplier do not seem to fit existing machines and technologies. One concern is that the type of partner simply affects the product and process innovations of own manufacturing firms.

The results of product innovations are also supported by robustness check. Main customer or supplier types do not affect product innovations. Technology transfer needs face-to-face and two-way flow of knowledge, especially in quality controls, cost controls, delivery controls, licensing, and adoption of ISO. Further evidence of product and process innovations is that manager’s experience with foreign firms (including Joint venture firms) is an important technology of innovations. Experience of foreign firms plays a key role on new knowledge to local firms. This evidence provides policy implication on diversity training.

REFERENCES

Berliant, M., and M. Fujita (2008) "Knowledge Creation as a Square Dance on the Hilbert Cube," *International Economic Review*, 49 (4): 1251-1268.

Berliant, M., and M. Fujita (2009) "Dynamics of Knowledge Creation and Transfer: The Two Person Case," *International Journal of Economic Theory*, 5: 155-179.

Blalock, G. and P.J. Gertler (2008) "Welfare Gains from Foreign Direct Investment through Technology Transfer to Local Suppliers," *Journal of International Economics*, 74: 402-421.

Bloom, N., B. Eifert, A. Mahajan, D. McKenzie and J. Roberts (2010) "Management Matters: Evidence from India," mimeo.

Bloom, N. and J. van Reenen (2007) "Measuring and Explaining Management Practices across Firms and Countries," *Quarterly Journal of Economics*, 122(4): 1351-1408.

Bloom, N. and J. van Reenen (Forthcoming) "Why do Management Practices Differ across Firms and Countries?," *Journal of Economic Perspectives*.

__________ (Forthcoming) "New Approaches to Measuring Management and Firm Organization," *American Economic Review Papers and Proceedings*.

Conley, T. and C. Udry (2010) "Learning About a New Technology: Pineapple in Ghana," *American Economic Review*, 100(1): 35-69.

Easley, D. and J. Kleinberg (Forthcoming) *Networks, Crowds, and Markets: Reasoning about a Highly Connected World*, Cambridge University Press.

Fujita, M. (2007) "Towards the New Economic Geography in the Brain Power Society," *Regional Science and Urban Economics*, 37: 482-490.

Goyal, S. (2007) *Connections: An Introduction to the Economics of Networks*, Princeton University Press.

Hsieh, C., and P. Klenow (2009) "Misallocation and Manufacturing TFP in China and

India," *Quarterly Journal of Economics*, 124(4): 1403–48.

Hortacsu, A. and C. Syverson (2009) "Why do Firms Own Production Chains?," mimeo.

Jackson, M. (2008) *Social and Economic Networks*, Princeton University Press.

Javorcik, B. (2004) "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages," *American Economic Review,* 94: 605-627.

Jones, B.F., S. Wuchty and B. Uzzi (2007) "Multi-University Research Teams: Shifting Impact, Geography, and Stratification in Science," *Science*, 322(21): 1259-62.

Keller, W. (2004) "International Technology Diffusion," *Journal of Economic Literature* 42(3): 752-782.

Kerr, W.R. (2008) "Ethnic Scientific Communities and International Technology Diffusion," *The Review of Economics and Statistics* 90(3): 518-537.

Kerr, W.R. (2010) "Breakthrough Inventions and Migrating Clusters of Innovation," *Journal of Urban Economics* 67(1): 46-60.

Kerr, W.R. and W.F. Lincoln (Forthcoming) "The Supply Side of Innovation: H-1B Visa Reforms and U.S. Ethnic Invention," *Journal of Labor Economics*.

Machikita, T. and Y. Ueki (2010) "The Impact of Face-to-face and Frequent Communications on Innovation: Evidence from Upstream-downstream Relations," mimeo.

Polanyi, M. (1966) "The Logic of Tacit Inference," *Philosophy*, 41(155): 1-18.

Polanyi, M. (1967) *The Tacit Dimension*, University of Chicago Press.

Rosenblat, T. and M. Mobius (2004) "Getting Closer or Drifting Apart," *Quarterly Journal of Economics*, 119(3): 971-1009.

Syverson, C. (2009) “What Determines Productivity at the Micro Level?,” mimeo, University of Chicago.

Wuchty, S., B.F. Jones and B. Uzzi (2007) “The Increasing Dominance of Teams in Production of Knowledge,” *Science*, 316: 1036-1039.