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How ICTs Raise Manufacturing Performance: Firm-level Evidence in Southeast Asia

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Abstract: This paper examines the effects of information and communication technologies (ICTs) on business performance, using firm-level data obtained through a questionnaire survey in four ASEAN countries (Indonesia, The Philippines, Thailand and Vietnam). Sources of information and new technologies exchanged via ICTs by firms are also explored to investigate the mechanism behind ICT adoption. Empirical results verify that the introduction of ICT to reorganize business processes is significantly correlated with business performance, in particular the development of export markets and improvement of production management. ICTs facilitate access to information and technologies accumulated in in-house departments and joint-venture (JV) affiliates of the respondent firms. There are considerable differences between multinational companies (MNCs)/JVs and local firms. MNCs/JVs make use of information and technologies obtainable via ICTs from their own R&D departments, JVs established with local partners and foreign-owned suppliers/customers to improve factory management, mostly for product quality improvement and production cost reduction. In contrast, local firms interconnect their own R&D departments via ICTs to enhance their business performance in broader areas than MNCs/JVs, including the development of export markets.

Keywords: ICT, Exportation, Quality Control, Cost Reduction, Lead-time, Linkages, Innovation, Southeast Asia

JEL classification: D83, L25, O32, O33, M15

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1. Introduction

This paper examines the effects of usage of information and communication technologies (ICTs) on business performance, using firm-level data obtained through a questionnaire survey in four Southeast Asia (Indonesia, The Philippines, Thailand and Vietnam). The effects of ICTs on business performance will depend on several factors other than investments in ICTs, such as human and financial resources, technologies, the organizational assets firms have, and intra and inter-firm production networks in which the firms are involved to interexchange information. As there will be large differences between local firms and multinational corporations (MNCs)/joint ventures (JVs) in the availability of ICTs and other factors that affect business performance, this paper emphasizes the difference in the effects of ICTs on business performance between local firms and MNCs/JVs.

It is very important to make comparison between local firms and MNCs/JVs regarding ICTs' contributions to business performance improvements and linkages through which they exchange information via ICTs. This is because MNCs have been playing dominant roles in industrial development in Southeast Asia, thus the development of local firms has been a prioritized policy issue in this region. By separating the sample into local firms and MNCs/JVs, empirical analyses in this paper provide the existing literature with new evidence related to the effects of ICTs on the business performance of the manufacturing sector in Southeast Asia.

The investigations also turn attention to linkages as channels for interchanging (via ICTs) information within a firm and between firms. In regard to linkages on which firms depend to obtain information and technologies, there will be differences between

local firms that will be based mostly on local production networks, and MNCs/JVs that form international production networks. The regressions allow the detection of such differences in information and technology sources working together via ICTs. These analyses take into consideration the recent new findings that firms in the region are achieving upgrading and innovation, obtaining information and new technologies through intra and inter-firm linkages.[1]

The estimation results show that the effects of ICTs are different between local firms and MNCs/JVs, hence the introduction of ICTs do not necessarily contribute to improving all kind of business performance. This estimated difference is considered to be caused by differences between local firms and MNCs/JVs in the strategic roles of production networks in their business strategies. MNCs/JVs in developing countries introduce ICTs with the intention of facilitating information exchange and collaboration with their internal departments, customers or suppliers in their mother country or third countries, to enhance their competitiveness in quality control and costs. Local firms introducing ICTs are succeeding in developing foreign markets, improving operations and reducing lead times. But their information exchanges via ICTs are limited to their internal R&D departments, even if they obtain information from not only their internal departments but also their neighboring firms. Although local firms have diversified knowledge sources, they have not been doing enough to establish ICT-based collaboration with their business partners. The estimation results lead to the suggestion that local firms may utilize ICTs mainly for simple data interchanges.

This paper consists of seven sections. Section 2 reviews the related literature. Section 3 presents the methodology, including an estimation model that associates ICTs

[1] Machikita *et al.* (2008), (2010) and Machikita and Ueki (2010) empirically examine the effects of linkages on upgrading and innovation by using the same dataset as this paper.

with business performance. Section 4 introduces the data used for the regressions, which was obtained from a survey conducted in four Southeast Asian countries. Section 5 provides estimation results. Section 6 explores a mechanism behind the business performance improvements with ICTs. Concluding remarks are provided in the final section.

2. Related Literature

ICTs have been recognized as an indispensable tool for enhancing productivity, enabling unprecedented systems of managements. Therefore many countries have promoted the diffusion of ICTs. This is true of Southeast Asian countries that have been encouraged to promote ICTs, especially after the Asian economic crisis in 1997 when awareness about the importance of efficiency or productivity was raised.[2]

Regional, urban and international economics provide a theoretical foundation for the policy of promoting the diffusion of ICTs. New economic geography (NEG) focuses on the agglomeration forces and knowledge spillover effects that arise from the dual effects of economic linkages and knowledge linkages (Fujita, 2007). In reality, agglomeration expands the local market, which affects location choice by firms in the region, whereas foreign direct investments (FDIs) transmit knowledge from MNCs to local firms, even if MNCs have been attracted by various incentives related to investment and exports, and by ample cheap labor. On the other hand, international economics emphasizes cross border technology transfer (Keller, 2004). These sources

[2] Giovannetti *et al.* (2003), Kagami *et al.* (2004), and Kuwayama *et al.* (2005) include case studies on ICT development in developing countries.

of knowledge and their impacts on innovation have been key issues for the literatures on innovation. Firm-level data have been used to examine correlations between intra and inter-organizational information sharing and innovation. But most of the empirical analyses are cases from Europe, using the Community Innovation Survey (CIS) (Fagerberg *et al*., 2009).[3] The related literatures have verified the importance of the exchange and sharing of information, technologies and knowledge, in promoting innovation.

Although ICTs are tools to facilitate exchanges of codified information among people and organizations efficiently, the effectiveness in productivity enhancement of investments in ICTs had remained an unsettled research question, known as the information technology "productivity paradox" since the 1980s.[4] However empirical studies based on micro data found significant positive correlations between investments in ICTs and productivity improvement (Bresnahan *et al*., 2002; Brynjolfsson and Hitt 1995, 2000, 2003; Brynjolfsson *et al*,. 2002). These literatures emphasize the importance of having sufficient organizational capital to take advantage of the potential benefits from investments in ICTs.[5] Recent literatures focus attention on ICTs and firm organization, both of which make a difference in productivity (Bloom *et al*,. 2007; 2009).[6]

In contrast to the recent progress of the related literatures on ICTs and productivity

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[3] The CIS is the harmonized survey approach based on the Oslo Manual developed by the Organisation for Economic Co-Operation and Development (OECD). The CIS can also make available data at the firm level on usage of ICTs. Battisti *et al*. (2007) and (2009) use data from the UK CIS.

[4] See, for example, David (1990) and Brynjolfsson (1993).

[5] For example, Bresnahan *et al*. (2002) examines complementarities among IT use, organization, and products and services to explain the biased increased demand for skilled labors.

[6] Insider Econometrics is dedicated to analyzing the effects of firm organizations and management practices on productivity, using firm-level data. See, for example, Bloom and Reenen (2007; 2010).

or business performance based on the data for the Europe and the U.S., case studies from Asia using firm-level micro data are scarce. Lal (2004) recognizes that firms in India adopting more advanced e-business tools have achieved better export performance. Motohashi (2007) shows the impact of information network use on the productivity of Japanese firms. Motohashi (2008) identifies the role of ICTs in productivity performance of Chinese firms. Tsuji *et al*. (2010) attempts to extract factors, including managerial orientation, which promote the introduction and usage of ICT by small and medium-sized enterprises (SMEs) in Japan. However, there have not been sufficient empirical studies of Southeast Asia, focusing on how ICTs help improve firm-level business performance, and how they facilitate information exchanges between organizations.

The previous studies on firms in developed countries emphasize the necessity of creating both cross-departmental or cross-organizational communication mechanisms and in-house organizational assets for effective information use. Although these have important implications for developing countries, case studies of Southeast Asia can provide practical guidance in the context of the actual situation faced by firms in developing countries. That is, indigenous firms in this region have much weaker resources and management capabilities than the firms in developed countries that most of the previous studies focus on. In reality local firms are forced to make a difficult choice as to whether they should make investments in ICTs, other equipment, or human resources. It is quite important for them to verify, by rigorous analysis, whether or not organizational assets equivalent to those that firms in developed countries have, are indispensable requirements for justifying investments in ICTs.

On the other hand, MNCs/JVs in developing countries have different organizational

characteristics from indigenous firms in developing countries or from the headquarters/domestic offices of MNCs in developed countries. Foreign affiliates of MNCs or JVs are members of the production networks governed by their headquarters. Their organizations in developing countries are designed to become fully operational only if they create complementary relationships with their internal departments and external entities, including their local and foreign customers or suppliers. Such organizational characteristics for MNCs/JVs located in developing countries will affect their optimal ICT usage. On the other hand, local firms do not have sufficient in-house resources to complete innovative activities, hence they need to make up for their resource shortage with externally available resources. It is expected that local firms will exchange information mainly between in-house departments and local business partners, if it is considered that local firms have insufficient technological capability to participate in production networks governed by MNCs.

Thus empirical studies on Southeast Asia will allow us to consider whether or not the findings from case studies from developed countries are applicable to developing countries. A comparison between local firms and MNCs/JVs will highlight differences in the potential benefits of ICT between them, and the challenges for local firms in realizing the benefits gained by MNCs/JVs. Moreover there will be differences between local firms and MNCs/JVs in the appropriate production networks to be connected via ICTs for information exchange, because local firms and MNCs/JVs have different capital, human, technology and organizational assets that create differences in the effects of ICTs on their business performance. These issues have not been investigated carefully by the previous studies.

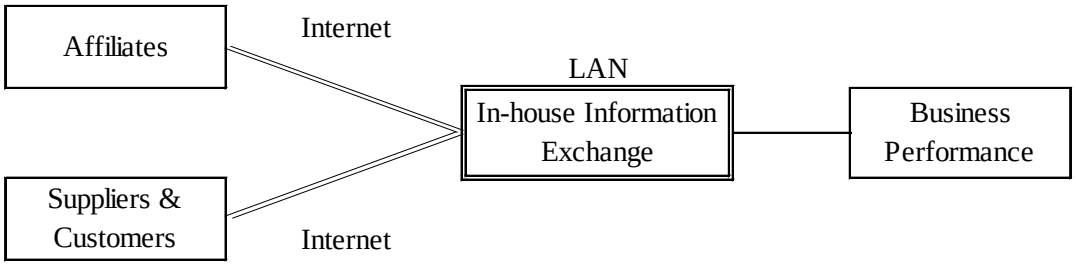
3. Framework

First, the empirical setting of this paper is discussed here to present the reasons why ICTs, information sources and business performance should be linked. Then a model is proposed to associate ICTs with business performance.

It is advantageous for firms to have more access to information to achieve innovation or improve their performance. Machikita and Ueki (2010) verifies that firms in Southeast Asia with more varieties of sources of information and new technologies can achieve more variety of technological upgrading and innovation. On the other hand, the increase in information sources may raise the cost of information management. ICTs have been expected to be indispensable tools in reducing information processing costs dramatically. However, as the related literatures emphasize, organizational changes are needed for firms to make effective use of such state-of-the-art tools. Therefore, firms need to design managerial mechanisms to arrange inter-organizational relationships and process information efficiently. Without them, investments in ICT will fail to achieve its forecast benefits.

Such relationships among information sources, ICTs and business performance can be conceptualized with a simple graphic as below (Figure 1). A firm interconnects its information network with the ICT systems of its affiliates, suppliers and customers via the Internet, to exchange information and codified knowledge. The firm combines the information obtained from external sources with internally available information and knowledge to reach its business goals. Firms with effective ICT-based business processes will achieve better business performance.

Figure 1. Linkages, ICTs, and Business Performance



These observations raise a research question on whether firms which have introduced ICTs to reorganize their business processes tend to achieve better business performance than firms which have not introduced ICTs. To exemplify the association, Table 1 tabulates two variables of "export value to developed countries (E.U., Japan or the U.S.) increased or not" as a variable for business performance and "introduction of ICTs to reorganize its business processes." The second row from the bottom of Table 1 for the whole sample confirms that 20.3% of the respondents increased the value of their exports to developed countries. The Pearson's chi-squared test indicates the two variables are not independent. That is, firms which introduced ICTs had a higher probability of increasing their export value than those which did not. This relationship is applicable only to the case when the sample is restricted to local firms. In the case of MNCs/JVs there is no statistically significant difference in the frequency of firms increasing their export value between those which introduced ICTs and those which did not.

Table 1. Effect of ICTs on Export to Developed Countries

Sample	Export Value to Developed Countries								
	Whole Sample			MNCs and Joint Ventures			Local Firms		
	Not increased	Increased	Total	Not increased	Increased	Total	Not increased	Increased	Total
Introduction of ICT									
Not introduced	296	51	347	93	27	120	203	24	227
	(85.3)	(14.7)	(100)	(77.5)	(22.5)	(100)	(89.4)	(10.6)	(100)
Introduced	132	58	190	72	29	101	60	29	89
	(69.5)	(30.5)	(100)	(71.3)	(28.7)	(100)	(67.4)	(32.6)	(100)
Total	428	109	537	165	56	221	263	53	316
	(79.7)	(20.3)	(100)	(74.7)	(25.3)	(100)	(83.2)	(16.8)	(100)
Pearson's chi-squared	19.015	***		1.119			22.191	***	

Note: *** indicates Pearson's chi-square test for independence is significant at the 1% level.

Source: ERIA 2008 SPLN.

In order to derive more convincing evidence of positive associations between ICTs and various business performance indicators, more comprehensive and rigorous analyses are needed. This paper explores the use of the following binary probit estimation in modeling the relation between business performance and ICTs.

$$\text{Probit}(BP_{ik}) = \alpha_1 + \beta_1 ICT_i + \gamma_1 x_{1i} + u_{1i}.$$

Estimations of this model are attempted using the whole sample, and dividing it into two subsets: (1) MNCs and JVs and (2) local firms. This sample division is based on the assumption that MNCs/JVs would have made more investments in capital equipments including ICTs and be more capable of adopting new technologies and business practices than local firms. Such gaps in available resources and capabilities make differences in the impact of ICTs on business performance and information-use behaviors between these two groups.

This binary probit model is developed to detect the types of business performance significantly related to ICT usage. The dependent variable *BP* is an indicator of the business performance (*k*). This variable is coded 1 if the firm (*i*) improved business

performance between 2007 and 2008, otherwise 0. In the estimation eight variables are identified as indicators of improving business performance: (1) Number of employees increased; (2) Export value increased; (3) Export value to developed countries (E.U., Japan or the U.S.) increased; (4) Productivity improved; (5) Product quality improved; (6) The number of product defects was reduced; (7) Production cost decreased; and (8) Lead-time (the period between a customer's order and delivery of product) was reduced.

The independent variables are *ICT* and other control variables. The variable *ICT* is a dummy variable taking 1 if the firm (*i*) introduced ICTs to reorganize its business processes between 2006 and 2008. The variables x_1 are other control variables such as asset size and country dummy variables.

4. The Data

4.1. Survey

The dataset used in this paper was created from the ERIA 2008 Survey on Production and Logistics Networks (SPLN) for manufacturing firms in four Southeast Asian countries including Indonesia, the Philippines, Thailand, and Vietnam (Limskul, 2009). The survey was designed to collect firm-level data on production and logistics networks, with the aim of pinpointing sources of knowledge transfer facilitated by economic integration in Asia. The sample population is restricted to selected manufacturing districts in each country (JABODETABEK area, i.e., Jakarta, Bogor, Depok, Tangerang, and Bekasi for Indonesia, CALABARZON area, i.e., Cavite, Laguna, Batangas, Rizal, and Quezon for the Philippines, Greater Bangkok area for

Thailand, and Hanoi area for Vietnam).

An original questionnaire was designed solely for the survey by reference to the Oslo Manual developed by the Organization for Economic Co-operation and Development (OECD). The questionnaire was distributed in December 2008 and January 2009. A total of 605 firms agreed to participate in the survey.[7] For the econometric analyses in this paper, 537 observations are used.

4.2. Summary Statistics

Firm Characteristics

Table 2 presents summary statistics of the variables used for the econometric analyses. The geographical distribution of the respondent firms is: 19.9% (107 firms) in Indonesia; 37.8% (203 firms) in the Philippines; 18.2% (98 firms) in Thailand; and 24.0% (129 firms) in Vietnam. By nationality of the firms' capital, 316 firms (58.8%) are local (100% local capital), thus the remaining 221 firms (41.2%) are MNCs or JVs. The locations of the respondents are introduced in the regression as country dummy variables. The reference country is Vietnam.

The variable "Asset Size" is the value of total assets rated on the scale of 10,000 to 10 million U.S. dollars. The firms responding to the survey were asked to indicate the value of their total assets by choosing one of the 10 categories.[8] The variable "Asset Size" is defined as the median value of each category. For example, if the respondent chose "10,000-24,999 U.S. dollars," this "Asset Size" is taken as 17,500 U.S. dollars.

[7] By country, 150 firms in Indonesia (24.8% of the whole sample); 204 firms in the Philippines (33.7%); 113 firms in Thailand (18.7%); and 138 firms in Vietnam (22.8%).

[8] (1) less than 10,000 U.S. dollars; (2) 10,000-24,999 U.S. dollars; (3) 25,000-49,999 U.S. dollars; (4) 50,000-74,999 U.S. dollars; (5) 75,000-99,999 U.S. dollars; (6) 100,000-499,999 U.S. dollars; (7) 500,000-999,999 U.S. dollars; (8) 1 million-4.9 million U.S. dollars; (9) 5-9.9 million U.S. dollars; (10) 10 million U.S. dollars and above.

The average asset size is about four million U.S. dollars, suggesting that the respondents are mainly small and medium-sized enterprises (SMEs).

Table 2. Summary Statistics

Variable	Min	Max	Whole Sample (Obs.=537) Mean	Whole Sample (Obs.=537) Std. Dev.	MNCs and JVs (Obs.=221) Mean	MNCs and JVs (Obs.=221) Std. Dev.	Local Firms (Obs.=316) Mean	Local Firms (Obs.=316) Std. Dev.	Difference (T-test)
Introduction of ICT to reorganize business processes	0	1	0.354	0.479	0.457	0.499	0.282	0.451	***
<Business Performance>									
Number of employees increased	0	1	0.380	0.486	0.416	0.494	0.354	0.479	*
Export value increased	0	1	0.263	0.440	0.335	0.473	0.212	0.409	***
Export value to developed countries increased	0	1	0.203	0.403	0.253	0.436	0.168	0.374	***
Productivity of operation improved	0	1	0.650	0.477	0.629	0.484	0.665	0.473	
Product quality improved	0	1	0.793	0.405	0.814	0.390	0.778	0.416	
Product defects were reduced	0	1	0.709	0.454	0.756	0.431	0.677	0.468	**
Production cost decreased	0	1	0.454	0.498	0.543	0.499	0.392	0.489	***
Lead-time reduced	0	1	0.577	0.494	0.629	0.484	0.541	0.499	**
<Information Sources (Linkage)>									
Own R&D department	0	1	0.335	0.472	0.231	0.422	0.408	0.492	[***]
JV established with local firms	0	1	0.313	0.464	0.294	0.457	0.326	0.469	
JV established with foreign-owned firms	0	1	0.378	0.485	0.425	0.496	0.345	0.476	**
Local supplier or customer	0	1	0.412	0.493	0.394	0.490	0.424	0.495	
Foreign-owned supplier or customer	0	1	0.462	0.499	0.538	0.500	0.408	0.492	***
<Firm Characteristics>									
Asset size	10000	1.00E+07	3,995,447	4,089,252	6,291,437	3,963,764	2,389,707	3,346,012	***
Light industry	0	1	0.302	0.459	0.195	0.397	0.377	0.485	[***]
Machinery industry	0	1	0.236	0.425	0.389	0.489	0.130	0.337	***
Indonesia	0	1	0.199	0.400	0.095	0.294	0.272	0.446	
Philippines	0	1	0.378	0.485	0.457	0.499	0.323	0.468	
Thailand	0	1	0.182	0.387	0.086	0.281	0.250	0.434	
Vietnam	0	1	0.240	0.428	0.362	0.482	0.155	0.363	
MNC or JV	0	1	0.412	0.493					
Local firm	0	1	0.588	0.493					

Note: The null hypothesis that the mean variable for MNCs/JVs is equal to that for local firms is rejected at the 1% (***), 5% (**), and 10% (*) level. [ ] means the alternative hypothesis is the mean for local firms is higher than that for MNCs/JVs.

Source: ERIA 2008 SPLN.

The variables "Light industry" and "Machinery industry" are dummy variables defined to control for differences in industry characteristics. Among the two, "Light industry" is coded 1 if the main business activity of the respondent is "food, beverages or tobacco," or "textiles, apparel or leather." On the other hand, "Machinery industry" is composed of the respondents whose main business activities are "machinery, equipment or tools," "computer or computer parts," "other electronics or electronic

components," "precision instruments," "automobile or auto parts," or "other transportation equipments and parts." The main business activities of the respondents are light industry (30.2% or 162 firms) and machinery industry (23.6% or 127 firms).

There are significant differences in firm characteristics between MNCs/JVs and local firms. The average asset size for MNCs/JVs is more than six million U.S. dollars, which is much higher than local firms, with a mean of about two million U.S. dollars. The main business activity for 38.9% of the MNCs/JVs is manufacturing of machinery products. In contrast, 37.7% of local firms are dedicated to light products.

Information Sources, ICT, and Business Performance

Table 2 also shows ICT usages, sources of information for innovation and upgrading, and business performance. Some 35.4% of the respondent firms introduced ICTs to reorganize their business processes during the period between 2006 and 2008. As internal information sources to conduct innovative activities, 33.5% of them depend on their own R&D department. The most widely utilized source is foreign-owned supplier or customer (46.2%). In contrast, JVs established with local firms are little used by the respondents (31.3%). There is great variety among the business performances that respondents achieved: 79.3% improved product quality while only 20.3% increased the value of exports to developed countries.

Considerable differences are also found between MNCs/JVs and local firms. In short, MNCs/JVs that introduced ICTs exploit information from JVs established with foreign-owned firms or from foreign-owned suppliers/customers, and achieved better business performance in various indicators with higher probability than local firms. Among the key variables on which this paper focuses, only the mean of the variable

"own R&D department" for local firms is significantly higher than that for MNCs/JVs.

5. Effects of ICTs on Business Performance

Table 3 presents the estimated marginal effects of ICT introduction and other control variables on the business performance. When the whole sample is used for the estimation, the variable *introduction of ICT* has positively significant coefficients at least at the 10% level, ranging from 0.082 to 0.125 (columns (1) to (8) in Table 3). This means that the introduction of ICTs to reorganize business processes leads to an increase in the probability of achieving better business performance by 8.2 to 12.5 percentage points.

The coefficients on asset size also show positively significant impacts on business performance, except in product quality improvements. The coefficients on the three country dummy variables indicate differences in the probability between each of these three countries and the reference country, Vietnam. They may be summarized by stating that these three countries, which industrialized earlier than Vietnam, have improved export-related performance, operational efficiency and quality management, whose marginal effects are positively significant. On the other hand, more Vietnamese firms have succeeded in decreasing production costs and lead-time with higher probabilities than firms in the other countries.

Table 3 also presents the estimated marginal effects using sub-samples divided into MNC/JVs and local firms. In the case of MNCs/JVs, only two models that have product quality improvement (column (5) in Table 3) and production cost reduction

(column (7)) as dependent variables have significant coefficients on ICT introduction, while the coefficients on asset size are not significant in these models. In addition, these estimated coefficients for MNCs/JVs are larger than those for the whole sample: the estimated coefficient on ICTs for the models of product quality improvement and production cost reduction, using the sample of MNC/JV, are 0.12 and 0.17 respectively. Those estimated from the whole sample are around 0.10. In contrast to these two models, the rest of the models have positively significant coefficients on asset size and statistically insignificant coefficients on ICT introduction. These results imply that MNCs/JVs apply ICTs effectively to their manufacturing process restructuring, while those with larger invested capital have expanded their business or improved operations and lead-time, utilizing their various capital investments other than ICTs.

There are considerable differences in the probability of achieving business performance improvements between ICT-equipped and non-equipped local firms. In particular, the introduction of ICTs by the local firms leads to a higher probability of increasing the number of employees and the value of exports by 19.9 percentage points (column (1) and (2)). The marginal effect of ICTs on the probability of improving operational productivity is 16.4 percentage points (column (4)). The marginal effects on the value of exports to developed countries and on lead-time are estimated at about 14 percentage points (column (3) and (8)).

Table 3. Correlation between Introduction of ICTs and Business Performance

Binary Probit Estimation (Marginal Effect)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variables	Number of employees increased	Export value increased	Export value to developed countries increased	Productivity of operation improved	Product quality improved	Product defects were reduced	Production cost decreased	Lead-time was reduced
Sample: Whole Sample								
Introduction of ICT	0.118**	0.125***	0.0822**	0.0904*	0.0995***	0.0930**	0.106**	0.0989*
	(0.050)	(0.045)	(0.040)	(0.048)	(0.038)	(0.046)	(0.053)	(0.051)
Asset size	2.00e-08***	1.38e-08***	1.57e-08***	1.06e-08*	6.19e-09	1.77e-08***	1.50e-08**	1.16e-08**
	(5.65e-09)	(4.98e-09)	(4.33e-09)	(5.67e-09)	(4.87e-09)	(5.41e-09)	(5.89e-09)	(5.90e-09)
Indonesia	0.026	0.165**	0.077	0.148***	0.134***	-0.004	-0.346***	-0.246***
	(0.066)	(0.075)	(0.069)	(0.055)	(0.037)	(0.061)	(0.053)	(0.066)
Philippines	-0.106*	0.227***	0.200***	0.201***	0.140***	0.074	-0.372***	-0.152***
	(0.055)	(0.060)	(0.057)	(0.050)	(0.038)	(0.051)	(0.052)	(0.058)
Thailand	-0.005	0.283***	0.255***	0.165***	0.175***	0.016	-0.236***	-0.023
	(0.068)	(0.078)	(0.077)	(0.057)	(0.034)	(0.063)	(0.064)	(0.074)
Observations	537	537	537	537	537	537	537	537
Pseudo R2	0.052	0.077	0.090	0.035	0.062	0.038	0.107	0.052
Sample: MNCs and Joint Ventures								
Introduction of ICT	0.050	-0.044	-0.033	0.007	0.120**	0.096	0.170**	0.047
	(0.073)	(0.066)	(0.058)	(0.073)	(0.054)	(0.062)	(0.075)	(0.072)
Asset size	2.98e-08***	1.53e-08*	1.76e-08**	2.59e-08***	-3.12e-09	1.39e-08*	1.14e-08	1.87e-08**
	(9.48e-09)	(9.02e-09)	(7.86e-09)	(9.31e-09)	(6.87e-09)	(7.77e-09)	(9.63e-09)	(9.09e-09)
Indonesia	-0.186*	0.604***	0.422***	0.192**	0.094	-0.031	-0.285**	-0.161
	(0.100)	(0.088)	(0.130)	(0.089)	(0.062)	(0.108)	(0.112)	(0.126)
Philippines	-0.074	0.451***	0.360***	0.365***	0.164***	0.108*	-0.371***	-0.182**
	(0.076)	(0.075)	(0.075)	(0.067)	(0.055)	(0.065)	(0.075)	(0.076)
Thailand	-0.042	0.591***	0.482***	0.287***	0.068	-0.020	-0.311***	-0.089
	(0.126)	(0.094)	(0.127)	(0.075)	(0.073)	(0.113)	(0.111)	(0.138)
Observations	221	221	221	221	221	221	221	221
Pseudo R2	0.056	0.178	0.136	0.109	0.075	0.041	0.110	0.050
Sample: Local Firms								
Introduction of ICT	0.199***	0.199***	0.144***	0.164***	0.064	0.087	0.016	0.141*
	(0.071)	(0.066)	(0.056)	(0.062)	(0.056)	(0.066)	(0.075)	(0.072)
Asset size	1.80e-08**	1.97e-09	1.02e-08*	8.92e-09	1.13e-08	2.43e-08***	1.22e-08	3.18e-09
	(8.45e-09)	(7.11e-09)	(5.82e-09)	(8.71e-09)	(7.76e-09)	(9.15e-09)	(8.56e-09)	(9.11e-09)
Indonesia	0.102	-0.074	-0.077	-0.003	0.170***	-0.023	-0.361***	-0.242***
	(0.090)	(0.065)	(0.057)	(0.086)	(0.051)	(0.087)	(0.066)	(0.088)
Philippines	-0.107	-0.031	0.021	0.014	0.123**	0.025	-0.374***	-0.095
	(0.082)	(0.066)	(0.064)	(0.083)	(0.055)	(0.082)	(0.068)	(0.089)
Thailand	-0.010	0.039	0.061	-0.048	0.242***	-0.001	-0.185**	0.012
	(0.091)	(0.077)	(0.072)	(0.095)	(0.044)	(0.091)	(0.086)	(0.100)
Observations	316	316	316	316	316	316	316	316
Pseudo R2	0.066	0.079	0.100	0.022	0.078	0.033	0.089	0.055

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. The reference country is Vietnam.

Source: ERIA 2008 SPLN.

Table 3 also shows sharp contrasts in the impact of ICTs on business performance between MNCs/JVs and local firms. The coefficients on introduction of ICT for local firms are positively significant, except those on product quality improvement, product defect reduction and decrease in product costs (columns (5), (6), (7) of Table 3). In addition, in contrast to the estimation results from the whole sample and MNCs/JVs, the significance of the coefficients on asset size is not robust in the case of local firms. Only the coefficients of the regressions of the increase in the number of employees, the increase in the value of exports to developed countries, and the reduction of product defects are positively significant (columns (1), (3), (6)). There are also differences in the significance of the country dummy variables between MNCs/JVs and local firms. In particular, significant differences in the probabilities of increasing the number of employees or the value of exports to developed countries and improving operational productivity are not verified between local firms from Vietnam and those from other advanced economies in ASEAN such as Indonesia, the Philippines and Thailand.

6. ICT-based Linkages and Business Performance Improvement

These estimations of the relationship between ICTs and business performance raise research questions regarding factors behind the difference between local firms and MNCs/JVs in the impact of ICT, used for reorganizing business processes, on business performance.

The literatures on knowledge transfer, sharing and spillover and their impacts on industrial upgrading and innovation suggest that ICTs would help firms to weave

codified information and technologies from various sources into their organizational practices relating to innovation, and so to achieve better business performance. Information exchanges through ICTs fundamentally affect firms' performance. Firms in the manufacturing sectors obtain their information mainly through internal and external networks for productive activities. Thus it is considered that the difference in their organizational assets, which include internal and external production networks and existing ICT assets, may lead to varying effects of ICTs on business performance, as between local firms and MNCs/JVs.

The relationship between the introduction of ICTs and information sources is exemplified in Table 4 using "JV established with local firms" as a variable for information sources. The second row from the bottom of Table 4 for the whole sample confirms that 35.4% of the whole sample of respondents had introduced ICTs. More firms operating JVs with local firms introduced ICT (83 of 168, or almost 50% of JV firms) than those not operating JVs (107 of 369, or 29% of non-JV firms)

. Significant differences in the frequency are also seen when the sample is restricted to MNCs/JVs and local firms. Therefore, it may be concluded from this tabulation that ICTs have been introduced by firms obtaining information from JVs established with local firms, regardless of national origins of the respondents.

Table 4. ICT and JVs Established with Local Firms

Sample	Introduction of ICT								
	Whole Sample			MNCs and Joint Ventures			Local Firms		
	Not introduced	Introduced	Total	Not introduced	Introduced	Total	Not introduced	Introduced	Total
JV with local firms									
Not operating	262	107	369	93	63	156	169	44	213
	(71.0)	(29.0)	(100)	(59.6)	(40.4)	(100)	(79.3)	(20.7)	(100)
Operating	85	83	168	27	38	65	58	45	103
	(50.6)	(49.4)	(100)	(41.5)	(58.5)	(100)	(56.3)	(43.7)	(100)
Total	347	190	537	120	101	221	227	89	316
	(64.6)	(35.4)	(100)	(54.3)	(45.7)	(100)	(71.8)	(28.2)	(100)
Pearson's chi-squared	21.028	***		6.042	**		18.203	***	

Note: *** and ** indicate Pearson's chi-square test is significant at the 1% and 5% level respectively.
Source: ERIA 2008 SPLN.

To identify, by rigorous methods, the sources of such information and technologies utilized by the firms that introduced ICTs, the following model is estimated.

$$\text{Probit}(ICT_i) = \alpha_2 + \beta_2 Linkage_{ij} + \gamma_2 x_{2i} + u_{2i}.$$

In this model, the dependent variable *ICT*. The independent variables are as follows. The variable *Linkage* is the firm (*i*)'s internal or external knowledge source (*j*). The variable *Linkage* takes 1 if the firm obtains information or new technologies for its innovative activities through the linkage. In the estimation, five types of linkage are introduced. Among them, (1) R&D department represents an internal linkage and knowledge source. The rest of the four types are classified as external sources, and include the following: (2) JV established with other local firm; (3) JV established with other foreign-owned firm; (4) local supplier or customer; and (5) foreign-owned supplier or customer. The variables x_2 are other control variables. Among these, "Asset size" and country dummy variables are the same as those defined in section 4. The dummy variables "Light industry" and "Machinery industry" are introduced to consider differences in industry characteristics.

Table 5 presents the estimated marginal effects of information sources and other control variables on the introduction of ICTs. The coefficients estimated from the whole sample indicate that the marginal effects of information sources on the probability of ICT introduction are considerable. The firms that recognize their own R&D department as an information source have a positive marginal effect significant at the 1% level, which enhances the probability of introducing ICTs by 17.9 percentage points over those not using such departments. JVs established with local firms and foreign-owned firms have also positive and significant marginal effects, which lead to an increase in the probability of introducing ICTs by about 11 percentage points.

Table 5. Correlation between Introduction of ICT and Sources of Information and New Technologies

Binary Probit Estimation (Marginal Effect)	Whole Sample					MNCs and Joint Ventures					Local Firms				
Dependent variable: Introduction of ICT	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Own R&D Department	0.179***					0.221**					0.147**				
	(0.057)					(0.102)					(0.063)				
JV established with local firms		0.113**					0.187**					0.013			
		(0.057)					(0.089)					(0.068)			
JV established with foreign-owned firms			0.110*					0.094					0.039		
			(0.061)					(0.090)					(0.078)		
Local supplier or customer				0.067					0.102					0.014	
				(0.053)					(0.091)					(0.061)	
Foreign-owned supplier or customer					0.095					0.223**					-0.039
					(0.062)					(0.110)					(0.075)
Asset size	3.80e-08***	4.00e-08***	3.88e-08***	3.92e-08***	3.86e-08***	3.67e-08***	4.12e-08***	3.95e-08***	3.96e-08***	3.92e-08***	2.47e-08***	2.60e-08***	2.58e-08***	2.59e-08***	2.57e-08***
	(5.38e-09)	(5.47e-09)	(5.44e-09)	(5.44e-09)	(5.44e-09)	(9.69e-09)	(9.70e-09)	(9.64e-09)	(9.61e-09)	(9.62e-09)	(6.96e-09)	(7.42e-09)	(7.27e-09)	(7.27e-09)	(7.29e-09)
Indonesia	-0.017	0.031	0.090	0.047	0.098	0.099	0.171	0.213*	0.213*	0.302**	-0.094	-0.085	-0.056	-0.082	-0.113
	(0.071)	(0.072)	(0.084)	(0.074)	(0.088)	(0.142)	(0.129)	(0.126)	(0.127)	(0.126)	(0.076)	(0.079)	(0.099)	(0.080)	(0.094)
Philippines	0.060	0.113*	0.148**	0.113*	0.158**	0.074	0.183**	0.171*	0.178*	0.305**	-0.043	-0.052	-0.023	-0.049	-0.090
	(0.059)	(0.063)	(0.074)	(0.066)	(0.080)	(0.085)	(0.089)	(0.101)	(0.098)	(0.121)	(0.078)	(0.080)	(0.101)	(0.082)	(0.098)
Thailand	0.362***	0.455***	0.494***	0.484***	0.515***	0.271*	0.394***	0.415***	0.418***	0.474***	0.311***	0.403***	0.420***	0.408***	0.396***
	(0.080)	(0.066)	(0.062)	(0.062)	(0.063)	(0.149)	(0.105)	(0.100)	(0.099)	(0.088)	(0.100)	(0.095)	(0.092)	(0.091)	(0.095)
Light industry	-0.140***	-0.116**	-0.119**	-0.122**	-0.122**	-0.013	0.018	0.000	0.006	-0.015	-0.165***	-0.154***	-0.151***	-0.154***	-0.157***
	(0.050)	(0.051)	(0.050)	(0.050)	(0.050)	(0.102)	(0.102)	(0.101)	(0.101)	(0.104)	(0.053)	(0.054)	(0.054)	(0.054)	(0.054)
Machinery industry	0.127**	0.117**	0.124**	0.126**	0.127**	0.218***	0.199**	0.200**	0.203**	0.207***	-0.050	-0.045	-0.039	-0.043	-0.048
	(0.057)	(0.057)	(0.057)	(0.057)	(0.057)	(0.080)	(0.080)	(0.079)	(0.079)	(0.079)	(0.068)	(0.071)	(0.072)	(0.071)	(0.071)
Observations	537	537	537	537	537	221	221	221	221	221	316	316	316	316	316
Pseudo R2	0.209	0.202	0.201	0.198	0.199	0.153	0.154	0.142	0.143	0.152	0.256	0.242	0.243	0.242	0.243

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. The reference country is Vietnam.

Source: ERIA 2008 SPLN.

Even after restricting the sample to MNCs/JVs, the coefficients on "own R&D department" and "JV with local firms" are significant at the 5% level, increasing the probabilities of ICT usage by 22.1 and 18.7 percentage points respectively. While the coefficient on "JV established with foreign-owned firms" is not significant, that on "foreign-owned supplier or customer" is significant at the 5% level, having 22.3 percentage points of marginal effect. It can be said that MNCs/JVs are linked via ICTs with their internal department and related firms, and with relatively highly capable internationalized firms.

In case of the local firms, only the coefficient for the firms using information from their own R&D department is significant at the 5% level. Its marginal effect is 14.7 percentage points, which is smaller than that for MNCs and JVs. The estimation result indicates that local firms exchange information only among their internal departments via ICTs but have off-line contacts with JVs established with other local firms, local suppliers or customers or foreign-owned entities. As shown in Table 2, local firms make use of various sources of information.

The estimated coefficients on other control variables also provide important information. The coefficients on asset size are positively significant at the 1% or 5% level, suggesting substantial financial burdens for smaller firms in making investments in ICTs, irrespective of firms' national origins. Firms in Thailand, whether they are MNCs/JVs or local firms, are more equipped with ICTs than those in Vietnam. Among the firms in the Philippines, only MNCs/JVs have higher frequencies of introducing ICTs than firms in Vietnam. On the other hand, there are not significant differences between firms in Indonesia and Vietnam. The estimations also suggest that the

characteristics of industries affect the probability of introducing ICTs. Firms in the light industry use ICTs less frequently. In particular, local firms in this industry have less than 15 percentage points of the frequency of ICT introduction compared to the rest of the industries. On the other hand, firms in the machinery industry introduce ICT more frequently. Especially the rate of MNCs/JVs using ICTs is about 20 percentage points higher than those in other industries.

7. Conclusion

This paper has attempted regressions to investigate the types of business performance improved by the firms which introduced ICTs to reorganize their business processes. Sources of information that would be exchanged via ICTs were also focused on, to investigate the elements affecting the strategic motivation leading to the adoption of ICTs.

The estimation results using the whole sample present positively significant correlations between introduction of ICT and various business performance indicators. A firm's asset size also affects the probability of ICT introduction. But there are apparent differences between MNCs/JVs and local firms in the factors having impact on their business performance. In the case of MNCs/JVs, ICTs affect product quality and production costs, while their other business performance improvements can be better explained by reference to asset size. On the other hand, local firms equipped with ICTs have increased their employment and exports, and improved operations and lead-times.

Notably, export values, operational productivity and lead-times are not influenced by the effect of asset size. These findings indicate more room for local firms to improve their business processes by making better use of ICTs. Therefore, more policy support for promoting the diffusion of ICTs among local firms would be justified in developing countries.

Even though the first estimations provide evidence of ICTs' positive effects on business performance, they do not necessarily specify the mechanism behind the adoption of ICTs, through which firms exchange "ingredients" that fundamentally affect firms' performance. To investigate this issue, the relationship between ICTs and linkages is estimated. The results of the estimations using the whole sample demonstrate that information exchanges via the Internet would be limited among firms having capital ties. Firms using information from their own R&D department, and JVs, are more likely to utilize ICTs to reorganize their business processes. This fact is in particular true of local firms: those introducing ICTs depend on information mainly available in their own R&D departments. In the case of MNCs/JVs, not only their own R&D departments and JVs established with local firms, but also foreign-owned suppliers or customers are important information sources that encourage them to introduce ICTs.

These findings suggest that local firms and MNCs/JVs are in different stages of ICT adoption. In general, firms start introducing ICTs to improve the performance of specific tasks at the department level. Then company-wide ICT systems are introduced to optimize information sharing at the company level, and for other tasks that require inter-department cooperation. Firms more advanced in ICT utilization interconnect

their information systems to establish supply chain collaboration aiming at optimizing various processes along their whole supply chains. As shown by the estimations, MNCs/JVs tend to be interconnected via the Internet with other international suppliers or customers that have established close transactional partnerships in the international market. Thus it seems that MNCs/JVs consolidate their inter-firm collaborations on ICT-based systems, so as to enhance their quality control and cost competitiveness at highest global standards. In contrast, local firms utilize ICTs for "primitive" applications. At best, firms with R&D departments, who probably have better innovation capability, have introduced intra-firm ICT networks to optimize their internal operations.

However this fact does not necessarily mean that local firms are isolated: They have off-line relationships with other firms and organizations. Therefore, more policy efforts are needed to promote online relationships among various types of entities to make exchanges of codified information, technologies and know-how in a more efficient and effective way. This is crucially important for the promotion of industrial upgrading, and for innovations in developing countries, as previous studies such as Frenz and Ietto-Gillies (2009), Machikita and Ueki (2010) and Vega-Jurado, *et al.* (2008) provide evidences that more innovative firms take advantage of external sources or more varieties of sources of information and technologies.

A remaining noteworthy finding from this paper is the contrasting situation of ICT utilization between local firms and MNCs. The former are less active in collaboration with external entities, based on ICTs, than the latter, which shows the successful result of the introduction of ICTs for quality control improvement and cost reduction. These

are prerequisite conditions for participating in international value chains, and represent difficult obstacles for local firms. Therefore policies are urgently needed for promoting better understanding of the effects of ICTs on improvements in business performance and the strategic roles of production networks that are behind the association between ICTs and performance, taking into consideration the difference in organizational assets between local firms and MNCs/JVs.

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