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# IT Investment and Constraints in Developing Countries: Evidence from Thai Manufacturers

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Abstract

Due to the rapid changes in technology, competition, and globalization, information has become businesses' most significant asset. Information technology (IT) has become indispensible for modern businesses because it helps shape and support competitive strategies. Investment in IT seems to be even more critical for any developing country in order to enhance its economic development. This paper aims at investigating constraints and determined factors of IT-related investment in a developing country by using Thailand as a case study. A survey of manufacturing data shows that the most critical constraints obstructing Thai manufacturers from investing in their IT-related needs is the lack of IT human resources, which includes lack of knowledgeable and trained IT personnel and lack of experienced consultants to provide IT-based solution systems. The association between a higher level of IT skill among production workers and a firms' investing in IT is found to be positively significant. Thus, providing training courses in IT-related skills should therefore be considered a necessary option. However, evidence from surveys shows that both in-house and external IT training courses have received less recognition among those manufacturers. Promoting research partnerships and providing incentives for both research and development (R&D) initiatives and the promotion of e-commerce have also been found to be effective policy options.

Keyword: IT Investment, constraints, developing countries, Thailand

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## 1. Introduction

Due to the rapid changes in technology, competition, and globalization, information has become the most significant asset of businesses. Information technology (IT) is indispensible for modern businesses because it helps shape and support competitive strategies and can also be used as a tool for innovation (Kalkan et al. 2011). As a result, business enterprise operation and management have seen a significant change with the use of IT (Huang et al. 2006).

Managers, policymakers, and researchers recognize the significance of new technologies and innovations on competitiveness and growth. Thus, the impact and importance of IT investment has received a lot of attention in the previous decades (Li and Ye 1999). But even though new technologies and innovations are important, not all lead to success (Koellinger 2008). Past research on firm performance and IT have yielded mixed results. According to Loveman (1994), the investment in IT by corporations did not have any positive impact on productivity. This is also confirmed by Landauer (1995) and Qing and Plant (2001). On the other hand, Prasad (2008) found that in developing countries, there is a positive relationship between IT investment and intangible benefits, particularly at the process level. Studies by Bhatt (2000) and Swierczek and Shrestha (2003) also confirm these findings.

Melville et al. (2004) conclude that even though IT investment is valuable, the extent and depth of its impact depend on internal and external factors such as a firm's resources, its competition, and the macro environment. That being noted, some benefits of IT investment by firms include convenience, generation of new products and services, and improvements in quality, timeliness, and variety (Brynjolfsson and Hitt 2000). In addition, Swierczek and Shrestha (2003) found that IT investment increases a firm's productivity.

Whether or not an organization invests in IT is dependent on the support that it receives from top management (Christensen and Walker 2004). Having top management on board is crucial because they are the ones who allocate resources; therefore, to obtain funding, a clear outline of the potential benefits of IT investment must be provided (Peansupap and Walker 2006). Besides top management support, organizational policy and vision, encouragement from technology gatekeepers, support for building an internal knowledge base of people, and interest in creating networks among professional institutions and universities are also important.

Criteria for decision making with regard to IT investment is significant for a couple of reasons. First, the criteria and how they are applied have a significant impact on the effectiveness of how IT investment decisions are made. Second, such criteria are important with respect to an organization's bottom line because they play a major role in determining the return on investment and the cost-benefit analysis of IT capital investment decisions (Bacon 1992).

The impact that IT has on the business and the economic environment has recently gained importance and has been attended to by business and science societies, policymakers, and technology developers. Its impact can also be seen within the private and the public sectors (Gatautis 2008). Studies on IT investment have been carried out in both developed and developing countries with varying results. In developed countries, some of the factors that influence IT investment include environmental dynamism, strategic orientation, and integration of IT into the overall strategic picture of a firm (Li and Ye 1999). On the other hand, the challenges that developed countries face with regard to IT investment are lack of

technological awareness among senior managers, technological immaturity, and industry standards (Peansupap and Walker 2006).

For developing countries, Das and Das (2012) found that intensity of competition, firm age, firm size, and support and incentives from the government are important factors that influence IT investment among firms. In addition, IT investment in developing countries faces challenges such as limited technological knowledge among the population and an absence of highly skilled labor. As a result of the lack of human capital and lack of innovation, developing countries have been caught in the "medium income trap" (Jitsuchon 2012). To escape, developing countries must invest in better education to improve their human resource pools and invest more in technological innovation (Schuman 2010; Jitsuchon 2012). IT investment can serve as a platform and a strategy for moving towards greater technological innovation; hence, the importance of countries and firms investing in IT.

This paper investigates the challenges and constraints of IT investment at the firm level in a developing country by using Thai manufacturers as a case study. It is interesting to investigate the manufacturing sector because it accounts for one-third the size of the business sector in Thailand and represents a third of the number of computers and of employees using computers (UNCTAD 2008).

The paper is structured as follows. Section Two discusses the relevant literature, which includes studies of IT investments and constraints and comparisons of IT investment in both developed and developing countries. Section Two also examines Thailand's status as a representative developing country. Sections Three and Four provide the empirical analysis for this study. Descriptive analyses of Thai manufacturing data are presented in Section Three while estimated regression for both the likelihood and magnitude of IT-related investment is discussed in Section Four. Section Five concludes the paper and provides some policy recommendations.

## 2. Status of IT Investment in Developed and Developing Countries

For the past three decades, the importance and significance of IT has been increasing in both developed and developing countries (Lee et al. 2011). Since the 1990s, the diffusion of IT in developed countries has been more rapid than in developing countries, which has led to an IT gap (Gholami et al. 2004). This still holds true today as evident from table 1, which shows that developed countries are way ahead of developing countries in basic IT infrastructure at the country level. In developing countries, the impact of IT has received less attention compared to topics such as development and culture.

### *2.1 IT Investment in Developed and Developing Countries*

In comparison, advanced developing countries have received more attention in terms of IT investments because they have typically have higher incomes per capita, a strong manufacturing sector, and relatively greater adoption of technology than less advanced developing countries (Prasad 2008). It has become increasingly difficult for developing countries to isolate themselves from the changes that have occurred with the developments in IT (Gholami et al. 2004). Furthermore, studies have shown that countries with a high number of skilled IT workers invest more in IT than countries with fewer skilled IT workers do

(Amin 2005). Since building a strong information infrastructure is so important, governments must encourage the use of IT by investing in human resources and in improving information infrastructure. The government must play a key role but can make these investments by collaborating with the private sector. This is especially true in the case of developing countries (Kraemer and Dedrick 1994).

**Table 1. IT infrastructure comparison (unit: percentage of 100 inhabitants)**

| IT Infrastructure | Developed | | | Developing | | | World | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| Fixed telephone[a] | 43.7 | 42.7 | 41.6 | 11.5 | 11.3 | 11.1 | 17.3 | 16.9 | 16.5 |
| Mobile cellular[a] | 119 | 123.6 | 128.2 | 78.3 | 84.3 | 89.4 | 85.5 | 91.2 | 96.2 |
| Active mobile broadband[a] | 55.1 | 63.3 | 74.8 | 8.2 | 13.3 | 19.8 | 16.6 | 22.1 | 29.5 |
| Fixed (wired) broadband[b] | 24.7 | 25.9 | 27.2 | 4.9 | 5.5 | 6.1 | 8.4 | 9.1 | 9.8 |
| Household with a computer[b] | 74.2 | N/A | N/A | 24.8 | N/A | N/A | 38.4 | N/A | N/A |
| Household with Internet access at home[b] | 70.2 | 74 | 77.7 | 20.2 | 24 | 28 | 33.6 | 37.4 | 41.3 |
| Individuals using the Internet[b] | 70.5 | 73.4 | 76.8 | 24.5 | 27.5 | 30.7 | 32.7 | 35.7 | 38.8 |

*Source*: International Telecommunications Union (2013).
*Note*: [a]Per 100 inhabitants, [b] percentage (%)

For developed countries, Colecchia and Schreyer (2002) studied the impact of IT on output growth in nine member-countries of the Organisation for Economic Co-operation and Development (OECD); namely, Australia, Canada, Finland, France, Germany, Italy, the United Kingdom, and the United States. The findings show that the growth effects of IT are not dependent on a large, IT-producing industry. The diffusion of IT plays a key role but it requires the right framework. The mere existence of an IT-producing sector is not sufficient. Zhu et al. (2003) attempted to measure the impact of IT adoption among firms in eight European countries (Denmark, Finland, France, Germany, Ireland, Italy, Spain, and the United Kingdom). The study covered thirteen industries in the manufacturing, distribution, and service sectors. Factors that were significant adoption drivers included competitive pressure, consumer readiness, firm scope and size, and technological competence. Morikawa (2004) also examined the relationship between IT and the performance of Japanese firms and found that there is a positive relationship between IT and firm profitability and innovation. Although this relationship was found to be true only for small firms, it is nevertheless very important because small firms make up a high proportion of economic activity in Japan.

In the case of developing countries like China, Lee et al. (2011) concluded that even though the direction and size of IT investment on productivity and its impact in China were similar to those in the United States, Chinese firms should still invest more in IT. Machikita et al. (2010) studied the effects of IT on business performance using firm-level data from four ASEAN countries (Indonesia, the Philippines, Thailand, and Vietnam) and found that IT adoption has a positive correlation with various business performance indicators such as product quality and production costs, increased employment and exports, and improved

operations and lead times. In addition, the size of a firm's assets also has an effect on its use of IT.

Cheong et al. (2009) concluded in their study of Malaysian companies that firm size as characterized by annual sales and number of full-time employees is a significant determinant of IT adoption. As a result, larger firms are more likely to invest in, and adopt, IT compared to smaller firms. Other factors that had a positive effect on, and an increase in, the likelihood of IT adoption were the number of IT employees in the firm, foreign investment in the firm, ownership, and market orientation.

### *2.2 Status of IT Investment in Thailand*

In a global context, Thailand, as a representative developing country, has a level of IT development that can be considered as average (Ministry of ICT 2009). In a narrower, Asian context, however, as represented by the figures in table 2, Thailand is ranked below Japan, South Korea, Taiwan as well as its neighbors such as Singapore and Malaysia in all the indices. In order to catch up with these countries, the Thai government introduced the Second ICT Master Plan (2009─13).

**Table 2: Comparative ICT development rankings of Thailand**

| Index/ Country | Global Competitiveness Index (2012--13) 144 countries | Networked Readiness Index (2012) 142 countries | Digital Opportunity Index (2005--06) 181 countries | IT Industry Competitiveness Index (2011) 66 countries |
|---|---|---|---|---|
| Japan | 10 | 18 | 2 | 16 |
| South Korea | 19 | 12 | 1 | 19 |
| Taiwan | 13 | 11 | 7 | 13 |
| Singapore | 2 | 2 | 5 | 3 |
| Malaysia | 25 | 29 | 57 | 31 |
| *Thailand* | *38* | *77* | *82* | *50* |

*Sources*: Global Competitiveness Index–WEF (2012a); Networked Readiness Index–WEF (2012b); Digital Opportunity Index–ITU (2007); IT Industry Competitiveness Index–BSA (2011).

The Second ICT Master Plan focuses on six key strategies, namely:

1. Promote information literacy among ICT professionals and the general population
2. Strengthen national ICT governance
3. Develop ICT infrastructure
4. Use ICT to support good governance in public administration and services
5. Upgrade the competitive capacity of the ICT industry to add value and increase earnings
6. Use ICT to build a sustainable competitiveness capacity for Thai industries (Ministry of ICT 2009)

Of the six strategies, the government has prioritized strategies the first three as urgent in order to close the gap between Thailand and other countries.

Under the first strategy, the government intends to develop IT personnel, especially in the manufacturing and service sectors. The aim is to bring personnel up to international standards

and to develop IT skills within business establishments. Part of the third strategy is to develop IT infrastructure that provides access to businesses and supports multimedia services and electronic transactions. The sixth strategy focuses on building sustainable competitiveness capacity for Thai industries. Some of the goals of this strategy focus on increasing the use of the Internet in private firms by increasing the number of businesses that use the Internet, increasing small-enterprise Internet connectivity by 25 percent, and increasing the number of online businesses by 5 percent (Ministry of ICT 2009).

To support the strategies outlined in the Second ICT Master Plan, the government has introduced initiatives such as low-interest loans for technological development in the private sector, an industrial technology assistance program; interest-free innovation; innovation-capital transformation; and the promotion of skills, technology, and innovation.

The constraint that Thailand faces in IT development is that even though there has been growth in the skilled labor force in both the public and private sectors, there is still a shortage of human resources in IT in terms of quantity and quality. There is a shortage of highly skilled and specialized personnel in a variety of subsectors. Other studies conducted on IT personnel have also concluded that there is a desperate need for an increase in the number of human resources in IT (Ministry of ICT 2009).

The 2009 labor force survey shown in table 3 displays the proportion of ICT personnel per total employed persons. The number of ICT personnel is 1.11 percent of the total number of employed persons (37.71 million). Although there was an increase from 0.99 percent in 2005 to 1.11 percent in 2009, it is still very minimal (Santipaporn 2010).

**Table 3: Proportion of ICT personnel per total number of employed persons, 2005—09**

| Proportion | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| ICT Personnel | 348,081 | 359,328 | 365,253 | 403,842 | 416,862 |
| Total Employed Persons (thousands persons) | 35,257.2 | 35,685.5 | 36,249.5 | 37,016.6 | 37,706.3 |
| Proportion of ICT Personnel per Total Employed Persons (%) | 0.99 | 1.01 | 1.01 | 1.09 | 1.11 |

*Source*: Labor Force Survey, National Statistical Office (2009b).

## 3. IT Investment and Constraints

The data used for this research paper rely on the secondary data from the Productivity and Investment Climate Survey (PICS), which contains firm-level survey data on the manufacturing sector in Thailand as a representative sample for a developing country. The collection of data was funded and implemented by the Royal Thai Government with technical assistance from the World Bank. Data collection was conducted in two rounds. The first round (PICS 2004) was conducted between March 2004 and February 2005 and surveyed 1,385 manufacturing establishments. The second round (PICS 2007) was conducted between April and November 2007 and surveyed 1,043 manufacturing establishments. The surveys can be considered as nationally representative as they cover six regions of Thailand (North, Central, Bangkok and vicinity, East, Upper and Lower Northeast, and South) and nine industries based on the classification of the International Standard of Industrial Classification (ISIC); namely, food processing, textiles, garments, automobile components, electronic components, electrical appliances, rubber and plastics, furniture and wood, and machinery and equipment.

Simple tabulations shown in table 4, which presents data for a period of only three years (between 2004 and 2007), show that Thai manufacturing firms' use of email and websites to interact with clients and suppliers increased significantly. Usage of email increased from 54.1 percent to 73.4 percent while the use of websites increased from 34.5 percent to 49.7 percent. Around 5 percent of total sales were conducted through websites. Firms in the auto components and electronic components industries had the highest proportion of website and email use compared to other manufacturers. Firms in the food processing industry also reported that as much as 10 percent of their total sales were conducted through their websites. In terms of firm size, there is no doubt that larger firms will likely make more use of email and websites for their interaction with clients and suppliers than will smaller firms.

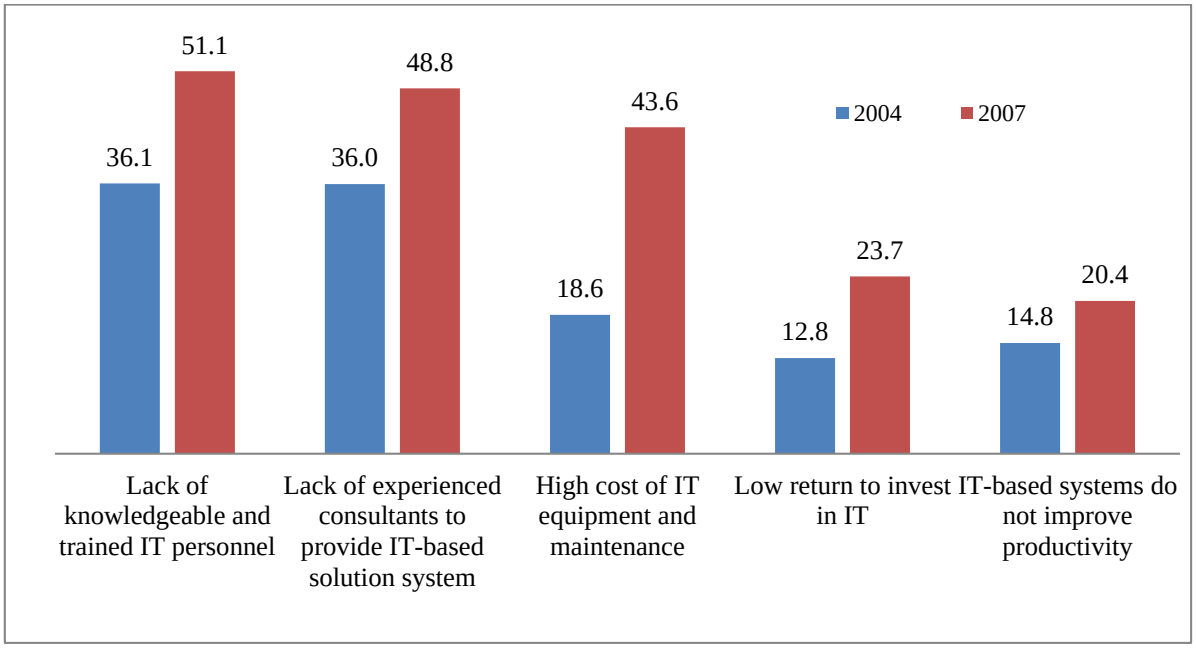
The questionnaire also asked firms to report their constraints on introducing IT or expanding IT use on a scale of 1 to 5. Compared to other constraints, the most significant was lack of IT-related human resources. As shown in figure 4, up to 51.1 percent of manufacturing firms in 2007 reported a lack of knowledgeable and trained IT personnel as either a very important (scoring 4 out of 5) or a critically important (5 out of 5) constraint. As many as 48.8 percent of all manufacturing firms reported critical constraints arising from a lack of experienced consultants to provide IT-based systems solutions. Even though the other constraints to IT investment included perceptions of low returns from IT investment and the belief that IT investment will not improve their firms' productivity, these constraints were still relatively less important and of less concern to Thai manufacturers compared to the lack of human resources (fig. 1). The high cost of IT equipment and maintenance has become yet another very important/critical constraint, increasing from 18.6 percent in 2004 to 43.6 percent in 2007.

**Table 4: Percentage of firms reporting the use of email and websites in their interaction with clients and suppliers**

| | Email | Website | Percentage of sales done through websites* | Number of firms |
|---|---|---|---|---|
| Year 2004 | 54.1 | 34.5 | 5.3 | 1,388 |
| Year 2007 | 73.4 | 49.7 | 5 | 1,043 |
| Industry | | | | |
| Food Processing | 59.6 | 45.6 | 10.9 | 287 |
| Textiles | 47.0 | 30.1 | 3.2 | 319 |
| Garments | 62.7 | 35.2 | 7.4 | 327 |
| Auto Components | 78.4 | 53.5 | 4.8 | 254 |
| Electronic Components | 73.7 | 52.1 | 4.2 | 338 |
| Rubber and Plastics | 59.4 | 36.8 | 2.9 | 498 |
| Furniture and Wood Products | 56.0 | 35.6 | 5.2 | 225 |
| Machinery and Equipment | 45.6 | 24.6 | 4.0 | 745 |
| Firm size | | | | |
| Small Firms (Less than 50) | 45.6 | 24.6 | 4.0 | 745 |
| Medium Firms (50-200) | 63 | 41.5 | 5.1 | 875 |
| Large Firms (Greater than 200) | 77 | 55.6 | 5.6 | 813 |

*Source*: PICS data (2004, 2007).
*Note*: *Percentage of sales done through websites is calculated only among firms reporting the use of websites in their interaction with clients and suppliers

**Figure 1. Percentage of firms regarding each of five constraints to introducing IT or expanding IT as Very Important (4 out of 5) or Critically Important (5 out of 5)**

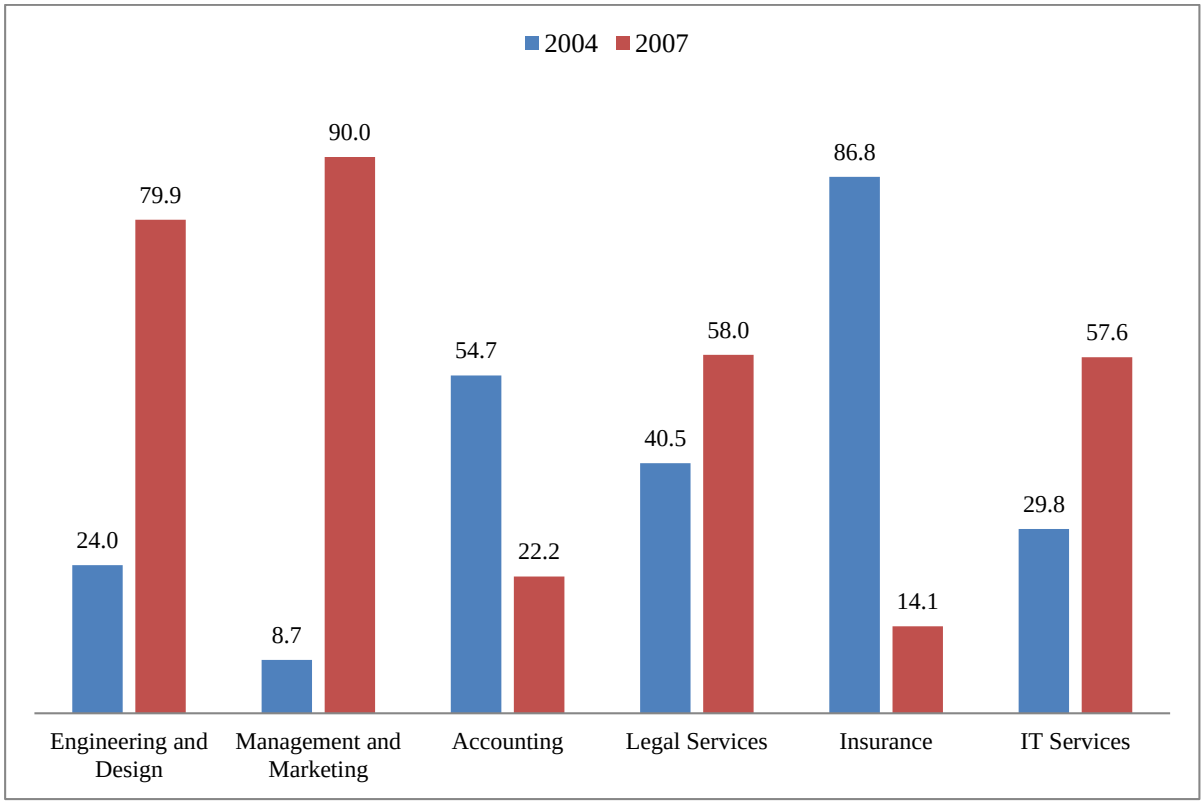



*Source*: PICS data (2004, 2007).
*Note*: In the questionnaire, firms were asked to report on a scale of 1 to 5, where 1 = not important, 3 = important, and 5 = critically important. Figures show the number of firms, in percentage terms, reporting a scale of 4 to 5.

In the PICS survey, firms were asked to report the affordability (for themselves) of certain professional services (fig. 2). In 2007, more than 57.6 percent of firms reported that they could afford and do employ IT personnel. Like the case for hired management and engineering positions, a higher level of affordability for IT personnel indicates a shortage of quality IT personnel, which has become a major problem for Thai manufacturers as they try to increase future IT-related investments. Adding to the problem, as a World Bank study found, Thai entrepreneurs in the manufacturing sector not only face problems recruiting people but their employees (especially the new ones) also tend to change jobs frequently. Another problem is the shortage of qualified personnel in the private sector where many current employees lack the basic and technical skills necessary for the use of computers and technology. Inadequately trained university graduates, however, may not be a major concern here since only a small number of firms (3.9 percent) were concerned that educational institutions are not producing adequately trained personnel to meet market requirements (fig. 3).

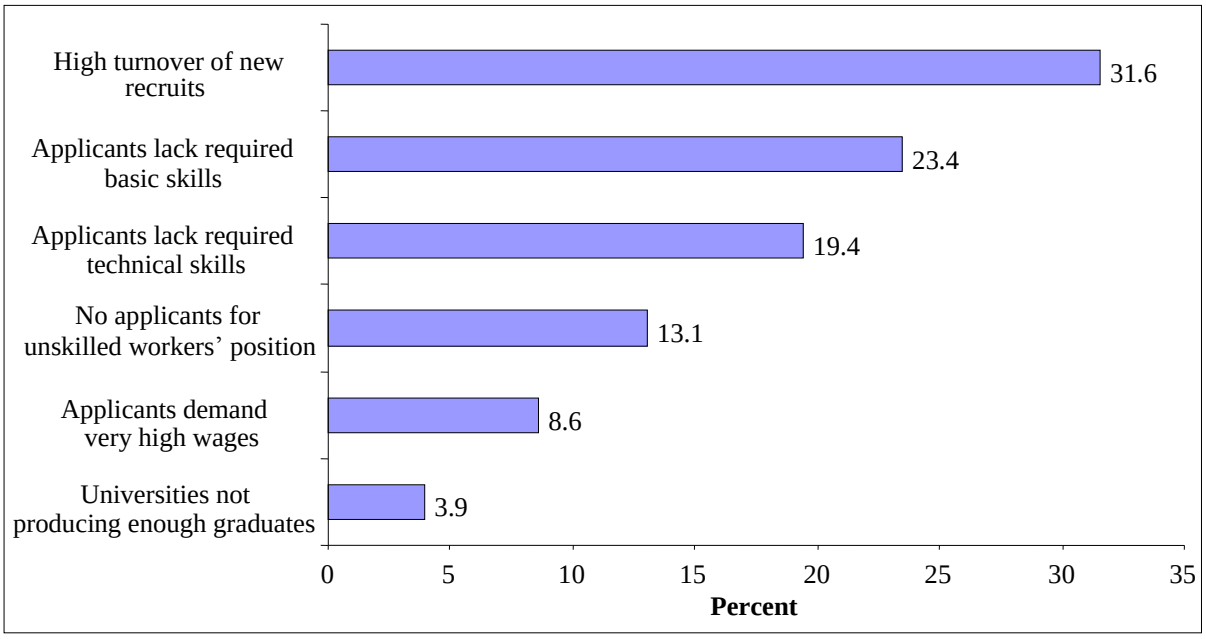
Figure 4 presents a microscopic view into each skill category, revealing that more than 85 percent of Thai manufacturers believe that IT is a skill that Thai workers lack, much more than "soft" skills such as creativity/innovation, leadership, etc. These results reflect the need for improvement in IT skills not only among IT-related personnel but also among general employees. This shortcoming is a problem that has serious implications for IT-related investment among Thai firms.

**Figure 2. Percentage of firms reporting the affordability of each professional service**



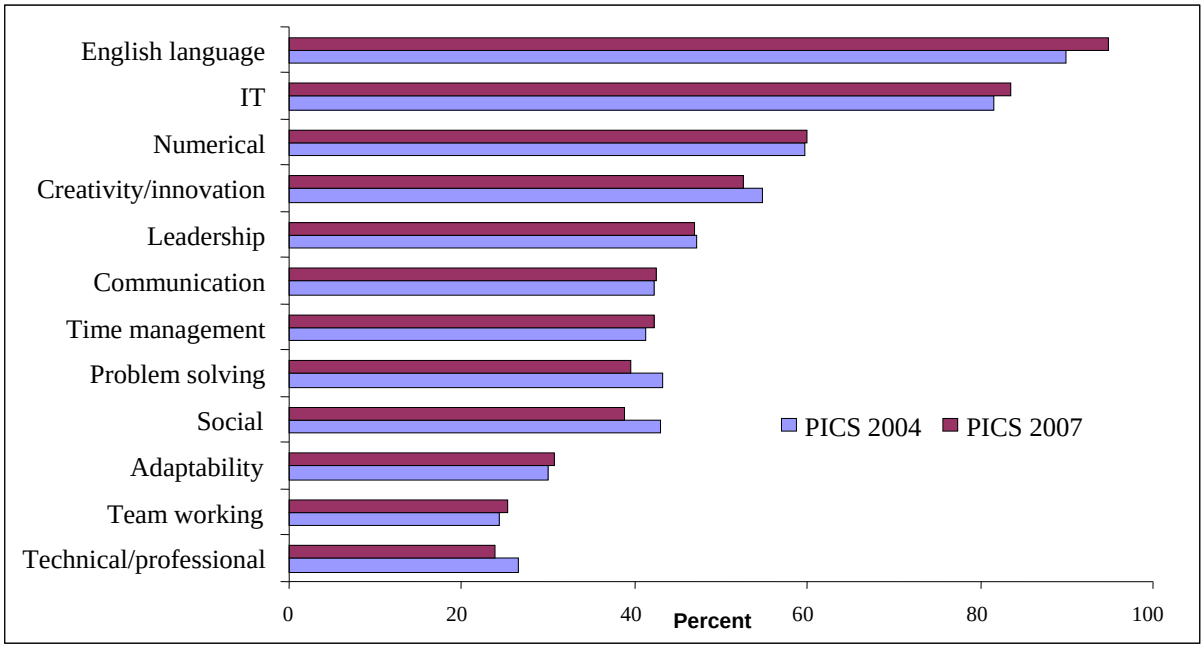

*Source*: PICS data (2004, 2007).

**Figure 3. Percentage of firms identifying a lack of qualified personnel classified by various causes**




*Source*: World Bank (2008).

**Figure 4. Shortage of skills in various categories**




*Source*: World Bank (2008).

Table 5 shows the classification that Thai manufacturers gave to their workers' IT skill levels, which were ranked from 1 to 4 (with 1 = very poor and 4 = very good). Thai manufacturers reported that, on average, they believe that professional workers have better IT skills than their production workers. In 2007, 44.5 percent of the Thai manufacturing firms surveyed rated their production workers' IT skills as 1 while 39.5 percent rated said workers' IT skills as 2. Both levels 1 and 2 correspond to poor IT skills.

**Table 5. Percentage of firms reporting IT skill levels of their professionals and skilled production workers (classified by skill level)**

| IT skill level | Professionals | | Skilled production workers | |
|---|---|---|---|---|
| | 2004 | 2007 | 2004 | 2007 |
| 1 | 9.5 | 5.5 | 45.2 | 44.5 |
| 2 | 30.2 | 29.3 | 37.4 | 39.3 |
| 3 | 47.3 | 48.8 | 16.3 | 14.3 |
| 4 | 13.0 | 16.4 | 1.1 | 1.9 |

*Source*: PICS data (2004, 2007).
*Note*: In the questionnaire, firms were asked to report on a scale of 1 to 4 where 1 = very poor, 2 = poor, 3 = fairly good, and 4 = very good.

This lack of IT skills results in a quality mismatch between employee skills and companies' workforce needs. As generally explained by economic theory, job vacancies always create invisible costs for firms since firms have to spend extra time and effort to find and recruit employees to fill the vacancies. Given that universities are evidently not producing quality graduates with the strong IT skills demanded by firms, providing either in-house or public training seems to be unavoidable. Such training would enhance new employees' IT skills and serve as incentive for firms to provide worker training as a way to foster employee loyalty.

However, classifying training programs by their content (table 6) shows that training on IT has received less attention than training on safety procedures, management skills, and production technologies. Only 2.2 percent of total in-house training programs and 4.9 percent of total outside training supported by a firm were IT-related programs. This dearth of IT training courses coupled with the low level of IT skills has proven to be a key constraint for future IT investment among Thai firms. The shortage of capable staff can have both short- and long-term effects on economic activity. In the short term, firms could operate below full capacity because they cannot find enough competent and experienced workers. In the long run, the shortage of well-trained staff limits a firm's efforts to enhance productivity. Nearly all firms believe investment in innovation activities yields high returns.

**Table 6. Content of training programs provided by manufacturers (percent of total training programs)**

| | In-House Training | | Outside Training | |
|---|---|---|---|---|
| Content of Training | 2004 | 2007 | 2004 | 2007 |
| Safety Procedures | 40.1 | 35.9 | 21.1 | 32.0 |
| Management | 33.1 | 25.1 | 27.2 | 37.1 |
| Production Technologies | 22.2 | 24.9 | 27.8 | 26.3 |
| Marketing | 2.5 | 2.8 | 5.3 | 4.6 |
| Information Technology | 3.1 | 2.2 | 3.1 | 4.9 |
| Language Skills | 5.9 | 1.2 | 0.6 | 0.5 |
| Intellectual Property | 1.3 | 0.4 | 0.7 | 1.8 |

*Source*: PICS data (2004, 2007).

Nonetheless, even though government does provide support in terms of R&D incentives and an export promotion scheme and both have been found to play critical role in fostering IT investment, only a small proportion of manufacturers actually benefit from these programs.

Table 7 presents survey results showing that only 1 percent of manufacturers benefited from government schemes. Many reported that they have never heard of these schemes. It is no surprise, therefore, that majority of the firms surveyed have never even applied for said schemes. The government should be made aware of this so that they can get the appropriate ministries and departments to advertise and encourage firms, especially small and medium enterprises, to participate in the program/scheme most relevant to them.

**Table 7. Firms' assessments of different schemes to promote innovation**

| Have firms benefited from this specific scheme? | Science Park Project | Low-interest loan from NASDA | Tax Reduction for R&D Expenditure | Thailand Innovation Project |
|---|---|---|---|---|
| 1. Yes. | 1.01 | 1.52 | 0.76 | 0.09 |
| 2. No, never heard about this scheme. | 38.31 | 27.59 | 43.21 | 37.61 |
| 3. No, I applied and was turned down. | 0.34 | 0.59 | 0.17 | 0.26 |
| 4. No, I never applied because the process is too long and complicated | 1.35 | 4.05 | 2.19 | 1.37 |
| 5. Never applied for other reasons | 58.99 | 66.24 | 53.67 | 60.68 |

*Source*: PICS Data (2004).

## 4. Determination of IT Investment Planning

This section aims to quantify the determination of the likelihood and magnitude of IT-related investment plans. IT-related investment decisions rely on many factors ranging from overall macroeconomic conditions, readiness of IT infrastructure, and government support policies, but firms' heterogeneity plays a different role. IT investment decisions also vary across firm-level characteristics (e.g., type of industry, location, production technology, firm size, firm age, and receipt of government support).

We will estimate two dependent variables: (1) the probability of IT investment, which is binary data constructed to be equal to 1 if a firm reports that there is a plan to invest in IT and 0 if there is no plan to invest in IT and (2) the magnitude of IT investment, which is the report of the proportion of IT-related investment to total investment plan in order to increase capacity or improve product quality within the next two years.

Unfortunately, this dependent variable of IT-related investment planning was elicited only in the 2004 round of the survey (PICS 2004) and not in the 2007 round (PICS 2007), which caused the sample size to decrease to 1,388 observations. Since this IT-related investment planning is measured by whether or not a firm has an IT-related investment plan, which is considered a future decision, the problem of endogeneity between IT investment and firm-level characteristics occurring from the estimation should, therefore, not exist in this case.

Tables 8 and 9 show that around 80 percent of firms had an IT-related investment plan in which around 7.6 percent (of a total investment plan) involved IT-related activities. Industries that reported a higher probability of an IT-related investment plan included textiles, garments, and furniture and wood products. Those industries also reported that a high proportion of their future investment plans were IT-related—10.9 percent for garments and 10.1 percent for furniture and wood products.

**Table 8. IT investment planning classified by industry and firm size**

| | Percentage of firms reporting an IT-related investment plan | Percentage of IT-related investment to total innovative investment | Number of firms |
|---|---|---|---|
| Industry | | | |
| Food Processing | 80.5 | 7.3 | 88 |
| Textiles | 91.9 | 8.5 | 73 |
| Garments | 90.5 | 10.9 | 72 |
| Auto Components | 80.0 | 8.1 | 113 |
| Electronic Components | 82.0 | 6.6 | 168 |
| Rubber and Plastics | 70.8 | 6.3 | 166 |
| Furniture and Wood Products | 89.6 | 10.1 | 49 |
| Machinery and Equipment | 68.0 | 6.2 | 74 |
| Firm size | | | |
| Small Firms (less than 50) | 85.6 | 7.07 | 368 |
| Medium Firms (50-200) | 80.1 | 7.58 | 497 |
| Large Firms (greater than 200) | 80.0 | 7.51 | 523 |

*Source*: PICS data (2004).

To analyze the human resource constraints of IT-related investment, we created a list of control variables in measuring firm-level characteristics (e.g., firm age, firm size, capacity utilization, factor intensity, the use of computer controls in production, workers' quality of education, foreign ownership, firm brand, and research partnership). In theory, some variables such as firm size, capital intensity, and computer control are predicted to have a positive significance in determining a firm's investment in IT. For example, firms using a higher percentage of computer controls in production would be expected to be more likely to invest in IT. Estimated coefficients of other control variables to IT investment (e.g., firm age, industry type, location, employee education level, and foreign ownership), however, would be doubtful.

Another set of independent variables include IT-related control variables; namely, number of IT staff employed by firms, quality of employees' IT skills, the ability of firms to make effective use of email and websites, proportion of sales made through websites (e-commerce), and incentives and promotions provided by the Thai government. These IT-related control variables can be classified into three groups: (1) IT staff and skills in proportion to IT staff, IT skills of professionals, and IT skills of production workers; (2) Internet usage as measured by whether a firm regularly uses email and websites in its interaction with clients and suppliers and whether sales are made through its website; and (3) impact of government policies as determined by whether a firm has benefited from e-commerce export promotion policies and whether it has received R&D incentives. Definition and mean of these control variables are reported in table 8.

Table 10 displays estimated binary Probit regression in models 1 to 4 to quantify the probability of a Thai firm deciding to invest in IT in the future given the various sets of independent variables mentioned above. Second, the magnitude of IT-related investment is quantified for those firms with no plans to invest in IT, which causes the dependent variable (amount of IT investment) to be left-censored to zero. The Tobit model, or a censored regression model, reported in models 5 to 8 of table 9, is designed to estimate linear relationships between proportions of IT investment where there is left-censoring (also known as censoring from below). The number of observations decreases in models 4 and 8 due to

missing IT human resources data (IT skills and proportion of IT staff). The number of observations goes down substantially from over 1,000 to 837 observations in model 8 due to the missing variable of IT staff.

Estimated coefficients of firm control variables show that a higher percentage of computer-controlled production machinery has a positive effect on the probability of IT-related investment. A 10 percent increase in the use of computers in controlling production machinery will increase the probability of a firm investing in IT-related activities by around 1 percent and increase the proportion of IT-related spending (total investment) by around 0.54 percent.

However, estimated coefficients show a strong negative relationship between capital-labor ratio and the probability of IT investment. One million baht more capital per worker seems to reduce the probability of IT investment by around 17 to 18 percent and reduce IT-related spending (relative to total investment) by around 5 percent. It seems that firms with relatively highly labor-intensive production find it necessary to have IT in the workplace to complement the nature of such production.

The control variable with the highest impact in determining the probability of IT investment and the amount of IT-related spending seems to be whether a firm has a research partnership with a number of universities or research institutes. Estimated coefficients show that firms with research partnerships with universities or research institutes have around 8.4 percent to 11.8 percent greater probability of investing in IT-related activities and of increasing their IT-related investment share by around 3 to 4.5 percent. This interesting finding supports the need for an industry-university linkages framework. The Thai government has been encouraging a linkages framework for decades because it helps foster innovation by creating opportunities for a firm to access more brain power, including well-trained graduates and knowledgeable faculty/researchers from universities. Firms can also improve their access to results from basic and applied research from which they can develop new products and processes, find solutions to specific problems, and tap into professional expertise not usually found in an individual firm.

This result seems to be similar to the case of the United States to where the importance of the success of industry-university partnership can be traced. The United States was able to become a world leader in IT because of the complex yet successful relationship between government, industry, and universities. This strong relationship between industry and universities is what made innovation in IT possible there (National Research Council 2012).

To successfully implement IT, firms must collaborate with external entities, a prerequisite for participating in international value chains (Machikita et al. 2010). It is crucial for firms to have relationships with other firms and organizations in order to exchange know-how and codified information in a more effective and efficient manner. Policy efforts must be made in order for this to happen as it also important for innovation, especially in industrial upgrading.

Our findings are somewhat inconsistent with Cheong et al.'s (2009) who found that in the case of Malaysian companies, firm size, as characterized by annual sales and the number of full-time employees, was a significant determinant of IT adoption. Larger firms are more likely to invest in and adopt IT compared to smaller firms. Das and Das (2012) also concluded that firm size has an impact on IT investment. In their study, larger firms were more likely to invest in IT than were smaller firms. They also concluded that firm age was an important determinant of IT investment. This meant that older, more established firms tend to invest in IT compared to younger firms. In our own study, however, the age and size of Thai

manufacturing firms did not show a statistical significance in determining IT investment. We also found no statistically significant impact of foreign investment in, or ownership of, a firm on that firm's IT investment. Thai manufacturers' capital utilization, ownership of a unique brand, and the level of education of their employees were also found to be not statistically significant to IT investment.

In terms of IT-related control variables, the higher IT skills of production workers and professionals was found to be statistically significant and strongly affected the probability of IT-related investment decisions. One level higher of IT skills on the part of production workers seemed to increase the probability of IT investment by around 5.7 percent and increased the percentage share of IT-related spending by around 2 percent. A higher level of IT skills of professional workers also increased the percentage share of IT-related spending by around 2.5 percent. This finding is consistent with the findings of Pimchangthong (2003) and Meephokee (2003). In the case of Thailand, this finding has an important policy implication: the introduction of training courses to upgrade the IT skills of production workers should benefit and stimulate IT investment among Thai firms. On the other hand, the low IT skill levels of production workers constitute a major obstacle for IT investment. This paper mentions some of the impacts of the dearth of human resources and a firm's IT investment, including the shortage of human resources in IT in Thailand, and suggests that both short-term and long-term government policies fostering improved IT infrastructure and developing human resources with strong IT skills be prioritized.

In addition, IT-related government policies; namely, the E-Commerce Export Promotion and R&D Incentive schemes, have also proven to significantly enhance the probability of IT investment. A firm that benefits from the E-Commerce Export Promotion scheme or receives R&D incentives from the government is more likely to increase its probability of investing in IT by around 13.6 to 20.8 percent and around 9.7 to 11 percent, respectively.

For Thailand overall, a firm's deciding whether or not to invest in IT in the next two years seems to depend on whether it has a high proportion of its production under computer control, whether it participates in research partnerships with universities and research institutes, and whether it receives R&D incentives and e-commerce promotions from the government. Also, promoting higher IT skills among production workers seems to be a key factor determining the probability of a firm having an IT-related investment plan and spending a higher proportion of its budget on IT.

Table 9: Definition and mean of variables

| Dependent Variable | Mean | No. of Obs | Definition |
|---|---|---|---|
| Probability of IT Investment | 0.8 | 803 | Defined to be equal to 1 if a firm expects to make IT-related investment between the next two years and 0 otherwise |
| Proportion of IT Investment | 7.6 | 1,388 | Percent of IT-related investment to total investment in order to increase capacity or improve quality |
| IT-Related Control Variable | | | |
| IT Staff | 0.9 | 1,388 | Percent of IT staff to total employment |
| IT Skills of Professionals | 2.6 | 990 | Quality assessment of IT skills among production skilled workers (Level 1-4): 1=very poor and 4 = very good |
| IT Skills of Production Workers | 1.7 | 1,371 | Quality assessment of IT skills among professional workers (Level 1-4): 1=very poor and 4 = very good |
| Regularly Use Email | 0.5 | 1,388 | Defined to be equal to 1 if a firm regularly uses email in its interactions with clients and suppliers and 0 otherwise |
| Regularly Use Website | 0.3 | 1,388 | Defined to be equal to 1 if a firm regularly uses website in its interactions with clients and suppliers and 0 otherwise |
| E-Commerce by Web | 1.8 | 1,367 | Percent of sales done through website |
| E-Commerce Export Promotion | 0.1 | 1,388 | Defined to be equal to 1 if a firm receives benefits from the E-Commerce Export Promotion scheme |
| R&D Incentive | 0.1 | 1,185 | Defined to be equal to 1 if a firm receives R&D incentives |
| Firm Control Variable | | | |
| Computer Control | 19.5 | 1,388 | Percent of production machines controlled by computer |
| Firm Age | 15.4 | 1,388 | Number of years since a firm commenced operations in Thailand |
| Small-Sized Firm | 0.3 | 1,388 | Defined to be equal to 1 if a firm employs less than 50 employees and 0 otherwise |
| Medium-Sized Firm | 0.4 | 1,388 | Defined to be equal to 1 if a firm employs between 50 and 200 employees and 0 otherwise |
| Large-Sized Firm | 0.4 | 1,388 | Defined to be equal to 1 if a firm employs more than 200 employees and 0 otherwise |
| Capacity Utilization | 77.0 | 1,380 | Percent of amount of output a firm actually produced relative to the maximum amount possible |
| Capital-Labor Ratio | 0.1 | 1,330 | Amount of machinery and equipment rented or owned by a firm divided by total number of employees in million baht |
| Foreign Ownership | 17.1 | 1,387 | Percent of firm owned by foreigner |
| Own Brand | 0.5 | 1,387 | Defined to be equal to 1 if a firm has its own brand and 0 otherwise |
| Research Partnership | 0.2 | 1,185 | Defined to be equal to 1 if a firm has research partnership with universities or research institutions |
| Primary Education | 11.4 | 1,388 | Percent of workers to total workers with primary degree |
| Secondary Education | 66.0 | 1,388 | Percent of workers to total workers with secondary degree |
| College Education | 22.6 | 1,388 | Percent of workers to total workers with college education |

*Source*: Computed from PICS (2004).

Table 10: Estimation of probability of IT-related investment (Probit) and proportion of IT-related investment to total investment plan

| Model | Binary Probit Model (Marginal Effect) | | | | Tobit Model | | | |
|---|---|---|---|---|---|---|---|---|
| Firm Control Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Computer Control | 0.001* | 0.001* | 0.001* | 0.001** | 0.054* | 0.054* | 0.046 | 0.046 |
| | *[0.001]* | *[0.001]* | *[0.001]* | *[0.001]* | *[0.028]* | *[0.028]* | *[0.029]* | *[0.032]* |
| Firm Age | 0.001 | 0.001 | 0.001 | 0.002 | 0.117 | 0.108 | 0.108 | 0.16 |
| | *[0.002]* | *[0.002]* | *[0.002]* | *[0.002]* | *[0.091]* | *[0.091]* | *[0.092]* | *[0.106]* |
| Medium-Sized Firm | 0.053 | 0.057 | 0.043 | -0.011 | 2.339 | 2.545 | 1.775 | -0.778 |
| | *[0.041]* | *[0.041]* | *[0.041]* | *[0.055]* | *[2.195]* | *[2.201]* | *[2.234]* | *[2.833]* |
| Large-Sized Firm | 0.074 | 0.070 | 0.055 | -0.031 | 3.682 | 3.571 | 2.645 | -1.517 |
| | *[0.046]* | *[0.046]* | *[0.047]* | *[0.061]* | *[2.466]* | *[2.475]* | *[2.573]* | *[3.121]* |
| Capacity Utilization | -0.001 | -0.001 | -0.001 | -0.008 | -0.002 | -0.008 | -0.013 | -0.048 |
| | *[0.001]* | *[0.001]* | *[0.001]* | *[0.001]* | *[0.048]* | *[0.048]* | *[0.048]* | *[0.055]* |
| Capital-Labor Ratio | -0.184** | -0.178* | -0.177* | -0.210** | -5.355 | -5.116 | -5.288 | -8.434 |
| | *[0.093]* | *[0.094]* | *[0.094]* | *[0.107]* | *[4.500]* | *[4.519]* | *[4.519]* | *[5.177]* |
| Foreign Ownership | 0.001 | 0.001 | 0.001 | 0.001 | 0.029 | 0.030 | 0.032 | 0.022 |
| | *[0.000]* | *[0.000]* | *[0.001]* | *[0.001]* | *[0.026]* | *[0.026]* | *[0.027]* | *[0.029]* |
| Own Brand | 0.042 | 0.034 | 0.024 | 0.038 | 2.358 | 2.071 | 1.426 | 2.451 |
| | *[0.030]* | *[0.030]* | *[0.031]* | *[0.037]* | *[1.630]* | *[1.642]* | *[1.675]* | *[1.908]* |
| Research Partnership | 0.118*** | 0.084** | 0.084** | 0.085* | 4.459** | 3.183* | 3.230* | 2.973 |
| | *[0.036]* | *[0.038]* | *[0.038]* | *[0.044]* | *[1.796]* | *[1.916]* | *[1.938]* | *[2.133]* |
| Secondary Education | 0.001 | 0.001 | 0.001 | 0.001 | 0.072 | 0.073 | 0.068 | 0.069 |
| | *[0.001]* | *[0.001]* | *[0.001]* | *[0.001]* | *[0.044]* | *[0.044]* | *[0.045]* | *[0.055]* |
| College Education | 0.001 | 0.001 | 0.001 | 0.001 | 0.058 | 0.061 | 0.053 | 0.068 |
| | *[0.001]* | *[0.001]* | *[0.001]* | *[0.001]* | *[0.052]* | *[0.052]* | *[0.053]* | *[0.062]* |

Table 10 (continued)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IT-Related Control Variables | | | | | | | | |
| R&D Incentive | - | 0.109** | 0.097* | 0.085 | - | 4.072* | 3.627 | 2.387 |
| | - | *[0.049]* | *[0.050]* | *[0.056]* | - | *[2.407]* | *[2.451]* | *[2.688]* |
| E-Commerce Export promotion | - | 0.148* | 0.136* | 0.208** | - | 4.494 | 3.561 | 5.174 |
| | - | *[0.075]* | *[0.076]* | *[0.085]* | - | *[3.537]* | *[3.595]* | *[3.886]* |
| Regularly Use Email | - | - | 0.028 | 0.021 | - | - | 0.129 | 0.532 |
| | - | - | *[0.033]* | *[0.040]* | - | - | *[1.830]* | *[2.077]* |
| Regularly Use Website | - | - | 0.021 | 0.010 | - | - | 3.459* | 3.368 |
| | - | - | *[0.035]* | *[0.040]* | - | - | *[1.857]* | *[2.059]* |
| E-Commerce by Web | - | - | -0.001 | -0.001 | - | - | -0.090 | -0.071 |
| | - | - | *[0.002]* | *[0.002]* | - | - | *[0.091]* | *[0.105]* |
| IT Staff | - | - | - | 0.014 | - | - | - | 0.248 |
| | - | - | - | *[0.009]* | - | - | - | *[0.246]* |
| IT Skills of Production Workers | - | - | - | 0.057** | - | - | - | 2.007* |
| | - | - | - | *[0.025]* | - | - | - | *[1.185]* |
| IT Skills of Professionals | - | - | - | 0.037 | - | - | - | 2.543** |
| | - | - | - | *[0.023]* | - | - | - | *[1.266]* |
| Observations | 1,129 | 1,129 | 1,109 | 837 | 1,129 | 1,129 | 1,109 | 837 |
| Pseudo R-Square | 0.084 | 0.094 | 0.078 | 0.091 | 0.024 | 0.025 | 0.026 | 0.027 |

Standard errors are in brackets. Significant at 10%; ** significant at 5%; *** significant at 1%.
Estimated coefficients of Industry Dummy, Regional Dummy, and constant term are not shown in this table.
Pseudo R-Square is reported for Probit and Tobit Regression

## 5. Conclusion and Policy Recommendations

Access to IT systems and the use of IT to assist in production is important in the manufacturing process as it reduces costs and increases productivity and competitiveness in the global market. Developing countries, however, find it difficult to make IT investments due to the latter's high cost. This is an obstacle for a developing country attempting to further enhance its economic development and certainly the case in Thailand, a developing country that has been stuck in a medium-income trap for decades.

Using a survey of manufacturing data, estimated results have shown that the most critical constraints obstructing Thai manufacturers' investing in IT is the lack of IT-savvy human resources, including both a lack of knowledgeable and trained IT personnel and a lack of experienced consultants to provide solutions for IT-based systems. Even though more than 50 percent of manufacturing firms can afford to fill such positions, the IT skills of potential employees do not meet their requirements, especially the IT skill requirements for production workers. Under this constraint, providing training courses in IT-related skills should be a priority. Evidence from surveys, however, reveals that manufacturers do not recognize the efficacy of in-house and external IT training courses.

Using binary Probit regression and Tobit regression, estimation for both the likelihood and magnitude of IT-related investment also confirms this finding; namely, that the lack of an IT-skilled workforce constitutes a significant constraint on IT investment. In terms of IT-related control variables, possession of higher IT skills among production workers is found to be statistically significant to the probability of positive IT-related investment decisions. A higher level of IT skills among production workers seems to increase the probability of IT investment by around 5.7 percent and increase IT-related investment as a share of total investment by around 2 percent. Higher IT skill of the professionals also increase IT-related investment share by around 2.5 percent. This finding leads to an important policy implication: introducing training courses to upgrade the IT skills of both production workers and professionals can stimulate IT investment among Thai firms. On the other hand, their low IT skill levels represents a major obstacle for IT investment.

Research partnerships with universities and research companies have also proven to be effective frameworks for increasing the share of IT investment. Firms with research partnerships with universities or research institutions were shown to increase their probability of investing in IT-related activities by 8.4 to 11.8 percent and to increase the share of their IT investment by 3 to 4.5 percent than did firms with no such research partnerships. This interesting finding supports the success of the linkages of industry-university/research institute framework that the Thai government has been promoting for decades. Research partnerships and industry-university linkages help foster innovation by creating opportunities for firms to access more brain power, including well-trained university graduates as well as knowledgeable faculty and researchers.

Another interesting finding is with regard to the significant impact of government policy on enhancing the probability of IT investment. A firm that benefits from the E-Commerce Export Promotion scheme or receives R&D incentives from government is more likely to increase the probability of its IT investment by around 9 to 11 percent and 13.6 to 20 percent, respectively. The impact is even stronger in the auto parts industry. Nonetheless, even

though government does provide support in terms of R&D incentives and an export promotion scheme and both have been found to play a critical role in fostering IT investment, only a small proportion of manufacturers actually benefit from these programs. Survey results show that only 1 percent of manufacturers receive benefits from government schemes. Many report that they have never heard about any particular government scheme. This evidence should, therefore, be directed to the government in order to get the appropriate ministries and departments to advertise the schemes and encourage firms, especially small and medium enterprises, to participate in the program most relevant to them.

Based on the results presented in this paper, there are a number of things the government can do in order to promote IT investment among Thai manufacturers. First, enhancing the IT skills of production workers and IT personnel should be a top priority. Findings show a positive relationship between a higher level of worker skill and a tendency for a firm to invest in its IT-related programs. On the other hand, a low skill level is proven to be a major constraint on investment. The Ministry of Education should thus play a major role in fostering IT knowledge starting from basic education to more technical training for those ready to enter the labor market. (In fact, along with providing basic education, the Ministry of Education's Department of Non-Formal Education has also long given priority to adult and nonformal education as a means of providing lifelong learning opportunities to the out-of-school population.)

Second, university-industry linkages (or industry linkages with research institutes) should be promoted and strengthened. There are a number of schemes to promote such relationships. In Thailand, however, the university-industry linkages are weak due to low levels of innovation and weak incentives, which result in little effort by the private sector to link up with universities (Brimble and Doner 2007).

The government should fund university-based and industry R&D because this has an important impact on IT. Universities should conduct long-term research projects since industries are not typically able to carry out such research on a long-term basis. Thailand can also emulate the characteristics of industry-university relationships seen in the United States. Research universities in the United States integrate research with education, thereby educating and equipping with the necessary skills the IT workers of the future (National Research Council 2012). These graduates are the most effective vehicles for technology transfer between academia and industry as well as between university labs and departments in industries. This also leads to the movement of personnel in both directions through the hiring of postdoctoral researchers, consultants, employees, and entrepreneurs. Creating strong research institutions is most crucial if Thailand wants to move towards high-tech economic development (National Research Council 2012).

Finally, since government policies related to tax incentives and e-commerce export promotion have been found to have positive relationships with IT investment, the government should help small and medium enterprises recognize the benefits available to them and encourage them to participate in the programs most relevant to them. These policy recommendations can serve as stepping-stones towards the long-term success of Thai firms and their ability to compete with other countries, especially in the ASEAN region.

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