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ABSTRACT

The phenomenon "productivity paradox" indicates that investment in information technology is not positively associated with financial performance. However, there have been debates as to whether this phenomenon is actually valid or not. In this study, we explore the different roles of IT for increasing productivity in manufacturing and service industries using the data mining method called Weka (Waikato Environment for Knowledge Analysis). We found that there exist both similarities and differences between the two industries. The role of CIO (Chief Information Officer) is addressed, as well as the role of E-learning Systems associated with productivity in the service industry. Finally, the vulnerability of small businesses to the IT productivity paradox is discussed.

Keywords

Productivity, Productivity Paradox, Manufacturing Industry, Service Industry, Data Mining, Weka

INTRODUCTION

For most of the past half-century, modern organizations have been increasing their investment in information technology, primarily because of the belief that IT (Information Technology) has a significant positive impact on organizational performance. Many practitioners and researchers have been interested in determining the validity of this belief, and various studies have been conducted (Osei-Bryson and Ko 2004). Contrary to this belief which suggests a positive association between investment in IT and improved financial performance, empirical evidence in the 1980s and early 1990s (e.g., Brynjolfsson 1993) suggested that there was no statistical association between IT spending and financial performance – this phenomenon is called the "productivity paradox." However, by the mid-1990s, a positive relationship had been established between the two (e.g., Brynjolfsson and Hitt 1996).

Such debates on IT productivity have continued to this day, and some studies, including Brinjolfsson (1993) and Morrison and Berndt (1990), have suggested that the role of IT productivity must be different between manufacturing and non-manufacturing industries.

The main goal of this study is to explore the different roles of information technology for increasing productivity between manufacturing and non-manufacturing (service) industries. Data collected from companies in South Korea is used for this

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study and a data mining method is applied to compare the different roles of IT in the two types of industries in terms of productivity.

LITERATURE REVIEW

IT Payoff

IT payoff is generally defined as the value to the organization returned by the investment in information technology (Sherer et al., 2003). IT investment refers to the portion of the total budget allocated to IT salaries, hardware, software and other IT support (Ross, 2002). Productivity, as a result of IT investment, can be divided into two categories: financial and nonfinancial performance. Early studies on IT payoff consider either financial or nonfinancial measures as IT productivity. However, at present, many studies consider both perspectives. For example, Smith et al. (1998) grouped firm performance metrics into six categories: cost efficiency, productivity, profitability, growth, cash management, and market ratios, which included both financial and nonfinancial measures. Based on these performance measures, Bin Jiang et al. (2006) concentrated on only three operational performance metrics (cost efficiency, productivity, and profitability), rather than financial characteristics.

Similar studies were found with relation to performance measures of IT investment. For example, Sethi and King (1994) categorized measurement of competitive advantage from IT into two approaches. The first categorization, referred to as the 'outcome approach', is reflected in concepts such as competitive efficiency, business value, and management productivity. The second approach, referred to as the 'attribute approach', identifies key attributes that characterize competitive advantage. This approach suggests that competitive advantage is embodied by the degree to which an IT resource possesses certain key attributes.

Based on such outlooks, a further literature review was conducted. It was found that productivity from IT investment can be measured by six indices: firm growth, market competitiveness, customer relationship, partnership with providers, firm operational efficiency, and downsizing. These indices are compounded with both financial and nonfinancial performance. Firm growth is referred to as growth in sales, net income, and operational productivity (Hitt and Brynjolfsson 1996; Ross 2002). Market competitiveness is defined as market share or market position and competitive advantages in the market (Kettinger et al. 1994). Customer relationship refers to the capability to provide better service to customers (Tippins and Sohi 2003). Partnership with providers is business performance by linking functions to improve their coordination, or by linking a company to its suppliers or customers in ways that increase responsiveness or reduce costs. Sethi and King (2007) mentioned operational efficiency as one of the recognized benefits of IT investment. Downsizing is associated with the basic concept of efficiency in human resource management by reducing the number of employees through IT adoption.

IT Productivity Paradox: Service versus Manufacturing Industries

Brynjolfsson and Hitt (1996) explain that the IT productivity paradox, despite enormous improvements in the underlying technology, has not been found in aggregate output statistics. Attention was first drawn to the productivity paradox by a simple but provocative study, “America’s Technology Dilemma: A Profile of the Information Economy” by Morgan Stanley’s chief economist Steven Roach, published in Morgan Stanley’s April 22, 1987 economics newsletter series. Roach attempted to explain why the measured productivity growth rate in the U.S. economy has slowed substantially since 1973. He observed that the amount of computing power per white-collar worker in the service industry was growing dramatically over the 1970s and 1980s, yet the measured productivity of this sector was flat compared with the traditional manufacturing industry. Their conclusion was that the tremendous increase in computerization has had little effect on economic performance, particularly for non-manufacturing (service) sectors of the economy with large numbers of information workers (Brynjolfsson and Hitt 1998).

Morrison and Berndt (1990) examined a set of production models by using a broad data set from the whole U.S. manufacturing sector. However, they also found that every dollar spent on IT delivers, on the margin, a return of only about $0.80, indicating a general overinvestment in IT in the manufacturing sector as well (Yorukoglu 1998).

In this sense, we posit that it should be valuable to identify the different roles of information technology for the two different sectors (i.e. manufacturing and service sectors) in terms of IT productivity. What kinds of IT investments improve productivity of the manufacturing sector? What kinds of IT investments play a critical role in improving productivity of the service sector? Are IT investments the same or different, depending on the sector? We will explore these issues using a data mining method called Weka.

METHOD

Data Mining and Weka

Data mining, which is also known as knowledge discovery in databases, is defined as "the application of specific algorithms for extracting patterns from data" (Fayyad et al. 1996). Since data mining is used to discover knowledge from a huge amount of data in databases, it can be applied to decision making, process control, and other applications (Chen et al. 1996).

In this study, we use a data mining package called Weka, which is probably the most well-known open source data mining software (Witten and Frank 2002). Weka is issued under the GNU (GNU is Not UNIX) General Public License for this process (Witten and Frank 2005), and it is "a collection of machine learning algorithms for data mining tasks" (http://www.cs.waikato.ac.nz/ml/weka/). Weka is known as an ease-of-use data mining tool, in that it requires minimal additional programming by users (Witten et al. 1999). Another advantage is its flexibility and extensibility, because it is done in JAVA (Witten and Frank 2002). Frank et al. (2004) pointed out the advantage of Weka's flexibility: "The aim in developing Weka was to permit a maximum of flexibility when trying machine learning methods on new datasets.This includes algorithms for learning different types of models (e.g. decision trees, rule sets, linear discriminants), feature selection schemes (fast filtering as well as wrapper approaches) and pre-processing methods (e.g. discretization, arbitrary mathematical transformations and combinations of attributes). By providing a diverse set of methods that are available through a common interface, Weka makes it easy to compare different solution strategies based on the same evaluation method and identify the one that is most appropriate for the problem at hand" (pp. 2479).

There are many studies using Weka to conduct data mining analyses (e.g. Frank et al. 2004; Goebel 1999; Kretschmann et al. 2001).The most frequently used model of Weka is a decision tree algorithm (See http://www.cs.waikato.ac.nz/ml/weka/ for details). The bottom line of decision trees are summarized as: "1) Choose an attribute that best differentiates the output attribute values, 2) Create a separate tree branch for each value of the chosen attribute, 3) divide the instances into subgroups so as to reflect the attribute values of the chosen node, 4) For each subgroup, terminate the attribute selection process if: a. All members of the subgroup have the same value for the output attribute, terminate the attribute selection process for the current path and label the branch on the current path with the specified value. b. The subgroup contains a single node or no further distinguishing attributes can be determined, and 5) for each subgroup created in '3)' that has not been labeled as terminal, repeat the above process" (http://grb.mnsu.edu/grbts/doc/manual/J48_Decision_Trees.html).

This study intend to explore what kind of IT investment (adoption) could improve the productivity of the manufacturing industry, but could not improve that of the service industry, and vice versa. We investigate each company's adoption status of fifteen of the most frequently employed information systems or IT policies, including ERP (Enterprise Resource planning), KMS (Knowledge Management Systems), CIO (Chief Information Officer), EAI (Enterprise Application Integration), and others (See Table 1). This means that the value of each measure must be Boolean (Adopted/Not adopted) (not clear why). Accordingly, the decision tree method from Weka appears suitable for this analysis, rather than general multivariate analysis methods. As stressed by Frank et al. (2004), Weka is very useful in comparing different solution strategies based on the same evaluation method and identifying the one that is most appropriate for the problem at hand."

In short, we chose a Weka package for this analysis since 1) it includes diverse methods, 2) it has an easy interface to use, 3) it has an application program interface (API) that allows the algorithm to be called from other programs (http://www.the-data-mine.com/bin/view/Software/WekaSoftware), and 4) it is suitable for academic use based on its flexibility and extensibility (Frank et al. 2004; Witten and Frank 2002; Witten and Frank 2005; Witten et al. 1999).

Data Collection

Data was collected by a research institution sponsored by the Korean government. Subjects were companies that had more than 10 employees and were registered in the firm list of the National Statistical Office in 2004 in Korea. Data collection methods include interviews, telephone and web surveys, and faxes/emails from September 6th, 2006 to November 17th, 2006. The number of samples actually collected was 5,253. Based on their industry classification, we selected 1,121 companies in the manufacturing sector and 298 companies in the service sector to use in our analyses.

Decision Tree Test and its Values

The data used in this decision tree analysis is composed of 16 common causes (independent variables), as depicted in Table 1. Definitions of each system/IT policy are presented in Appendix A. In addition, to measure productivity from IT investment of companies sampled, 6 questions were asked to managers when data was collected, including questions about firm growth, market competitiveness, customer relationships, partnerships with suppliers, operational efficiency, and downsizing. These questions were originally measured using a 5-point Likert scale (1: Strongly disagree, 2: Disagree, 3: Neither agree nor disagree, 4: Agree, and 5: Strongly agree), and we then summed up the results of all six questions (i.e. a company's possible maximum productivity score would be 30).

After that, we classified companies into three different groups using a trisection method: low productivity (ranging from 1 to 10), normal productivity (11 to 20), and high productivity (21 to 30). In the manufacturing industry (n=1,121), 719 companies were classified into the low productivity group, 79 into the normal, and 323 into the high. In the service industry (n=298), 126 companies were classified as low, 172 as high, and there were no companies classified as normal.

	Test	Value
1	Did your company adopt any of Electronic Tendering System?	yes, no
2	Did your company adopt any of Enterprise Resource Planning Systems?	yes, no
3	Did your company adopt any of Customer Relationship Management Systems?	yes, no
4	Did your company adopt any of Knowledge Management Systems?	yes, no
5	Did your company adopt any of Enterprise Application Integration Systems?	yes, no
6	Did your company adopt any of Supply Chain Management Systems?	yes, no
7	Did your company adopt any of Business to Business Integration Systems?	yes, no
8	Did your company adopt any of Product Lifecycle Management Systems?	yes, no
9	Did your company adopt any of Human Resource Management Systems?	yes, no
10	Did your company adopt any of E-Learning System?	yes, no
11	Did your company adopt any of Strategic Enterprise Management Systems?	yes, no
12	Did your company adopt any of Enterprise Risk Management Systems?	yes, no
13	Did your company adopt any of Business Process Management Systems?	yes, no
14	Did your company adopt any of Electronic Document Management Systems?	yes, no
15	Does the company have Chief Information Officer (CIO)?	yes, no
16	The scale of the capital in the company.	numeric
17	**Productivity from IT investment** *After adopting those systems/IT policies,* 1) My company could increase the sales volume and revenue. 2) My company could achieve market competitiveness. 3) My company could provide better service and quicker response to customers. 4) My company could achieve better partnership with suppliers. 5) My company could achieve operational efficiency through improving quality of communications for decision making 6) My company could achieve downsizing by reducing the number of employee.	Low, Normal, High

Table 1. Decision Tree Test and its Value

Results

Figure 1 and 2 show the results of decision tree analysis for manufacturing and service industries using Weka. In the figures, there are three types of elements – circles, lines, and rectangles. A circle denotes the condition to get the result which is referred to as test criteria, and a line links and combines significant test criteria, showing selected values of each test criteria. Finally, a rectangle shows the extracted consequence (e.g. low, normal, high productivity) from the combined conditions (circles) of the test criteria.

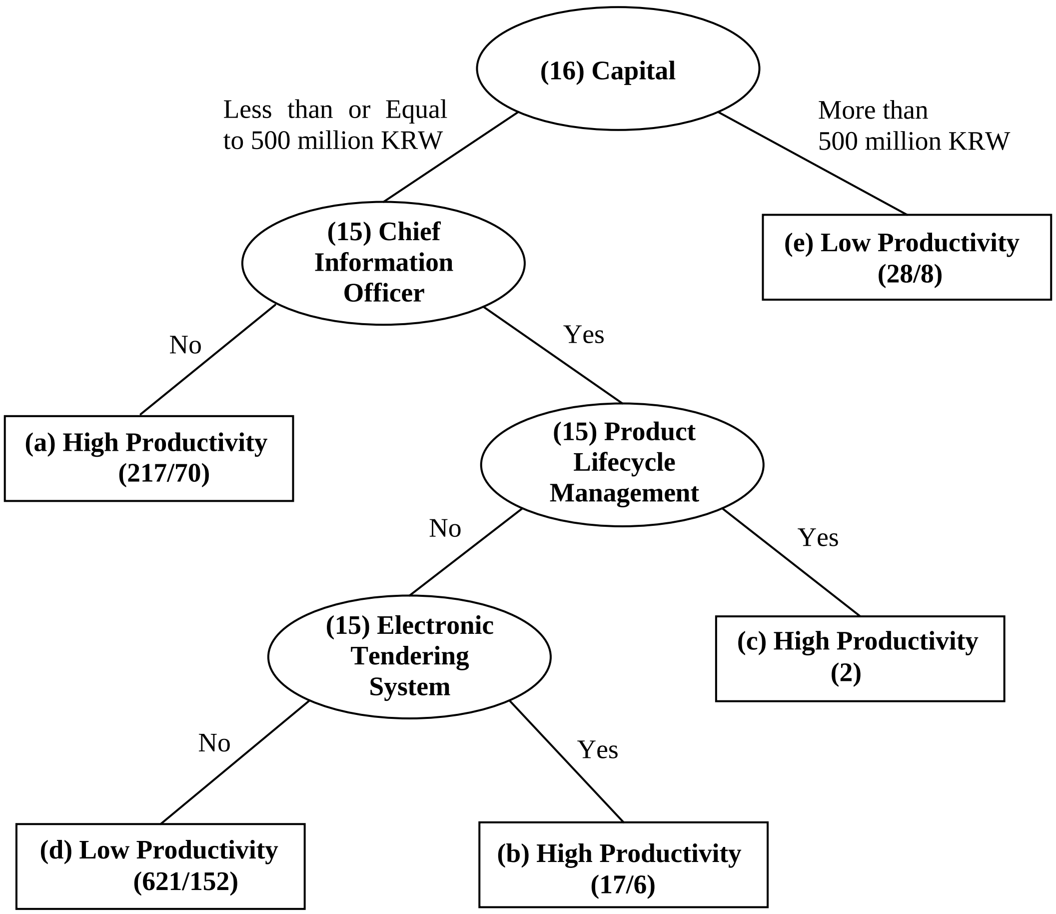

Figure 1. Decision Tree for the Manufacturing Industry

As described in Figure 1, IT productivity of the manufacturing industry is discriminated by combining 4 test criteria (circles), including the scale of the capital of the company, Chief Information Officer (CIO) engagement, Product Lifecycle Management System (PLM) adoption, and Electronic Tendering System (ETS) adoption. Using these 4 test criteria, we can obtain two types of results – high productivity and low productivity. Table 2 and 3 summarize these results with the correctness of classification. The correctness is calculated using the equation $\frac{\text{Number of Correctly Classifed Elements}}{\text{Number of Classifed Elements}} \times 100$.

	Capital	CIO	PLM	ETS	Correctness (%)
(a)	Less than 500 million KRW (about 5,000 USD)	No			217/(217+70) =75.61
(b)	Less than 500 million KRW (about 5,000 USD)	Yes	No	Yes	17/(17+6) =73.91
(c)	Less than 500 million KRW (about 5,000 USD)	Yes	Yes		2/2 =100

Table 2. High Productivity from IT Investment in the Manufacturing Industry

Table 2 depicts the three cases of achieving high IT productivity in the manufacturing industries. Companies in the manufacturing industry achieve high IT productivity (a) in the case that its sum of capital is less than 500 million KRW (about 5,000 USD) but there is no CIO, or (b) in the case that its sum of capital is less than 500 million KRW with CIO, adopting Electronic Tendering Systems, but not adopting Product Lifecycle Management, or (c) in the case that its sum of capital is less than 500 million KRW with CIO, and adopting Product Lifecycle Management. However, in case (c), the percentage of the correctly classified companies is 100%, but the number of classified company is only 2 among a total of 1,121, which means that it is hard to confirm that the finding from (c) is reliable. Similarly, (b) is also unreliable (only 23 cases were classified among 1,121). As shown in Table 2, it is concluded that the only reliable finding of the analysis is case (a). Consequently, in the manufacturing industry, companies whose sum of capital is less than 500 million KRW (without CIO achieve a high IT productivity.

	Capital	CIO	PLM	ETS	Correctness (%)
(d)	Less than 500 million KRW (about 5,000 USD)	Yes	No	No	621/(621+152) =80.34
(e)	Less than 500 million KRW (about 5,000 USD)				28/(28+8) =77.78

Table 3. Low Productivity from IT Investment in the Manufacturing Industry

Table 3 shows the two cases of achieving low IT productivity in the manufacturing industry. However, the number of classified elements of (e) is very small (n=28), which is again unreliable. Thus, only (d) is considered a reliable finding (i.e. high correctness and a large number of classified elements). Thus, it is concluded that in the manufacturing industry, companies achieve low productivity for their IT investment when the sum of capital is less than 500 million KRW with CIO, but adopting neither Electronic Tendering Systems nor Product Lifecycle Management.

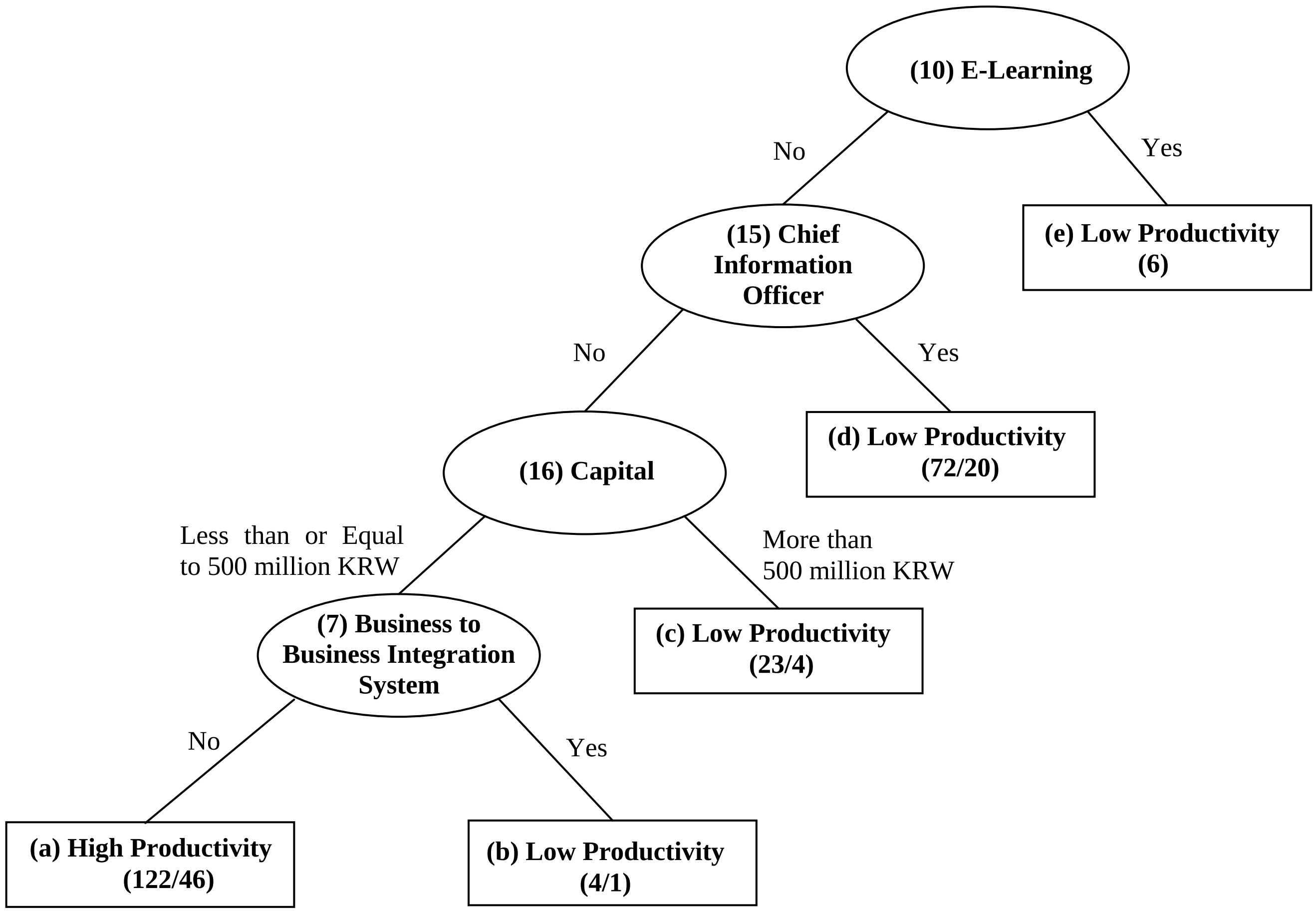

Figure 2. Decision Tree for the Service Industry

In Figure 2, companies in the service industry are classified by 4-test criteria, including E-learning systems, Chief Information Officer, the scale of the capital of the company, and Business to Business Integration (B2BI) Systems. Using these 4 test criteria, we can obtain two types of results – high productivity and low productivity. Table 4 and 5 summarize these results, with the correctness of each case.

	E-Learning	CIO	Capital	B2BI	Correctness (%)
(a)	No	No	Less than 2,200 million KRW (about 22,000 USD)	No	122/(122+46) =72.62

Table 4. High Productivity from IT Investment in the Service Industry

As illustrated in Table 4, in the service industry the company achieved high productivity from IT investment when its sum of capital was less than 2,200 million KRW (about 22,000 USD) without CIO, and without adopting E-learning Systems or B2BI Systems. This finding is reliable in that the number of classified elements in (a) is 168 (n=298) with 72.62% correctness.

	E-Learning	CIO	Capital	B2BI	Correctness (%)
(b)	No	No	Less than 2,200 million KRW (about USD 22,000)	Yes	4/(4+1) =80.00
(c)	No	No	More than 2,200 million KRW (about USD 22,000)		23/(23+4) =85.19
(d)	No	Yes			72/(72+20) = 80.00
(e)	Yes				6/6 = 100%

Table 5. Low Productivity from IT Investment in the Service Industry

Table 5 shows the four cases achieving low productivity from IT investment in the service industry from the analysis. However, (b), (c), and (e) do not look reliable due to their small number of classified elements. Therefore, as shown in case of (d), it is concluded that the company with a CIO position but no E-learning Systems achieves low productivity from its IT investment in the service industry.

In summary, in the manufacturing industry, companies with less capital (less than 5,000 USD) and without CIO achieve high productivity. In contrast, those with less capital but with CIO, adopting neither Electronic Tendering Systems (ETS) nor Product Lifecycle Management (PLM), achieve low productivity from IT investment. These findings from the manufacturing industry somewhat illustrate the relationship between the company size and the role of CIO. When company size is relatively small, the role of CIO seems to be diminished. Also, investment in ETS and PLM adoption in small manufacturing companies did not work as expected

In the service industry, the role of CIO also turned out to be relatively small in the small company (less than 22,000 USD). Also, E-learning Systems and B2BI Systems for small companies in the service industry does not guarantee efficiency. The most interesting finding in the analysis is that of the role of E-learning Systems in the service industry in general. As discussed earlier, in the service industry, companies with a CIO position but no E-learning Systems achieve low productivity from their IT investment. This finding suggests that CIO in the service company must drive top management into the adoption of E-learning Systems for the organization members to avoid low productivity from IT investment.

Discussion

It is important for managers to assess the impact of IT investments on the firm. It is necessary to decide appropriate measurements for evaluating the value of IT investments. Many previous studies have found that both upper and lower thresholds exist in relation to IT investment (Hitt and Brynjolfsson, 1996; Osei-Bryson and Ko, 2003). The level of investment in IT stock for a firm must exist between upper and lower thresholds. When the level exceeds the upper or falls below the lower threshold, a productivity paradox may appear. This means that a firms' optimal proportion of IT stock always exists between two thresholds, which are vertical. From the analysis of this study, we found that small businesses are more likely to be vulnerable to the productivity paradox than larger businesses. Top management of small businesses needs to take a cautious attitude when they consider a new IT investment. Otherwise, the expected strategic effects might not be achieved, resulting in a big loss.

This study also explored horizontal thresholds. It was found that there exist differences, to some degree, in terms of IT roles for productivity between manufacturing and service sectors. We used a data mining method, Weka, and explored the differences between the two sectors, but did not find answers to why the differences occur. Investigating these differences in more detail will be our next research goal.

This study has several limitations. We only used a cross-sectional sample for analysis. There is always some lead time when an IT investment project is performed, but the analysis in this study did not consider this time gap. A time-series analysis is suggested for future studies. In addition, the sample size of the service industry was relatively small; this should be increased in order to obtain more reliable findings. Finally, Weka does not show any causality between variables. Thus, we must exclude existing causalities between variables that we found during the analysis.

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Appendix A. The definition of Systems/IT Policies

No	Classification of e-business system
1	**ETS: Electronic Tendering System -** downloading and uploading electronic tender documents via the Internet (Chua et al. 2004)
2	**ERP: Enterprise Resource Planning -** business software packages that impose standardized procedures on the input, use and dissemination of data across an organization, and integrate business processes and associated work flows (Wanga et al. 2007)
3	**CRM: Customer Relation Management -** manage relationships with customers, including the capture, storage and analysis of customer, vendor, partner, and internal process information (Wikipedia 2008b)
4	**KMS: Knowledge Management System -** class of information systems applied to managing organizational knowledge (Alavi and Leidner 2001)
5	**EAI: Enterprise Application Integration -** allows diverse systems to connect with one another quickly to share data, communications, and processes, alleviating the information silos that plague many businesses (Gable 2002)
6	**SCM: Supply Chain Management -** a group of information systems working together in an inter-organizational environment, supports business partners to carry out their operations and decision making (Caldelas-Lopez et al. 2007)
7	**B2BI: Business to Business integration -** key elements of successful B2B integration and collaborative e-commerce by highlighting business needs, technologies and development strategies (Ratnasingam 2002)
8	**PLM : Product Lifecycle Management -** : set of tools and technologies that provide a shared platform for collaboration among product stakeholders and streamlines the flow of information (Ameri and Dutta 2005)
9	**HRMS : Human Resource Management System -** shape an intersection in between human resource management (HRM) and information technology (Wikipedia 2008c)
10	**E-Learning -** technologies and associated methodologies in learning using networked and/or multimedia technologies (Wikipedia 2008a)
11	**SEM : Strategic Enterprise Management -** tools designed to enable advanced cost management, profitability analysis, and performance measurement capabilities (Brignall and Ballantine 2004)
12	**ERM : Enterprise Risk Management -** a process designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives (Liebenberg and Hoyt 2003)
13	**BPM : Business Process Management -** methods, techniques, and tools to support the design, enactment, management, and analysis of operational business processes (Aalst et al. 2003)
14	**EDM : Electronic Document Management –** a set of applications offers a level of control over information flow within the construction process, whether documents are in hard copy or in electronic format (Finch et al. 1996)