Small Business Economics (2006) 26: 241–256
DOI 10.1007/s11187-005-0215-9

Adoption of Enterprise Application Software and Firm Performance

Ilsoon Shin

ABSTRACT. Due to the rapidly changing business and IT environments, firm-level adoption of IT shifted from in-house development to purchasing EA software. This paper analyzes the effects of EA (Enterprise Application) software – ERP, CRM, SCM, Groupware, KM, EAI – on SMEs' productivity. The distinct feature of this paper is that I use a formal econometric approach with combined data of SMEs' accounting and IT usage aspects, while case studies have been mostly used in the previous works. The empirical results show that Groupware and SCM significantly raise the SMEs' productivity, and the manufacturing sector has stronger effects than the service sector. From these results, the following implications are derived. First, the adoption rate and the real benefits of EA software are not closely related domestically. Second, in SMEs, EA software facilitating the inter-firm relationship is more effective than EA software focusing on the internal efficiency. Third, easy-to-understand, and relatively long-experienced enterprise applications are more effective than hard-to-understand and brand-new applications. Finally, the government IT policy on SMEs should focus on the process coordination and standardization of the manufacturing sector with upstream and downstream firms.

KEY WORDS: SMEs, Enterprise Application Software, ERP, CRM, productivity

JEL CLASSIFICATION: D21, D24

1. Introduction

As for the drivers of rapid transformation of recent global economy, Information Technology (IT) and the Internet are two major sources that have been commonly focused on (Acs et al., 2002). The IT and the Internet have such noble characteristics as sharp decline in the prices of information processing, rapid growth in computing power and new development in networked organization. From early days of IT development, business organizations have been actively adopting such technologies to improve their competitiveness and strategic advantages.

Following this global trend, the domestic IT investment in business organizations has increased rapidly. According to Bank of Korea (2000), the growth rate of IT investment was less than 10% in the first half of 1990s, but it reached 60% in 1999. Consequently, the proportion of IT investment in the total equipment investment has increased from 10% in the first half of 1990s to 30% in the second half of 1990s. Korean government has also made great endeavors to rapidly deploy a solid IT infrastructure. As a result, Korea has become one of the world's most connected countries[1] and recorded as a number one country in the broadband Internet access[2].

Ever since IT became an important factor to determine competitiveness and strategic advantages of businesses, domestic SMEs have faced both opportunities and challenges. The Internet have been told as a "great equalizer", allowing the smallest of businesses to access markets and have a presence that allows them to compete against the giants of their industry[3]. Since SMEs take a large share of Korean economy like other countries, the opportunities seem to be wide. In 1999, the portion of SMEs in total establishments was 99.2%, 73% of total labor force was employed in SMEs, and their amounts of shipment made up 47.4% of total shipments. However, the utilization and application of IT

Final version accepted on January 5, 2005

School of Economics
Inha University
253, Yonghyun-Dong
Nam-Gu, Incheon
402-751, Korea
E-mail: ishin@inha.ac.kr.

among SMEs have been low. This is attributable to a weak infrastructure for IT diffusion, which includes diverse standardization, weak logistic support and legal structure. Also, low transparency in accounting systems and unrecorded transactions are additional behavioral obstacles to the widespread usage of IT in the SMEs[4].

Meanwhile, enterprise information system strategies have undergone a profound change to minimize the custom-built system and to include advanced and standard business processes. This is so-called 'Enterprise Application (EA) Software' approach, implying that firms purchase application software from outside vendors, rather than develop their information system in-house. As this trend continues, the brand and marketing power of EA software vendors and consulting firms become more important factor. Often, EA software is provided by combined efforts of EA vendors and consulting firms, and in most cases, the share of consulting firms is larger than EA vendors. For example, the majority (up to 60%) of ERP project cost is devoted to setup, installation and customization of the software, services typically provided by outside consultants (Dolmetsch et al., 1998; Oesterle, et al. 2000)[5].

In this situation, IT vendors and consulting firms argue that it is necessary for enterprises to adopt EA software, especially for SMEs to survive in globalized economic environments. Domestic government policy also reflects this proposition. In Korea, SMEs building ERP system receive investment tax credit up to 10% of total investment amount by Article 24 of the "Act on the Limitation of Tax Preference". Besides, government supports sectoral ERP template development for SMEs' easy deployment of ERP without much modification. There are also several discussions on similar investment tax credit on CRM and SCM adoption in SMEs.

In these domestic circumstances, therefore, it is very important to analyze whether EA software has real effects on business performance in SMEs and what effects, if any. If EA software affects firm performance positively, the efforts of EA software vendors and consulting firms are rationalized, and the government should take the action to boost the adoption of EA software in private sector. Otherwise, we need to study which factors underlie the negative effects of EA software and how to remedy such negatives.

Despite the importance of analyzing the effects of EA software, most previous studies on the benefits of EA have been in the form of individual case studies, and focused on ERP (e.g., Cotteleer et al. 1998; Dolmetsch, et al., 1998; Gibson et al., 1999; McAfee, 1999; Westerman et al., 1999). While case studies offer concrete and meaningful lessons for implementation strategies based on other firms' experience, it may not give a clue for economy-wide effects. With case studies, the comparable results across various EA may not be produced since each EA needs different performance metrics.

In this paper, I study the economy-wide productivity and business performance effects of several EA software using a survey data on SMEs' IT system combined with their financial data. My goal is to better understand the economics of EA software implementations specifically, and more broadly, contribute to the understanding of the differing effect of individual EA software and the reason of this difference. Using a simple but comparable metric such as TFP (Total Factor Productivity), the difference in business performance of various EAs can be tackled. Since this study deals with SMEs in Korea, international variance may apply.

This paper proceeds as follows. In Section 2, I will discuss the research design of this paper. Section 3 describes the data used in this analysis. The basic model and results are presented in Section 4. Section 5 concludes.

2. Research design

In this section, the production function-based econometric model is explained and compared with the case study approach. In doing so, I point out relative merits and drawbacks of this approach.

Figure 1 depicts the case study approach for the business effects of EAs. When specific EA software is picked, its adoption processes are described. Then the firm specific factors, for example, general features such as firm size, industry type, and product type as well as particular features such as adoption strategy, business strategy and goal are described. After that,

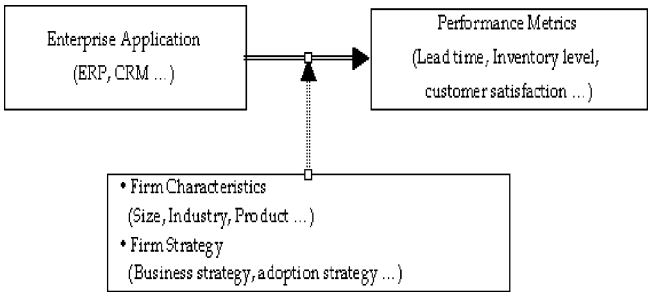

Figure 1. Case Study for Business effects of EAs.

improvements of performance metrics, such as the lead-time, inventory level, or customer satisfaction, are presented. Finally, key success factors or reasons for failure are analyzed.

The case study approach has certain merit in that it can guide concrete implementation strategies based on a specific firm's experience, thus suits well for analyzing an individual firm's experience and extracting lessons from that. However, the case study approach has a generic shortcoming that it may ignore the mixed effects of EA with other features of a business organization in a definite form. The other shortcoming is that it is based on anecdotal studies, thus hard to grasp the economy-wide effects of EA. In addition, the proper metrics may differ according to each EA system of interests. Thus, when one is interested in the economy-wide effects of EA, and wants to compare the differing effects, the case study approach has a limitation. In this case, one can think of another model for business effects of EAs.

Figure 2 shows the production function-based econometric model for business effects of EAs. Like an ordinary production function approach, it assumes that each firm produces through inputs such as labor, physical capital stock and IT capital stock. The EA effects can be analyzed through inserting specific EA application into this otherwise standard production function. Industry and time dummies are usually included to control the sectoral differences. When we specify the estimation equation for this, firm-level data are used to estimate the production function parameters, and relative TFP (Total Factor Productivity) of adopting firms can be calculated.

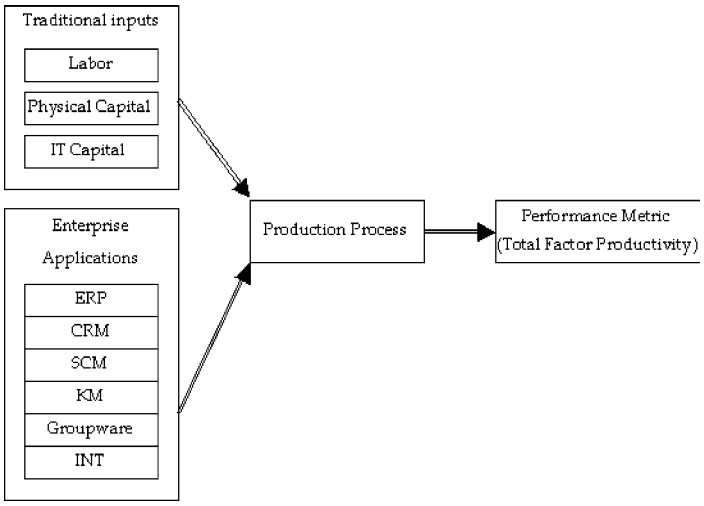

Figure 2. Production function-based econometric Model for Business effects of EAs.

Note that this is not based on an individual firm, but based on many firms, thus the parameters can be interpreted as economy-wide effects. Especially, since this approach can be used without further modification across EAs, we can compare the differing effects of each EA.

However, the production function approach has also several drawbacks. First, the formulation can overly simplify various production processes. Some firms rely heavily on intangible assets such as know-how, organizational features, while other firms' production are based on the physical, tangible input-output relationship. Second, the input variable should be measurable with a comparable scale. Labor force and capital stocks quite suits for this, while EA software does not. Thus, the minimal variable for EA may be whether the firm adopts the specific EA or not. However, since EA has various forms according to firm-size, industry type, and so forth, it still has some problems.

In this study, I choose whether or not a firm adopts specific EA software as an EA variable. The consistency needed for this variable is handled through surveying process as much as possible. In this way, the actual utilization is modeled as an endogenous variable which is determined in the specific firm's production process.

3. Data description

Data used in this study matches two sources of SME level data: a cross-sectional survey of organizational IT investment and adoption of EA Software[6] with KIS-VALUE measures of production function inputs and outputs over 2000–2001 period. The cross sectional survey was conducted in 2002. Once firms with any missing data are removed, the remaining number of firms is approximately 525 domestic SMEs in the sample. Here I briefly describe each data source and measures of key variables.

3.1. *Data source: IT stock and EA Software*

I surveyed IT department managers in 2002. The main questions were on the IT infrastructure and usage. Especially, the firm-level amount of IT investment and adoptions of various EA software packages in 2000 and 2001 were major questions related to this study. I used telephone/fax survey to gather data rather than doing individual interviews. Six EA software packages were considered in this study, that is, ERP (Enterprise Resources Planning), CRM (Customer Relation Management), SCM (Supply Chain Management), KM (Knowledge Management), GW (Groupware) and EAI (Enterprise Application Integration).

There was some concern that EA systems, especially in SMEs, vary so much in size and complexity. To avoid such variation as much as possible, respondents of the survey were provided the following guidance. First, a short description of each EA was provided, and both major foreign and domestic EA vendors were exemplified.[7] Second, respondents were guided to write down only individually "purchased" software and not to write down pilot project.[8] Short definitions, variable names used in formulas, data sources and descriptive statistics can be found in Tables I and II.

The universe of potential respondents was limited to the "statutory audited" firms that reported input and output data on KIS-VALUE.[9] Among 5,200 such firms, I selected SMEs of which the number of employees was less than 300. Next, I narrowed down using the "stratified random sampling method" according to the KSIC (Korean Standard Industry Classification). This yielded a total population of around 1,000 firms, which were contacted by e-mail, telephone and fax to yield 525 survey responses. Approximately 55% of the observations are from manufacturing firms and 45% are in services.

IT stock is converted from IT investment using the following formula. Since the survey covers only two years of IT investments, special assumptions for the calculation of firm-level IT capital stock are required. I assume the followings: first, the growth rates of IT capital stock is constant, and second, the growth rates of IT capital stock is the same as that of the total capital stock. Under these assumptions, the following IT capital accumulation equations are derived.

$$\mathrm{IK}_{t+1} = (1+g)\mathrm{IK}_t = (1-\delta)\mathrm{IK}_t + \mathrm{II}_t, \tag{1}$$

$$\mathrm{IK}_t = \frac{1}{g+\delta}\ \mathrm{II}_t. \tag{2}$$

Here, IK and II denote IT capital stock and IT investment, g is the growth rates of IT capital stock and δ is the depredication rates of IT stock. For ths value of IT depreciation rates, I set it to be 22.4% as in Shin (2000).

3.2. *Data source: value added and other inputs*

I used KIS-VALUE firm data to calculate employment levels, labor expense, sales, capital, and value added. I also used this data to assign firms to KSIC code industry. Firm-level value added is measured by adding up ordinary income, employment cost, net interest expenses, rent, taxes and dues and depreciation. Non-IT capital stock is measured by total tangible assets less IT capital stock, of which calculation is described before. Table I and II provides variable names and descriptive statistics.

Some firms provided only partial data or were missing data from KIS-VALUE, reducing the sample size for many of the analyses below. Empirical analyses are primarily based on the common sample that has complete data for the core measures. This includes a total of 637 firm-year of data.

3.3. *Adoption of Enterprise Application Software in Korean SMEs*

With the dataset described above, the general features of EA software adoption can be derived by the basic statistics (See Table III). First, we can see the difference of adoption rates in EA software packages. Table III shows that domestic SMEs have adopted Groupware and ERP relatively more than other EA software that I considered. The adoption rates are 25.2% and 28.5%, respectively. The high adoption rate for Groupware may reflect the fact that it is introduced earlier and cheaper than others. The wide adoption of ERP may be caused by the government policies described earlier. Compared to these, the adoption rates of the other EA software are around or below 10% (See the bottom of Table III).

TABLE I
Data description

Variables	Definition	Methods	Source
V	Value added	Value Added = Ordinary income + Employment cost + Net interest expenses + Rent + Taxes and dues + Depreciation	KIS-VALUE
K	Capital stock	Total tangible assets	KIS-VALUE
IK	IT capital stock	IK(85) = II(85)/(g+d) IK(t) = II(t) + (1-d)IK(t-1) where g is average growth rates of II, d is depreciation rate of IK, which is assumed as 22.4%	Survey
NK	Non-IT capital stock	Total tangible assets - IK	Survey KIS-VALUE
L	Labor	Employment cost	KIS-VALUE
ERP	Enterprise resources planning	ERP = 1, if the firm adopts ERP ERP = 0, otherwise	Survey
CRM	Customer relation management	CRM = 1, if the firm adopts CRM CRM = 0, otherwise	Survey
SCM	Supply chain management	SCM = 1, if the firm adopts SCM SCM = 0, otherwise	Survey
KM	Knowledge management	KM = 1, if the firm adopts KMS KM = 0, otherwise	Survey
GW	Groupware	GW = 1, if the firm adopts GW GW = 0, otherwise	Survey
EAI	Integration software	EAI = 1, if the firm adopts EAI EAI = 0, otherwise	Survey

TABLE II
Summary statistics (unit: million won)

Variables	Number of observation	Minimum	Maximum	Average	Standard Deviation
V	637	−61537.4	340,220.2	6,740.6	19,810.2
L	637	0.0	77,854.8	2,041.7	4,773.2
IK	637	0.0	43,152.9	1,016.3	3,462.3
NK	637	0.9	30,58,635.8	29,804.7	16,6282.5
II	637	0.2	10,000.0	253.4	846.7

Furthermore, the adoption distribution by industry and firm size is also indicated in Table 3. It is shown that the adoption rates of all the EA software considered in this table increase exponentially with the firm size. For example, the adoption rate of ERP among firms of less-than-30 employees is only 13.2%. It increases to 19.2% among firms of 30–100 employees, 40.6% among firms of 100–300 employees. From this, we can see that the firm size should be above some critical point to rationalize the initial fixed cost of EA software.

Table 3 also reveals the characteristics of adoption distribution by industry. First, Groupware is distributed relatively evenly among sectors, but there is a sector (chemicals and petroleum) which shows an exceptionally high adoption rate. Second, the adoption rate for ERP is higher in the manufacturing sector, especially in chemicals and petroleum (38.9%), electronic and other electronic equipment (45.2%) and motor vehicle and transportation equipment (49.5%). Third, contrary to ERP, service sectors show higher adoption rate for CRM, such as in hotels and restaurants (25.6%), transportation and communications (19.6%), financial institution and business services (21.4%). Forth, SCM is adopted in the sectors of which either upstream or downstream product flows are related to large-sized firms. For examples, chemicals and petroleum, motor vehicle and transportation equipment, transportation and communications record 11–14% adoption rates. Finally, SMEs are very slow in adopting KM and EAI.

4. Effects of enterprise applications on SMEs' productivity

4.1. *Basic model*

Since this paper focuses on organizational productivity and the use of EA software, these two factors should be modeled respectively. First, I need to model the production function to calculate the firm-level productivity. For this purpose, I assume that each firm produced according to the baseline production technology as described in equation (3). Notice that the information capital stock is augmented to otherwise standard Cobb-Douglass production function. It is the most commonly used functional form for the production function, which has the advantages of both simplicity and empirical robustness for the calculation of firm performance (see Brynjolfsson and Hitt, 1996 for a discussion of this formulation; Varian, 1990 discusses general properties of production functions).

$$V_{it} = A_{it} \exp(\sum \alpha_j D_j) L_{it}^{\beta_1} \mathrm{IK}_{it}^{\beta_2} \mathrm{NK}_{it}^{\beta_3}. \quad (3)$$

Here, V is value added, and A is firm-level Solow Residual (Total Factor Productivity), IK is information technology capital stock, NK is traditional non-information technology capital stock, and L is labor input. D's are time and industry dummy variables. The subscript i, t are representing firm and time. When we take logarithm in both sides of (3), the equation becomes additive form.

Next, I insert two additional terms in (3) to analyze the EA software effects on firm-level productivity. Those terms are γ_1 and γ_2 (log IK · EA). The first term is inserted because it captures

TABLE III
SMEs' Adoption Rates of EA Software by Industry and by Firm-size

		GW	ERP	CRM	SCM	KM	EAI	Total Number of Firms
By industry	Agriculture, forestry, fishing, and mining	16.7%	–	–	–	–	–	6
	Food, tobacco, textile, and apparel	13.9%	25.0%	2.8%	8.3%	–	2.8%	36
	Lumber, wood, paper and printing	20.0%	20.0%	–	–	–	10.0%	10
	Chemicals and petroleum	44.4%	38.9%	5.6%	11.1%	11.1%	-	18
	Primary and fabricated metal, Instruments	14.5%	22.6%	3.2%	1.6%	1.6%	1.6%	62
	Electronics and other electronic equipment	30.6%	45.2%	4.8%	4.8%	1.6%	3.2%	62
	Motor Vehicle, Transportation equipment and other manufacturing	30.1%	49.5%	10.8%	14.0%	8.6%	9.7%	93
	Electric, gas, sanitary services and construction	19.4%	19.4%	8.3%	11.1%		2.8%	36
	Wholesale and Retail trade	27.3%	18.2%	15.9%	6.8%	6.8%	6.8%	44
	Hotels, other lodging and Restaurants	28.9%	14.4%	25.6%	7.8%	12.2%	5.6%	90
	Transportation and communication	21.7%	26.1%	19.6%	13.0%	10.9%	4.3%	46
	Financial institution, Insurance and business services	14.3%	14.3%	21.4%		7.1%	7.1%	14
	Public and personal services	14.3%	4.8%	9.5%				21
By Firm-size	Less than 30 employees	10.5%	13.2%	9.2%	3.9%	2.6%	2.6%	76
	30–100 employees	15.7%	19.2%	11.1%	5.6%	2.5%	5.6%	198
	100–300 employees	37.3%	40.6%	14.1%	11.2%	7.6%	7.6%	249
	Total	25.2%	28.5%	12.2%	8.0%	4.9%	6.1%	525

TABLE IV
EA Software and firm-level productivity of SMEs: Regression Results

Variables	Baseline	ERP		CRM		SCM	
Constant	1.6445***	1.6575***	1.6750***	1.6368***	1.6822***	1.6748***	1.9951***
	(3.52)	(3.52)	(3.54)	(3.48)	(3.54)	(3.52)	(4.12)
IK	0.0269	0.0259	0.0245	0.0272	0.0268	0.0267	0.0187
	(1.57)	(1.46)	(1.36)	(1.57)	(1.56)	(1.55)	(1.07)
NK	0.0971***	0.0972***	0.0972***	0.0973***	0.0963***	0.0964***	0.0906***
	(4.65)	(4.65)	(4.65)	(4.64)	(4.59)	(4.59)	(4.32)
L	0.8277***	0.8273***	0.8270***	0.8280***	0.8258***	0.8264***	0.8135***
	(22.88)	(22.84)	(22.83)	(22.85)	(22.68)	(22.72)	(22.35)
ERP		0.0178			0.0741		
		(0.24)			(0.46)		
IKERP			0.0026			0.0043	
(logIK × ERP)			(0.44)			(0.35)	
CRM				−0.0161			0.1997***
				(0.16)			(2.62)
IKCRM							
(logIK × CRM)							
SCM							
IKSCM							
(logIK × SCM)							
DM	0.0648	0.0611	0.0583	0.0627	0.0626	0.0632	0.0555
	(0.98)	(0.90)	(0.86)	(0.93)	(0.95)	(0.96)	(0.85)
DT	−0.0493	−0.0498	−0.0502	−0.0492	−0.0501	−0.0498	−0.0540
	(0.77)	(0.78)	(0.78)	(0.77)	(0.78)	(0.78)	(0.85)
Adj R^2	0.5987	0.5981	0.5982	0.5981	0.5982	0.5982	0.6024
Obs	637	637	637	637	637	637	637

Variables	KM		GW		EAI	
Constant	2.0917***	1.6428***	1.6462***	1.6546***	1.8291***	1.8573***
	(4.25)	(3.51)	(3.52)	(3.51)	(3.92)	(3.97)
IK	0.0143	0.0267	0.0265	0.0265	0.0196	0.0174
	(0.81)	(1.55)	(1.54)	(1.52)	(1.14)	(1.01)
NK	0.0896***	0.0968***	0.0968***	0.0969***	0.0957***	0.0955***
	(4.27)	(4.63)	(4.63)	(4.62)	(4.62)	(4.61)
L	0.8111***	0.8281***	0.8280***	0.8273***	0.8203***	0.8202***
	(22.24)	(22.86)	(22.86)	(22.82)	(22.82)	(22.82)
ERP						
IKERP						
(logIK × ERP)						
CRM						
IKCRM	***0.0167******			0.0013		
(logIK × CRM)	***(2.79)***			(0.16)		
SCM		0.0465			0.3893***	
		(0.33)			(3.37)	
IKSCM			0.0034			0.0295***
(logIK × SCM)			(0.29)			(3.39)
DM	0.0563	0.0666	0.0663	0.0669	0.0613	0.0619
	(0.86)	(1.01)	(1.00)	(1.00)	(0.94)	(0.95)
DT	−0.0534	−0.0498	−0.0497	−0.0493	−0.0547	−0.0534
	(0.84)	(0.78)	(0.78)	(0.77)	(0.86)	(0.84)
Adj R^2	0.603	0.5981	0.5981	0.5981	0.6052	0.6053
Obs	637	637	637	637	637	637

Note: *$p < 0.1$, **$p < 0.05$, *** $p < 0.01$, Numbers in parentheses are T-value.

the EA software's effect on firm-level productivity when other things being equal. Besides, EA software can affect productivity indirectly through its impact on IT capital stock. For example, when an enterprise introduces an ERP system, it may increase the existing IT capital stock's (e.g., PCs, servers) utilization, resulting more productivity pick-up. This indirect effect is reflected in the second term.

$$\log V_{it} = \log A_{it} + \sum \alpha_j D_j + \beta_1 \log L_{it} + \beta_2 \log \mathrm{IK}_{it} + \beta_3 \log \mathrm{NK}_{it} + \gamma_1 \mathrm{EA}_{it} + \gamma_2 (\log \mathrm{IK}_{it} \cdot \mathrm{EA}_{it}) + \varepsilon_{it}. \quad (4)$$

In equation (4), EA represents the dummy variable which is equal to 1 if a firm adopts the relevant EA software, and to 0 otherwise. By the way, the coefficient γ_1 and γ_2 in equation (4) are the same as the coefficients when the TFP is regressed on EA as in the equation (5).

$$\log(\mathrm{TFP}_{it}) = \gamma_0 + \gamma_1 \mathrm{EA}_{it} + \gamma_2 (\log \mathrm{IK}_{it} \cdot \mathrm{EA}_{it}) + \omega_{it}. \quad (5)$$

Here, the TFP is defined as in (6), using the estimates in the equation (3).

$$\log(\mathrm{TFP}_{it}) \equiv \log V_{it} - [\sum \hat{\alpha}_j D_j + \hat{\beta}_1 \log L_{it} + \hat{\beta}_2 \log \mathrm{IK}_{it} + \hat{\beta}_3 \log \mathrm{NK}_{it}]. \quad (6)$$

In equation (6), $\hat{\beta}$ means the estimate of β Since the variable EA is a dummy variable, we can rearrange equation (5) to represent the difference of the TFP between an adopting firm and a non-adopting firm. When TFP_1, TFP_0 denote the TFP of an EA adopter and a non-adopter, the following equation is satisfied on average.

$$\log \left(\frac{\mathrm{TFP}^1}{\mathrm{TFP}^0} \right) = \hat{\gamma}_1 + \hat{\gamma}_2 \log \bar{IK}. \quad (7)$$

Here, $\bar{\mathrm{IK}}$ is the mean value of IK. The first term in equation (7) denotes the direct productivity effect of EA software, while the second term means the indirect contribution from EA software via the interaction with existing IT capital stock.

4.2. *Results*

Table IV reports the results using the regression formulation described in equation (3) and (4). The firm-level value-added is regressed on production input variables and an indicator variable of each EA software (ERP, CRM, SCM, KM, GW and EAI) adoption respectively, controlling for industry and time using dummy variables. Each column of Table IV shows the result of different EA software measure regressions with the baseline regression in the first column.

As shown in the baseline regression, the traditional capital stock has the output elasticity more than three times larger than that of IT capital stock, and 82% of domestic SMEs' value added is contributed by labor inputs. Coefficients on dummy variables show that SMEs' value added is about 6% higher in manufacturing sector, and about 5% higher in 2001. From the estimated output elasticity, we can calculate the rate of return of IT stock and non-IT stock by the following equations (8a–b).

$$\frac{\partial V_{it}}{\partial \mathrm{IK}_{it}} = \beta_2 \frac{V_{it}}{\mathrm{IK}_{it}}, \quad (8a)$$

$$\frac{\partial V_{it}}{\partial \mathrm{NK}_{it}} = \beta_3 \frac{V_{it}}{\mathrm{NK}_{it}}. \quad (8b)$$

Using this formula, we can see that IT stock has a 17.9% of rate of return, and non-IT stock 2.2%, which indicates 15.7% excess return of IT stock.[10]

Looking at the other columns in Table 4 shows that existing coefficient estimates are not significantly affected by the inclusion of EA adoption variables. When we see the newly introduced variables, the most interesting result is that only GroupWare and SCM are significantly affecting the SMEs' productivity. The others (ERP, CRM, KM, EAI) have insignifi-

TABLE V
Direct and Indirect productivity effects of EA software

Enterprise Application	**Direct Effect** of EA software (Relative increment in TFP of adopters to non-adopters)	**Indirect Effect** of EA software (Relative increment in TFP of adopters to non-adopters)
ERP	1.78%	1.80%
CRM	−1.61%	0.90%
SCM	38.93%	20.43%
KM	7.41%	2.98%
Groupware	19.97%	11.56%
EAI	4.65%	2.35%

cant, even negative, effects on firm-level productivity. Thus, domestic SMEs are benefiting from only a few EA software rather than all EAs under consideration. Furthermore, it is quite surprising that the most widespread EA, ERP, has insignificant effects on SMEs' productivity. What causes these differing results of individual EA software? Let me explain the results in the followings.

First, previous studies showed that the ERP implementation is hard to have real effects. This is caused by several factors, such as organizational changes associated with ERP, the need for simultaneous process redesign of multiple functional areas within the firm, the need to adapt processes to the capabilities of the software, and the improvement of the human capital within SMEs.[11] SMEs have pros and cons in these respects. They have advantages in the sense that the business function and process are simple and less complicated, implying quite easy adaptation to ERP. On the other hand, ERP implementations often experience significant cost overruns (Koch, 1996) and short-term declines in firm performance (Wah, 2000). Thus, firms must have sufficient levels of resources to withstand the financial strain of ERP implementations. In general, smaller firms are riskier than larger firms because they have more frequent losses (Hayn, 1995) and display greater heterogeneity with respect to liquidity and solvency (Huff et al., 1999).

The result in this study shows that domestic SMEs are still lacking the proper redesign of the business process for ERP to have benefits.[12] Another reason might be that the government policy was started in 2000, thus most SMEs do not have enough time to adjust their organizations and processes to the newly adopted ERP system.

Second, CRM is generally regarded to have real effects in the firms which transact with final consumers, such as telecom, credit card or financial companies. Since these firms are mostly listed in the stock market and large-sized in domestic situation, a small number of SMEs adopting CRM do not enjoy much benefit on productivity. In fact, most domestic SMEs are providers of parts or intermediary inputs, thus they lack the chance of transacting with the final consumers. As providers of intermediary inputs or parts manufacturers, they don't need to analyze consumers' behavior, but need only to be careful about the needs of large companies who demand their products, which could be matched without much help of IT.[13]

Third, KM generally suits for the companies where the knowledge and human capital accumulation levels are extremely high, which is often the case of large firms. Furthermore, KM is not usually set up in an enterprise until formal data managements for production, sales and accounting are established. In addition, SMEs have a relative advantage in communicating the "informal knowledge" due to their simple organization and small size. Those two factors taken together, we can understand that the adoption rate and the real effect of KM are very low.

Fourth, EAI is effective to the companies who have already chunk of complicated information systems. However, those conditions are generally for large firms, not SMEs.

Table V shows the direct and indirect effects of various EA software-adopting firms relative to non-adopting firms using equation (8). Note that both are measured by TFP, and the indirect effects are from the combined effects of EA software with the firm's existing IT stock.

As predicted, the effects of SCM and Groupware are much larger than the other EA software. Especially, the productivity of the

SCM-adopting firms is about 59% larger than that of the non-adopters. This is a huge productivity difference between adopters and non-adopters, but we have to be careful about its interpretation. Above we can see that the adoption of SCM is concentrated in industries like chemicals and petroleum, motor vehicle and transportation equipment, transportation and communications, and in firms with 100–300 employees. Even though I control industry features in the actual estimation by taking dummy variables, there remains certain industry or firm-level characteristics that may underlie this huge difference. On the other hand, the productivity of Groupware-adopting firms is 31% larger than that of non-adopters. We know that the adoption of Groupware is evenly distributed among industries and firm-sizes compared to SCM, thus the remaining industry and firm-size effects are less than SCM.

Another noticeable result is that the relative magnitude of the indirect effect of ERP system is large, while this is not the case in other EA applications. Remember that the indirect effect is from the interaction of ERP with existing IT capital stock. This may happen because ERP supports not a specific business function, but overall business processes and various functions, which cover large stock of existing IT capital.

From these results, I can derive the following implications.

First, even though specific EA software is adopted widely, it may not affect firm performance. For example, ERP and CRM are the first and third widely adopted EA software, but their effects on productivity are insignificant and negative.

Second, from the large SMEs' benefits of the SCM implementation, it may be concluded that EA software facilitating the inter-firm relationship is more effective than EA software just focusing on the adopting firm's own efficiency. Note that many domestic SMEs, especially in the manufacturing sector, produce intermediate goods and parts, and are closely tied with the downstream firms. In this situation, SMEs' firm performance depends not only on their own organization, but also heavily on their relationship with downstream firms. Furthermore, such downstream firms consist of large assembly firms, which usually initiate SCM project with the aim of improving their business performance.

Considering these industry types, there is an important factor for SCM to affect SMEs' performance. While demand information passes on its way from the point of sale to the supplier, distorted and incorrect information leads the suppliers to face a weak correspondence of demand and production pattern, resulting in

TABLE VI
Differing effects between manufacturing and service sectors of EA software

Variables	ERP	CRM	SCM	KM	GW	EAI
Constant	1.6598**	1.5947***	1.5789***	1.6427***	1.7583***	1.6332***
	(3.62)	(3.44)	(3.44)	(3.53)	(3.79)	(3.45)
IK	0.0253	0.0268	0.0231	0.0271	0.0212	0.0268
	(1.43)	(1.55)	(1.34)	(1.57)	(1.22)	(1.56)
NK	0.0975***	0.0986***	0.0967***	0.0962***	0.0925***	0.0975***
	(4.65)	(4.70)	(4.64)	(4.58)	(4.42)	(4.65)
L	0.8269***	0.8330***	0.8215***	0.8268***	0.8195***	0.8291***
	(22.90)	(22.96)	(22.75)	(22.53)	(22.38)	(22.90)
EA	0.0093	−0.0576	0.1982**	0.0300	0.1065	−0.0204
	(0.13)	(0.72)	(2.06)	(0.21)	(1.64)	(0.19)
DMEA	**0.0414**	**0.0893**	**0.0382**	**0.0533**	**0.0480**	**0.0749**
(DM*DERP)	**(0.87)**	**(1.60)**	**(0.68)**	**(0.85)**	**(1.05)**	**(1.26)**
DT	−0.0533	−0.0510	−0.0556	−0.0525	−0.0554	−0.0520
	(0.83)	(0.79)	(0.87)	(0.82)	(0.87)	(0.81)
Adj R2	0.5980	0.5989	0.6013	0.5977	0.6017	0.5980
Obs	634	634	634	634	634	634

exaggerated fluctuation of orders and higher inventory level. This is what is called "Bullwhip Effect" (Lee et al., 1997). Thus the large and significant result from SCM may be caused by the specific industrial organization of SMEs in the Korean situation.

This result has an important implication for the future IT policy to SMEs. That is, government policy in the form of supporting individual SMEs may be less effective than the "value-chain approach", which deals with not only SMEs, but upstream and downstream firms.

Third, easy-to-understand, and relatively long-experienced enterprise applications are more effective than hard-to-understand and brand-new applications. This is indicated by the effectiveness of Groupware and the insignificance of KMS and EAI. KMS and EAI are recently introduced EA software, and may be quite effective to some firms, but largely they could not have real effects in the coming 5—10 years when we judge from the situations of domestic SMEs. This result also has an important implication for future IT related policy to SMEs. That is, if government intends to boost up EA software in SMEs, it should consider user convenience and understanding among other things.

4.3. *Differing effects on manufacturing and service sectors*

In this section, I estimate the differing effects of EA software between manufacturing and service sectors. To do this, we change the regression equation (4) into the following way:

$$\log V_{it} = \log A_{it} + \sum \alpha_j D_j + \beta_1 \log L_{it} + \beta_2 \log IK_{it} + \beta_3 \log NK_{it} + \delta_1 EA_{it} + \delta_2 D_m \cdot EA_{it} + e_{it}. \quad (9)$$

Here D_m is the dummy vaiable denoting the manufacturing sector. According to this equation, ($\delta 1 + \delta 2$) is the direct productivity effect of EA software in the manufacturing sector, while δ_1 is the effect in the service sector.

Table VI presents the results. Overall, I find that most EAs have stronger effects in the manufacturing sector, even though the estimates of the manufacturing dummy (δ_2) are not significant. One interesting point is that this is the case not only for ERP and SCM, of which the adoption rate is higher in the manufacturing sector, but also for CRM of which the adoption rate is higher in the service sector. If we compare the results in Table 4 and 6, we can see that CRM affects positively in manufacturing firms, but negatively in service firms, and the magnitude of negative effects are so large that the overall effect results to be negative.

SMEs in the service sector supply their service to firms and final consumers, while SMEs in the manufacturing sector mostly transact with other upstream and downstream firms. Thus, it is generally acceptable that Business-to-Business transaction heavy sectors are more applicable to EA software than Business-to-Consumer transactions heavy sectors, and the government IT policy on SMEs has to focus on the process coordination and standardization of the manufacturing sector with upstream and downstream firms.

5. Conclusion

Since the early 1990s, many firms around the world have shifted their IT strategy from in-house development to purchasing application software such as ERP, CRM, SCM systems. Following this trend, the Korean government supports the adoption of application software, especially in SMEs. In these circumstances, it is important to analyze whether EA software has real effects on business performance in SMEs and what effects, if any.

This paper analyzes the effects of various enterprise applications on SMEs' productivity. The distinct feature of this paper is the use of a production-based econometric approach with combined data of SMEs' accounting and IT usage, compared to case studies mostly used in the previous works.

The results show that SCM and Groupware significantly raise the SMEs' productivity, and they have stronger effects in the manufacturing

sector than in the service sector. Taken individually, these results are not especially novel, and mostly matched with the previous results from general firms. Most previous case studies indicate that the mere adoption of EA software does not necessarily guarantee the successful performance of business organizations (Dolmetsch et al., 1998; Cotteleer et al., 1998; Swan et al., 1999; Rigby et al., 2002). However, compared to previous studies, this study analyzes the effectiveness of various EAs, especially in the SMEs with the purpose of characterizing the economy-wide effects and comparing individual EA software's effectiveness by a common criterion.

From the results, following implications are derived. First, the adoption rate of EA software and the real benefits are not closely related domestically. Second, in SMEs, EA software facilitating the inter-firm relationship is more effective than EA software focusing on the adopting firm's own efficiency. Third, easy-to-understand, and relatively long-experienced enterprise applications are more effective than hard-to-understand and brand-new applications. Finally, the government policy on SMEs should focus on the process coordination and standardization of the manufacturing sector with upstream and downstream firms, especially in the short-run.

One main shortcoming of this paper is that the dynamic aspects of EA software are not analyzed. The main reason for this is the lack of data. If the time series data on the adoption of EA software were available, richer analysis could be done. It is quite reasonable to think that the real benefits from EA software take place after several years from the adoption time, since the firms' other assets, especially, organizational change, education and business process need to be adjusted subsequently. Future availability of data and times-series methods might help to solve this problem.

Acknowledgement

Comments from the anonymous referees are gratefully acknowledged. All remaining errors are mine.

APPENDIX A: Questionnaire for EA adoption Question: Please check in each row of the following Table.

Enterprise Application[a]	Adopted	Not adopted
ERP (Enterprise Resources Planning)[b]		
CRM (Consumer Relationship Management)[c]		
SCM (Supply Chain Management)[d]		
KM (Knowledge Management)[e]		
Groupware [f]		
INT (Business Application Integration)[g]		

Notes:

[a] All the answers should be based on the "purchased" software. Pilot project are excluded.

[b] ERP (Enterprise Resource Planning) is an industry term for the broad set of activities supported by multi-module application software that helps a manufacturer or other business manage the important parts of its business, including product planning, parts purchasing, maintaining inventories, interacting with suppliers, providing customer service, and tracking orders. Respondents must answer based on the purchase from the foreign vendors such as SAP, Oracle, Peoplesoft, J.D. Edwards, and domestic vendors such as SDS, Duzon, Hinet, Ksystem.

[c] CRM (Customer Relationship Management) system means software, and usually Internet capabilities that help an manage customer relationships in an organized way. Respondents must answer based on the purchase from the foreign vendors such as Siebel, Oracle, Clarify, Peoplesoft, and domestic vendors such as Handysoft, Unibossizentech, Cnmtech, Kongyong Tech.

[d] SCM (Supply Chain Management) is the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. Respondents must answer based on the purchase from the foreign vendors such as i2, Managistics, J.D. Edwards, Aspen, and domestic vendors such as Zionex, Kepix.

[e] KM (Knowledge Management) is the name of a concept in which an enterprise consciously and comprehensively gathers, organizes, shares, and analyzes its knowledge in terms of resources, documents, and people skills. Respondents must answer based on the purchase from the vendors such as Ontheit, Kcube, Wyzsoft, Handysoft, Penta.

[f] INT (Enterprise Application Integration) is a business tools aimed to continue to use legacy applications while adding or migrating to a new set of applications that exploit the Internet, e-commerce, extranet, and other new technologies. Respondents must answer based on the purchase from the vendors such as Itplus, Miracom, Metabuild.

[g] Groupware refers to programs that help people work together collectively while located remotely from each other. Respondents must answer based on the purchase from the vendors such as Lotus (Notes), Action (Coordinator), Campbell (On-time), IBM (Team Focus), Mustang (Brainstorm).

Notes

[1] TIME Asia (2000).
[2] OECD (2001).
[3] Borland (1999).
[4] MIC (2002).
[5] For a typical ERP, project cost breaks down as follows: software licensing (16%), hardware (14%), consulting (60%), training and other internal staff costs (10%). For more detail, see Zhou et al., (2001).
[6] We have to rely on the survey method since the adoption of EA software as well as IT investments/stock of Korean firms is not published by a research company like "Computer Intelligence Info Corp (CII)" in US. For example, CII conducts a telephone survey to inventory specific pieces of IT equipment for firms in the Fortune 1000 (surveying approximately 25,000 sites).
[7] For example, I pointed out in the survey that the response of ERP system adoption must be based on the purchase of foreign vendors such as SAP, Oracle, Peoplesoft, J.D. Edwards, and domestic vendors such as SDS, Duzon, Hinet, Ksystem are exemplified. Survey questionnaire related to EA is presented in the appendix.
[8] Although EAs in SME have various meaning, we may expect there is less variety than expected, since the surveyed firms are not from all the universe of domestic SMEs, but from "statutory audited" SMEs of which asset value is over 7 billion won (about 7 million dollars) as explained in Note 10.
[9] KIS-VALUE reports financial statements of firms listed on the Korean Stock Exchange (KSE), KOSDAQ and statutory audited firms. Data can be acquired from www.kisvalue.com operated by KIS (Korea Information Service). The statutory audited firms are defined as having more than 7 billion won assets and required to report their financial statements to FSS (Financial Supervisory Service) other than firms listed on KSE and KOSDAQ. Since we cannot access smaller firms' financial data, we exclude them.
[10] With firm-level data for a developed country, it is usual to find excess return in IT stock. See Dedrick et al. (2002).
[11] See Zhou et al. (2001). Lucchetti and Sterlacchini (2004) also find that both market-oriented ICTs and production-integrating ICTs are associated with the share of highly educated employees.
[12] Swan et al. (1999) argued that the ERP implementation failure stems from the difference in interests between customer organizations who demand unique business solution and ERP vendors who prefer generic solution. Soh et al. (2000) further suggested that organizational fit of ERP might be worse in Asia, because reference process model underlying most ERP systems is influenced by European and U.S. industry practices, which is different from Asian business practices.
[13] Another possible reason might be the insufficient business changes on SMEs following CRM adoption. A recent research done by the Gartner Research Group in North America found that 55% of all CRM projects fail to produce results (Rigby et al., 2002). Another study by Ernst and Young (2001) of managers who had implemented CRM found that the two biggest challenges in implementing CRM strategies were internal organizational issues (53% of respondents), followed by the ability to access all relevant information (40% of respondents). The evidence suggests that for CRM to be successful, changes are required in the way firms manage customer information internally.

References

Acs, Zoltan J., L. F. de Groot Henri and Peter Nijkamp, 2002, *The Emergence of the Knowledge Economy: A Regional Perspective*, Springer-Verlag.

Bank of Korea, 2000, 'Recent Changes in Equipment Investment', *BOK Monthly Report*, 1–22.

Brynolfsson, E. and L. Hitt, 1996, 'Paradox lost?: Firm-level evidence on the returns to information systems', *Management Science* **42**(4), 541–558.

Cotteleer, M., R. Austin and R. Nolan, 1998, '*Cisco Systems, Inc.: Implementing ERP*', Harvard Business School Case, Report No. 9-699-022.

Dedrick J., V. Gurbaxani and K. L. Kraemer, 2002, 'Information Technology & Economic Performance: Firm and Country Evidence', manuscript, Center for Research on Information Technology and Organizations University of California, Irvine.

Dolmetsch R., T. Huber, E. Fleisch and H. österle 1998, 'Accelerated SAP: 4 case studies', Institute for Information Management, University of St. Gallen, Switzerland.

Ernst and Young (2001), *Eighth annual special report on technology in banking and Financial Services*.

Gibson, N., C. Holland and B. Light, 1999, 'A case study of a fast track SAP R/3 implementation at Guilbert', *International Journal of Electronic Markets* **9**(3), 190-193.

Hayn, C. 1995, 'The information content of losses', *Journal of Accounting and Economics* **20**, 125–153.

Huff, P. L., R. M. Harper, Jr., and A. E. Eikner, 1999, 'Are there differences in liquidity and solvency measures based on company size?', *American Business Review* **17**(2), 96–106.

Koch, C. 1996, 'The integration nightmare: Sounding the Alarm', *CIO Magazine* 6–10.

Lee, H. L., V. Padmanabhan and S. Whang, 1997, 'The bullwhip effect in supply chains', *Sloan Management Review* **38**(3), 93–102.

Lucchetti, Riccardo and Alessandro Sterlacchini 2004, 'The Adoption of ICT among SMEs: Evidence from an Italian Survey', *Small Business Economics* **23**(2), 151–168.

McAfee, A., 1999, 'The impact of enterprise resource planning systems on company Performance', Unpublished presentation at Wharton Electronic Supply Chain Conference.

MIC, 2002, *e-Korea: Vision 2006*, Ministry of Information and Communication Republic of Korea.

OECD, 2001, *The Development of Broadband Access in OECD countries*, www.oecd.org

O'Leary, D., 2000, *Enterprise Resource Planning Systems: Systems, Life Cycle, Electronic Commerce, and Risk*, Cambridge University Press.

österle, H., E. Feisch and R. Alt, 2000, *Business Networking: Shaping Enterprise Relationships on the Internet*. New York: Springer.

PriceWaterhouseCoppers, 1999, *Technology Forecast,* Palo Alto, CA: PriceWaterhouseCoppers.

Rigby, D. K., F. F. Reicheld and P. Schefter 2002, 'Avoid the four perils of CRM', *Harvard Business Review*.

Shin, I., 2000, 'Use of Information Network and Organizational Productivity: Firm-level Evidence in Korea', *Economics of Innovation and New Technology* **9**(5), 447–463.

Soh, C., S. S. Kien and Tay-Yap, 2000, 'Cultural fits and misfits: is ERP a Universal Solution?' *Communications of ACM* **43**(3), 47–51.

Swan, J., C. Newell and M. Robertson 1999, 'The Illusion of 'best practice' in Information System for Operations Management', *European Journal of Information Systems* **8**, 284–293.

TIME Asia, 2000, 'Wired for life overnight', 12–11, 2000.

Varian, H. 1990, *Microeconomic Analysi*s, Cambridge: MIT Press.

Wah, L. 2000, 'Give ERP a Chance', *Management Review* 20–24.

Westerman, G., M. Cotteleer, R. Austin and R. Nolan 1999, '*Tektronix: Implementing ERP*', Harvard Business School Case, Report No. 9-699-043.

Zhou, Xiaoge, Hitt, M. Lorin and D.J. Wu, 2002, 'ERP investment: business impact, productivity measures', *Journal of Management Information Systems* **19**(1), 71–90.