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Economic Impact of the Adoption of Enterprise Resource Planning Systems: A Theoretical Framework

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1. Introduction

According to Deloitte Consulting, Enterprise Resource Planning (ERP) systems are packaged business application software suites that allow an organization to automate and integrate the majority of its business processes, share common data and practices across the entire enterprise, and produce and access information in a real-time environment. The scope of an ERP solution includes financials, human resources, operations logistics, sales and marketing modules (Ragowsky & Somers 2002).

The benefits that ERP brings to organization are multidimensional and include tangible and intangible benefits (Shang & Seddon, 2002). One of the key characteristics of ERP systems is the potential for data and process integration across different units of an organization (Deloitte, 1999; Ross & Vitale, 2000; Markus et al., 2000; Volkoff et al., 2005). Such integration enables real-time decision-making based on ready access to reliable up-to-date information. ERP also allows centralization of data and streamlining of business process. This results in efficiency of business process and reduction in cost (Spathis & Constantinides, 2004). Many studies have shown the benefits of ERPs, ranging from improving productivity (Hitt et al., 2002; Ifinedo & Nahar, 2006), decision support benefits (Holsapple & Sena, 2005) and integration benefits of various information systems (Hsu & Chen, 2004).

According to Huang et al. (2004), ERP generates tremendous amount of information goods, helps create value chain and increases value-added activities by categorizing available information, such as information about customers, suppliers, transactions cost, and the price of unit sold. Information could be categorized according to cost-benefit information with respect to logistic and shipping, marketing, sales and purchasing, and resource allocation, after sale service support, and resource optimization. A few assumptions are requisite. For example, the assumptions of constant returns to scale and perfect competitive in the product market are often imposed in the estimation of input shares. Constant returns to scale refer to the output increases at the same rate as the inputs in the production function. To build up information goods, there involves high level of fixed cost and these cost of productions remain constant in the future. That is to say, all information goods are replicated with zero or very low marginal cost. With information goods in the marketplace, firms with ERP systems are able to gain competitive advantage, a more practical coordination and

interaction between supplier-customer and hence minimize cost and ultimately optimize market efficiency.

In this paper, to further extend the above study, we propose an economic analysis framework of the impact of ERP at the firm level. We will use economic production theory to examine ERP role in this regard. This is important because it extends the understanding of ERP system's impact and this framework can be used as a basis for research.

This paper is organized as follows: Section 2 describes related research in this area, Section 3 presents the conceptual framework, Section 4 provides a brief discussion and Section 5 concludes the chapter.

2. Related works

Many research studies examine the relationship between IT and economic performance or productivity growth. These studies on economic impact are on firm level, sub-plant level, and country level. Productivity is the elementary economic measure of a technology contribution. There has been considerable debate whether information technology (IT) revolution was paying off in higher productivity (Dedrick et al., 2003). However, results are inconclusive. The Nobel Laureate economist Robert Solow said that "we see computers everywhere except in the productivity statistics" (cited in Brynjolfsson, 1993). Prior to 1990s studies found productivity paradox between IT investments and productivity in the U.S. economy. Thereafter, many studies found greater IT investment and revolution observed in higher productivity gains at both firm and country levels. However, there were studies who found IT capital has marginal impact on technical progress (Morrison & Siegel, 1997), and some claimed that IT has insignificant contribution to output growth (Oliner & Sichel, 1994; Loveman, 1988).

Four explanations for this productivity paradox include mis-measurement of outputs and inputs, lag effects as a result of adjustment, relocation and rakishness of profits, and mismanagement of information and technology. According to learning-by-using model, the optimal investment strategy sets marginal benefits lesser than marginal costs in the short run. But firm will only see the impacts after sometime due to lag effect and increasing economies of scale might only be experienced in the long run. Kiley (1999, 2001) argues that adjustment costs have contributed to some negative relationship between IT and productivity and he further argued that adjustment costs have created frictions that cause investment in IT capital to be negatively associated with productivity. Meanwhile Roach (1998) argues that much of the productivity stimulation is due to the secular trend toward service related industries that are caused by rising mis-measurement errors, such as over-allow work flexibility, causing unnecessary longer overtime labor hours claims. Thus, actual labor hours in the IT related industries may not be reflecting the true productivity growth figure.

Some studies have analyzed firm level data and find evidence of significant and positive returns from IT capital investment (e.g., Brynjolfsson & Hitt, 1996; Dewan & Min, 1997). The advantage of the firm level approach is that it gives better measurement of IT contributions to both quality and variety of products that covered at aggregate level. Some others have examined economy level time series data to quantify the contribution of IT toward output growth of a single country, with mixed findings on the contributions of IT.

The above discussion is on IT in general. Now turning to ERP as a specialized area of IT, from the extant literatures, many studies examine the relationship between ERP systems and its economic impact. Research on the impact of ERP can be broadly divided into level of analyses (for example, firm level and sub-plant level) or the different dimensions of impact (for example, financial, operational and managerial). Studies on firm level focus on the effects on the whole organization. These can be financial impacts, or the five classification by Shang & Seddon (2002); namely operational benefits, managerial benefits, strategic benefits, IT infrastructure benefits, and organizational benefits.

Studies on financial impacts of ERP typically measure performance of financial statements (Poston & Grabski, 2001), financial ratios (Hendricks et al., 2007; Hunton et al., 2003; Matolcsy et al., 2005; Poston & Grabski, 2001; Wieder et al., 2006; Wier et al., 2007) and share price of the company (Hendricks et al., 2007; Hitt et al., 2002). These performances are usually compared for a group of companies that adopted ERP against those companies that do not over a period.

Results from these research listed above have consistently indicated that financial performance will be negatively affected in the first two to three years during the ERP implementation and only after two to three years, will the firm see improvements (Hendricks et al., 2007; Hitt et al., 2002; Hunton et al., 2003; Matolcsy et al., 2005; Poston & Grabski, 2001; Wier et al., 2007). From the list above, only one study that seem to contradict the claim that there is no significant differences between adopters and non-adopters (Wieder et al., 2006). However, that study did not account for the time after the ERP implementation has taken place and the small sample size.

Besides the financial impact, it was found that the benefits of implementing ERP systems extend to the operational (Cotteleer & Bendoly, 2006), managerial, strategic and planning and control process integration of supply chain management (Su & Yang, 2010). Managerial, operational and IT infrastructure benefits was observed one year after implementation of ERP (Spathis & Ananiadis, 2005). ERP was also shown to improve the accounting process (Spathis & Constantinides, 2004).

Research into sub-plant level found that the benefits of ERP is more when the sub-units ("business function or location") are more dependent on each other and less when the sub-units are vastly different (Gattiker & Goodhue, 2005). Analysis and research of the impact of ERP at the firm aggregate level has been scarce although there are many similar IT research at this level. Huang's (2004) economic analysis of ERP as information goods generated positive externalities value which will increase as more numbers of suppliers and customers of the firms are interconnected. This has been called the network effect. The authors also argue that although the cost of implementation of ERP is high but the cost supplying information is almost zero once the adoption of ERP system is on.

3. Conceptual framework

The purpose of this section is to explain and justify the conceptual framework proposed by the authors. The framework is based on a synthesis of the economic production theory and network externalities. In other words, the framework classifies economic impact based on a productivity function and the network externalities.

How inputs are transformed to output is commonly illustrated in a production function. As seen in the Section 2 many studies examine the effect of ERP on productivity growth by examining stock prices and profitability. The more recent studies use panel analysis and the longitudinal approach to estimate inputs to Gross Domestic Product (GDP) outputs and its returns from IT investment in the aggregate level. Generally, output growth in firms, sectoral and the country level may be due to an increase in input level, improvement in the quality of input, and productivity growth of inputs. Furthermore, the effect of IT adoption in a neoclassical theory rests on labor productivity and can be explained using capital deepening effects (Stiroh, 1998; Jorgenson & Stiroh, 1999), embodied technological change, and productivity spillovers. Capital deepening refers to the growth of capital (e.g. information processing equipment and software) that workers have available for use in a firm. ERP systems may allow total factor productivity gains since it allows production of improved capital goods at lower prices via some production spillovers or positive externalities effects (see Bresnahan, 1986; Redmond, 1991; Bartelsman et al., 1994).

A positive network externality has been widely used in the study of technology adoption. It is an economic concept describing a consumer's demand may be affected by other people who have purchased the good, and gained the benefit in consumption due to the widespread adoption of physical goods and services. Earlier studies (eg. Jensen, 1982) on internet and e-commerce have shown that people are more likely to adopt certain technology if others within the same industry or region likewise use it. An ERP adopting organization can integrate the ERP system with its suppliers and customers thereby creating an electronic market. The ERP that enables electronic markets comprised of supply and demand networks to facilitate information exchange (Huang et al., 2004). The suppliers and customers may or may not be using ERP systems. However, they can access the information goods generated by the ERP. Thus, ERP in the electronic markets serves as the information processing function to generate and exchange information among suppliers and customers. This electronic transfer of information goods can reduce the cost of paperwork and processing requirements of all the parties involved. Hence, marketable information goods produced by ERP would bring additional profits to organization. Next section, we discuss the production theory and network effects respectively in detail. The proposed framework is depicted in Figure 1 below.

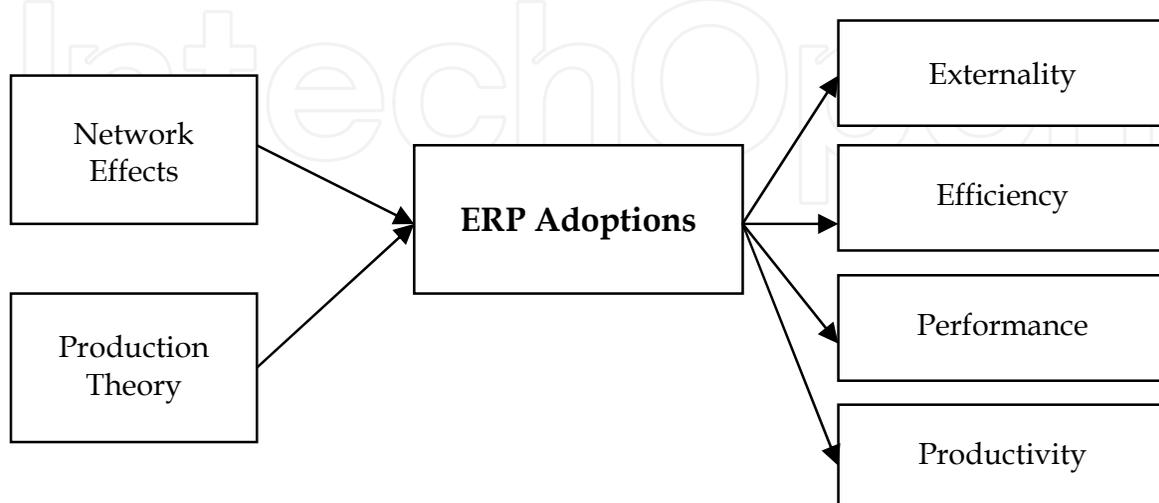


Fig. 1. The proposed framework.

3.1 Network effects

Network effects impact technology choice (Katz & Shapiro, 1994). Network effects arise when there is interdependence between different components of an economic system (Young, 1928). We may ask questions such as how does a change in technology affect the increase in output and will this become an incentive for firms to exploit the increasing returns for adopting this technology (Arthur, 1996). Integrated with e-data interchange, ERP can be used to restructure supply chain operations via B2B e-hubs with supply chain partners to run transactions in real time (Zeng & Pathak, 2003). As more supply-chain partners become integrated with the ERP systems, the entire supply chain can be integrated and streamlined with other functions to be more competitive, reduce the marginal cost of productions, increase the profitability of the organization, and maximize productivity of the firm. To enable electronic markets, internal networks structures are important fundamental economic characteristic.

According to Majumdar and Venkataraman (1998), there are three network effects in the literature. The first is conversion effect, driven by operations-related increasing returns to scale that firms enjoy in converting from one system to another. The second is consumption effect, driven by demand-side increasing returns to scale that it is a firm-level effect that arises where customers are interconnected. The third is an imitative effect that arises when the inter-firm information flows are induced by imitation pressures between firms.

The conversion effect arises when there are increasing returns moving towards the usage of advanced technology. Cost-benefit analysis hypothesizes that inputs affect outputs to determine the identifying statements of organization goal such as maximization revenue, minimize cost, and maximize profits. An initial ERP adoption is likely to involve high cost. There are incentives to convert to the new technologies because of the possibilities of enhancing operating efficiencies. The greater the relative size, the higher the incentive to exploit conversion effects since there are larger numbers of customers and suppliers who provide the means to write-off adoption costs.

Consumption effect exists when there is demand interdependence among customers. This effect is enhanced by the density and composition of customers in the network. When there is high network density and variety of user population in a network, there will be an increase in network functionality. This implies a larger potential market, and therefore brings about higher utility to the customers. Hence, network density and user population are expected to be positive at all times. Meanwhile imitation effect is salient in industries where firms share a common infrastructure, and that many channels are available for dissemination of information between those interconnectivity firms and the nature of equipment. Therefore there are increasing returns to the inter-firm spread of information (Markus, 1992). When managers face a new technology with uncertain trade-offs, imitation provides a solution with low risk (Majumbar & Venkataraman, 1998). Therefore, the imitative effect will have positive effect on the new technology, the ERP system adoption, at all times.

3.2 Impact of network externality on the adoption of ERP

There are many models to test for the presence of network externalities on the adoption of ERP process (Katz & Shapiro, 1986; Farrell & Saloner, 1986; Cabral, 1990). For instance,

Cabral's (1990) model allows for heterogeneity in the benefits available from network dynamic. The benefits from membership upon adoption are $B(h,n,t)$, where n is the measure of adopters at time t , h is a parameter that characterizes a technology (the higher the h for a firm, the higher is the benefit from adopting ERP membership, all other things remain equal), and t is time. The assumption that there are externalities in network participation is captured by $B_n > 0$, $B_h > 0$, and $B_t > 0$. The latter assumption reflects the exogenous trend to increase benefits from adopting the shared network technology, reflecting improvements in the ERP technology itself.

Since information can be reproduced at zero or very low marginal cost, and supply chain network using ERP system can be connected in constant returns to scale, all inventory information can be stored in the system and causing information supply networks to exhibit positive network externalities of production. Market dynamic works in such a way that the supply curve with network externalities of production starts high and decreases toward zero. The impact of network technologies on financial institutions depends on assets, number of employees, and number of branches (Zhu et al., 2004).

Positive network externalities of consumption are a kind of demand side network economics of scale. It is highly dependent on the number of organization already connected to the ERP systems. If there are large numbers of organization connected to ERP systems, the willingness to pay for the marginal organization is also low because every organization that valued it higher has already connected to ERP systems. Therefore, an organization's demand for the information goods depends on the marginal willingness to pay. The reservation price for information goods is determined by the marginal willingness to pay, which at first increases and then decreases with the number of organizations connected to the demand network (Huang et al., 2004). Therefore, the demand curve for information goods with network externalities of consumption is hump-shaped. Hence, for market dynamics, the supply and demand curves with network externalities will intersect only if there is a small number of organization connected to the markets and information good exchange are low, i.e., happen when there is a low equilibrium level (Majumdar & Venkataraman, 1998).

3.3 Economic production theory

Economic evaluation orientation to IT impact ranges from relatively simple cost-benefit analysis (King & Schrems, 1978) to rigorous production function (Kriebel & Raviv, 1980) that mostly focuses on profit of the organization. Mapping major microeconomic production indicates that ERP has been used in operational or management control decisions for production modeling. ERP systems have been used in diverse areas of transaction processing in accounting, finance, marketing and management.

The production function is a commonly use tool in analyzing the process of economic growth and performance of a firm. A production function relates the inputs of the production process. A firm production function uses decisions and firm resources (e.g. labor, raw materials, information, IT capital, non-IT capital, decisions, inventory decision, and etc) as inputs and the attainment of organization goals (eg. profit maximization, sale maximization, revenue maximization, or cost minimization) as output to achieve economic performance outcomes (eg. economic growth, labor productivity, profitability, or overall welfare). A productive firm will generally enjoy higher profitability, or a firm is perceived to

be productive if a firm is able to produce the same output level with fewer inputs and thus experiences a cost advantage, or produces higher quality output with the same level of inputs and enjoys a price premium.

Many scholars have examined the relationship between IT-economic performance or IT-productivity growth. Input productivity is important determinants of economic growth. Productivity is a measure of how efficient resources are converted into goods and services in a production process. It can be calculated as the ratio of output to input. Hence labor productivity is the output produced per unit of labor, and it can be calculated using total output divided by the total unit of labor employed. Labor productivity always means average product of labor or average productivity. Therefore, average productivity (AP) is calculated by output/labor input, and it is often used as a measure of efficiency. When a firm experiences productivity increases, it means that output per unit of labor input has been increased. However, as more and more of one input (eg. labor) is added with a given amount of another input (eg. capital), the increases in output will eventually decline. This is called the law of diminishing returns. Similarly, as worker acquires more capital, there is diminishing return to that capital. If this process continues in a longer period, the growth will gradually slow to zero.

Total factor productivity pertains to the efficiency of the inputs mix to produce output. Efficiency gains could be achieved through more effective distribution arrangements, greater economies of scale, better management, shift from low productivity production to high productivity activities, the adoption of new technology, innovation and intervention, or the replacement of old capital, or retrained the workers that enable greater output production using the same level of input mix. There are generally two factors that affect productivity. The first is human capital and the second is technology. Human capital refers to worker's investment in education and training that could upgrade the skills of the existing labor force and improve the quality of labor force, with more IT literate and more congenial staff, they are able to easily adapting newly installed technologies, and the increase in human capital investment is a major contributor to the long-run economic growth. This is also called the embodied technical progress. Meanwhile, investment in technology involves the way inputs are mixed in the firm, such as innovation and invention of new products, improvements in organize production, advances in management and industrial organization, and better manage economic factors of productions that increase the output level even when the amount of labor and capital are fixed. Adoption of ERP systems can produce all such benefits as identified in extant literatures, such as Shang and Seddon (2002), Huang et al. (2004), and Wieder et al. (2006). This is also called disembodied technical progress. The productivity gain resulting from technological progress seem unlikely to be sustainable over the very long run whenever we reach the point of diminishing returns to the technology investment (Sharp et al., 2006). In terms of ERP systems, it is necessary to upgrade the system quite frequently to keep up with the technological and business changes. Such upgrades require new capital infusions.

3.4 Model

Economic theory shows that the basic way to measure productivity is the standard firm production model that is based on a gross output production function that relates firm gross output to the factors of productions such as capital and labor, intermediate inputs such as

energy and raw materials, and total factor productivity. The simple model of production shows the relationship between inputs and outputs is formalized by a simple production function as:

$$Y_t = f(K_i, L_i, M_i, \dots) \quad (1)$$

where Y represents the firm's output or return on assets (ROA) or return on sales (ROS) (Wagner et al., 2002) during a period, K denotes the capital usage during the period, L represents hours of labor work, M represents raw materials used, and notation represents the possibility of other variables influencing the production process.

The same level of output can be produced with fewer inputs. For example, with a level of capital input of K , it previously took L_2 unit of labors to produce Y_0 , now it takes only L_1 . Output per worker has risen from Y_0/L_2 to Y_0/L_1 . However, it is noteworthy that an increase in capital input to K_2 could also lead to a reduction in labor input to L_1 and produce similar level of Y_0 . If this is the case, output per labor would also rise, but there could have been no technical progress. To measure technical progress we could write in a simple equation as follows:

$$Y = Z(t)f(K, L) \quad (2)$$

where the term $Z(t)$ represents technical progress as a function of time that shows the factors that determine Y other than K (capital hours) and L (labor hours). Technical progress in the Cobb-Douglas production function could be represented by $Y = Z(t)f(K, L) = Z(t)K^\alpha L^{1-\alpha}$, for simplicity, we assume constant returns to scale and that technical progress occurs at a constant exponential mode (θ). We can rewrite the function as: $Y = Z_i(t)f(K, L) = Z_i(e^{\theta t})K^\alpha L^{1-\alpha}$.

Suppose that $Z=10$, $\theta=0.01$, $\alpha=0.5$, and the firm uses input mix of 2 units of capitals and labors each ($K=L=2$) currently (at time $t=0$), therefore output is 20 ($Y_t=10e^{0.01(0)}2^{0.5}2^{0.5}$). After 10 years, the production function with this input mix becomes 22 ($Y_{t+10}=10e^{0.01(10)}2^{0.5}2^{0.5}$). However, if output increases more rapidly than the inputs, given the fixed technology, this would imply that there is an increasing returns to scale. With the adoption of ERP systems, it is believed that technical innovation operates through the positive effects. These positive externalities help to generate increasing returns to scale and drive the firm's performance.

To account for total factor productivity or multifactor productivity, term Z is included in the function. They can be represented in a function as: $Y_t = f(K_i, L_i, M_i, Z_i)$

where Y is real output or ROA or ROS, K is capital, L is hours worked, M is intermediate inputs or raw material used, and Z is a total factor productivity index for firm i .

Generally, we perceive competitive market structure exists in capital and labor, therefore constant return to scale is assumed. We can rewrite the growth rate of real output equals to the growth rates of the capital and labor inputs weighted by their shares in real gross output as follows:

$$\omega(Y_t) = \omega(K_i)W(K_i) + \omega(L_i)W(L_i) + Z_i \quad (3)$$

where $\omega(Y_t)$ is the growth rate of output, ROA or ROS, $\omega(K_i)$ is the growth rate of capital investment (including net depreciation), $\omega(L_i)$ is the growth rate of labor, and $W(K)$ and $W(L)$ are the weighted shares of capital and labor in the firm, respectively. $\omega(K_i)W(K_i)$ is the

growth rate of capital multiplied by the ratio of capital to labor, which we called as marginal product of capital. Similarly $\omega(L_i)W(L_i)$ is the growth rate of labor multiplied by the ratio of labor to capital, which we called as marginal product of labor, and Z_i is the productivity efficiency factor, which is a residual term that is not accounted for by the growth of labor and capital.

Suppose that a firm has a growth rate of output of 5 per cent, the growth rates of capital and labor of 10 and 2 percent, respectively, and the weighted shares of capital and labor are 20 and 80 percent, respectively. Therefore Z_i has to be equaled to 0.014. This reflects that technical progress account for slightly less than 1.5 percent of the output growth of 5 percent.

$$\omega(Y_i) = \omega(K_i)W(K_i) + \omega(L_i)W(L_i) + Z_i$$

$$0.05 = 0.2(0.10) + 0.8(0.02) + Z_i$$

$$Z_i = 0.014$$

Past studies present econometric estimates using Cobb-Douglas production function (e.g. Gera et al., 1999; Brynjolfsson & Hitt, 1996; Lehr & Lichtenberg, 1998), cost function (e.g. Morrison & Siegel, 1997) or panel estimation (e.g. Stiroh, 2001). There are some microeconomic productions properties apply to the Cobb-Douglas production model for ERP systems, assuming a constant elasticity of substitution (CES). The CES production technology exhibits a constant percentage change in factor (e.g. capital and labor) proportions due to a percentage change in marginal rate of technical substitution (MRTS). MRTS is the amount of one input that must be substituted for one unit of another input to maintain a constant level of output. First is marginal productivity. It is the rate of increase of the output for a small increase in the input. The Law of Diminishing Marginal Productivity will set in if the marginal product is positive but diminishing. Second is input substitutability, where inputs will be substituted more of one input and less of another to produce the same level of output. Third, it is assumed that decision making is in steady state (i.e., constant input and output levels, all other parameters remain unchanged).

Alternatively, one can study how different types of capital affect labor productivity growth. This can also be carried out using Cobb-Douglas production function that can explicitly decompose capital into IT-related and non-IT related categories. This can be written using Cobb-Douglas production function in the form of $Y_{it} = f(IT_{it}, K_{it}, L_{it})$. It can be tested for many firms, with $i = 1, 2, \dots, N$ using years of data, in Year $t = 1, 2, \dots, T$. The output production Y_{it} is annual performance of the firm, and the inputs are IT capital stock (IT_{it}), non-IT capital stock (K_{it}) and annual labor hours employed (L_{it}). For example, for a data of 20 firms over the period of 10 years, then $N=20, T=10$. Normally, the regression model will be controlled for firm effect and year specific effect. For the functional form of $f(\cdot)$, we can write the Cobb-Douglas production function at the log form as follows:

$$\log Y_{it} = \alpha + \sigma_t + \beta_{IT} \log IT_{it} + \beta_K \log K_{it} + \beta_L \log L_{it} + V_i + e_{it} \quad (4)$$

where σ_t is a time effect captured by year dummy variables in the regression, V_i is a firm-specific effect invariant over time, and e_{it} is the random error term in the equation, representing the net influence of all unmeasured factors (Dewan & Kraemer, 2000). From this Cobb-Douglas function, the output elasticities of β_{IT} , β_K , and β_L that measure the

increase in output associated with a small increase in the corresponding inputs could be estimated. For example, the output elasticity of IT capital (β_{IT}) shows the average percentage increase in GDP for a 1% increase in IT capital. In other words, it is the output elasticity of IT capital. Other output elasticity parameters with respect to capital and labor have analogous interpretations.

Pooling data from firms increases the variation in the variables, and is therefore crucial to account for firm effects. There are two general models to capture cross-sectional heterogeneity. They are fixed effects and random effects models. Fixed effects approach could be carried out by putting in dummy variables. This is very costly since we can easily lose the degrees of freedom. This makes the random effects model more engaging. However, the random effects model requires the potentially restrictive assumption that the V_i be uncorrelated with the regressors to avoid inconsistency (Greene, 1990).

In practice, it is not easy to get good proxy for capital stock. Among those proxy measures of capital stock in total factor productivity are the rate of R&D investment, and rate of investment in computers and investment in human capital (Siegel, 1997), the number of information systems workers (Brynjolfsson & Hitt, 1996), investment figures to measure the increment to capital (Dowling & Valenzuela, 2004), return on capital employed (Wagner et al., 2002), and inventories reductions to show a higher efficiency of producing and delivering goods (Varian et al., 2002). They have reported that an increase in investment in IT has a positive effect on the productivity performance in a given firm. Meanwhile, indicators commonly used as proxy for human capital include total years of schoolings derived from educational enrolment ratios, international test scores, number of workers with tertiary education (Barro & Lee, 2001), the number of educational years in higher education and the experience of the works (Barros et al., 2011), labor in terms of man-hours, man-years worked, labor cost as a fraction of profit (Dewan and Kraemer, 2000), or construct a series by multiplying the labor series by an index to show rising educational attainment over time, or by introducing a new factor of production, such as education and training, and then measure its contribution to output separately (Dowling & Valenzuela, 2004). Bresnahan et al. (2002) use IT demand, human capital investment and value-added as dependent variables, and they found that IT, organization change and human capital, technological and organization changes are complementary to each other, and these variables can boost up market value of firms.

From the empirical studies, we propose that the output for production function can be measured as follows:

$$Y_t = f(K_i, L_i, H_i, M_i, Z_i) \quad (5)$$

For the functional form of $f(\cdot)$, we can write the Cobb-Douglas production function at the log form as follows:

$$\log Y_{it} = \alpha + \beta_K \log K_{it} + \beta_L \log L_{it} + \beta_H \log H_{it} + \beta_M \log M_{it} + \varphi_{Tt} DT_t + Z_i + e_{it} \quad (6)$$

where subscript i is the i^{th} firm and t is the time period; the output Y_{it} is annual performance of the firm, or output production, or ROA or ROS, and the inputs are physical capital stock (K_i), human capital variables expressed in average number of employees with tertiary education (H_i), annual labor hours employed (L_i), M is

intermediate inputs or raw material used, DT_t is the dummy variable for different years to capture technology change, and the parameter φ_{Tt} can be used to measure technical level over time. The technical progress or the rate of change in technical level can be calculated using $\varphi_{Tt} - \varphi_{Tt-1}$. Z_{it} is the random errors, reflecting total factor productivity for firm, with $Z_{it} \sim N(0, \sigma^2)$ and e_{it} is a non-negative truncated normal random error with the probability distribution of $e_{it} \sim N(\mu, \sigma^2)$.

4. Discussion

How much of an economic transformation is the ERP likely to produce in an organization? How will the ERP systems affect the performance of the organization and the skills of the people? How customizing ERP information affects market dynamic? Will it be significant determinant in sustaining and maintaining the dramatic increase in productivity recorded since the mid-1990s?

The economic contributions of information technology in general and ERP in particular, have important policy implications and have attracted the attention of researchers (Dewan & Kraemer, 2000). Cost saving and productivity have been reported positive relation in computer and software industries (Gordon, 2000; Oliner & Sichel, 2000). The cost savings are largely projected to be one-time savings for each firm or spread over in individual firm, while at the sector level a process of diffusion from first-adopters to followers should generate a pattern of productivity savings (Litan & Rivlin, 2001). Cost savings from the networking of ERP system often offer some important gain to consumers from added convenience, variety of product mix, and customization that ERP makes possible. These significant savings could be generated from the large productivity increases in ERP adoption.

Performance of an organization could be improved through better management, innovation and re-skilling of the workforce. ERP forces firms to conform and standardize their business process to the best practices. Thus, ERP systems innovate the old business processes and thereby make the processes more efficient. As best practices streamline the business processes the management of an organization could make better decisions in terms of meeting market demands such as introduction of new product lines etc

ERP adoptions facilitate integration of divisions within a firm as well as externally with suppliers and customers. Such externalities offer the benefit of connecting and communicating between different systems, not having to maintain separate systems and ability to easily share information between systems. This would result in better strategic and operational decision making and thus, higher profits. For example, in the petrochemicals industry, it is difficult to find companies without ERP because sharing of information electronically is crucial for their survival (Davenport, 1998).

The ERP-skilled workforce can improve the firm's performance in several ways. For example, cycle time reduction through completing tasks with less time, proposing continuous improvements to the business processes etc. The benefits of added convenience and customization are inherently much more difficult to quantify (Varian et al., 2002), and are not likely to show in GDP.

5. Conclusion

ERP technology enables firms to cut costs, improve transactions and enlarge markets, foster productivity growth, and improve the skills of the workforce. Firms that discover ways to use the ERP productively will be on the cutting edge of their markets. To conceptualize these impacts, we proposed a framework based on the production theory and the network effects of the information goods. In the production theory, ERP system is treated as a capital investment. The premise is that the higher the investment in capital the higher the productivity. Higher productivity results in higher output of goods and services per unit of raw materials. As mentioned earlier, these productivity increases result from better integration effects (network effects), cost savings from ERP and the streamlined of business processes.

Besides the internal impact from ERP that arise from the production function, we also incorporate the external impact from the network effects. As more firms adopt ERP systems within a supply chain of a firm, the benefits that these firms bring to new firms adopting ERP are increasing to scale. This is termed the network effects and can comprise of the conversion effect, consumption effect and imitative effect.

The proposed framework explains why firms adopt ERP despite the risks and costs; how it impacts internally through the production function and how the external factors through the network effects encourage firms to adopt ERP. Likewise, this framework allows an understanding of how ERP affects the firm as a whole from the production function and network effect.

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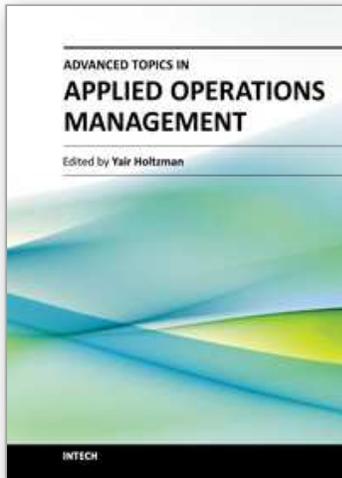
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