ERP Investment Evaluation Based on Options Theory

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Abstract

ERP investments are costly, lengthy, and risky, replete with complex organizational factors such as initially unknown requirements, unexpected user adoption contingencies, and rapidly changing IT environments. Previous knowledge reveals that the ERP investment is a phased process. Companies do not invest all their resources until the pre-investment phase is finished. To justify ERP investments, it is necessary to consider the value of this deferral option value under uncertainty. Traditional ERP evaluation methods such as NPV, require a "now-or-never" decision, which does not take this managerial flexibility into account; thus important opportunities may be missed. Given this background, we view ERP investments from a deferral options perspective, rather than as "now-or-never events". Our contribution is twofold. 1) We evaluate costly and risky ERP investments under uncertainty. 2) We investigate the value of managerial flexibility offered by the deferral option, which is the unique feature in the pre-investment phase of an ERP investment.

Keywords: ERP investment; evaluation; options; uncertainties

ERP 投資評估——以實質選擇權理論為基礎

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摘要

企業資源規劃系統（ERP）乃一昂貴、費時，且牽涉許多不確定因素之投資。ERP 系統與其他資訊系統投資之不同處，在於其特有之可遞延投資前階段（deferrable pre-investment phase）。以往以淨現值法（Net Present Value）為基礎之評估方式，無法將 ERP 此一可遞延之特性納入考慮，致使組織評估 ERP 投資時無法反應出真正的價值。選擇權理論為一針對管理彈性，強調在不確定性下的投資評估方法。本文以選擇權理論觀點納入此一 ERP 投資特性以評估 ERP 投資。結果顯示，選擇權理論與以往使用之淨現值法所得到之評估結果存在很大差異，而此差異來自於 ERP 投資所具有且向來被忽略之管理彈性。

關鍵字：不確定性、企業資源規劃、投資評估、選擇權理論

1. INTRODUCTION

Investments in Enterprise Resources Planning (ERP) now form a major part of the capital budgets of many organizations (Balasubramanian et al. 1999) and an important strategy by which enterprises acquire competitive advantages and achieve good quality of service. ERP systems streamline business processes by creating an enterprise-wide transaction structure which integrates the key functions of different departments within an integrated information system platform and are therefore key strategic systems. According to statistics, ERP projects have become the largest single investment in information system projects. For example, ERP investment was the largest segment of U.S. companies' applications budget throughout 2004 (Sumner 2000).

However, studies show that as many as three-quarters of past ERP projects were judged to be unsuccessful by firms that had invested them (Bingi et al. 1999; Chen 2001; Ferranti 1998; Griffith et al. 1999). Previous studies in ERP have focused on the topics of ERP success (Hong et al. 2002; Scheer et al. 2000), the interaction of ERP and organizations (Gattiker et al. 2004; Markus et al. 2000b; Soh et al. 2000; Somers et al. 2003), and ERP system development (Kremers 2000; Purnendu et al. 2003), but few have discussed ERP investment evaluation. Because ERP systems are complex pieces of software and entail high risks, many ERP investments that were difficult, lengthy and over budget were terminated before completion. For instance, Dell Incorporated failed in their ERP project after committing two years and expending $200 million. Waste Management Incorporated aborted its ERP investment after spending $45 million of an estimated $250 million budget (Abdinnour-Helm et al. 2003). Even worse, failure in ERP investments has led to problems as serious as bankruptcy (Davenport 1998; Markus et al. 2000b). Therefore ERP investment evaluation has been an important concern of researchers and the practitioners given its significance (Irani et al. 2001; Stefanou 2001).

Because incorrect ERP evaluation results in incorrect decisions, an effective ERP project evaluation discipline that considers uncertainties is needed. Lacking such a discipline, inadequate ERP investment decisions can be made that incur huge losses. Most ERP investment evaluations are conducted on a Net Present Value (NPV) basis (Murphy et al. 2001; Stefanou 2001). However, this traditional valuation tool ignores the issue of uncertainty, and does not take managerial flexibility into account (Trigeorgis 1996). Failure to consider the value of managerial flexibility means that the perceived benefits of a project are lower than the actual benefits, so managers are apt to reject or prematurely cancel projects that would in fact be economically viable (Keila et al. 1999). Moreover, NPV assumes that investments are reversible, and non-deferrable. In the real world, however, ERP investments are irreversible, deferrable and undertaken in conditions of uncertainty (Dixit 1995; Paddock et al. 1988; Pindyck 1988).

Options theory is a risk-hedging approach and is especially suitable for projects that involve both a high level of uncertainty as well as opportunities to dispel that uncertainty when new information becomes available (Copeland et al. 2004). Since ERP investment actually conceals enormous risks, managers must consider both technical and market uncertainties, respond to the changing environment, and take appropriate actions. All these characteristics make evaluation of ERP projects contingent on as yet unknown future states. For these reasons, the options approach is quite suitable for ERP evaluation. For example, it has the ability to evaluate wait and learn options and resolve the uncertainty inherent in ERP investment decisions. The timing option generates additional value in terms of managerial flexibility, and enables managers to make decisions until the uncertainty factors are resolved.

This paper addresses the research questions: 1) In a costly and risky ERP investment, how to evaluate ERP projects under uncertainty? 2) What is the value of managerial flexibility provided by the deferal option embedded in an ERP investment? We endeavor to answer these questions to enable evaluation by managers undertaking costly and time consuming ERP investment.

2. LITERATURE REVIEW

An ERP system streamlines business processes by creating an enterprise-wide transaction structure that integrates the key functions of different departments within an integrated information system platform. It considers every business transaction entered into, regardless of where the transaction is recorded. Data is updated continuously, ensuring that every level in the organization is provided with the latest information. Through the integration of these diverse systems, organizations obtain many benefits from the latest information available (Dhar et al. 1997).

Traditional ERP evaluation uses NPV (Mabert et al. 2003), which must be established at a specific point in time and results in a huge opportunity cost. A static now-or-never decision is made which neglects the value of postponing the project. NPV provides a measure that takes into account expected benefits and costs. A negative NPV suggests that the costs of ERP outweigh the benefits, and that management should bring to an end their ideas of using ERP. A positive NPV signals to management that the benefits outweigh the costs, justifying the investment of ERP without a need for future decision-making, simply based on the NPV result. Simple well-defined IT applications such as office automation systems (OAS) and transaction processing systems (TPS), designed to replace workers such as payroll clerks who perform repetitive tasks, work well with the NPV criteria because application costs and benefits are determined relatively easily and requirements are clear (Martinsons et al. 1999; Stefanou 2001).

However, applying NPV to ERP evaluation can create problems. Firstly, ERP differs from other information systems in that substantial costs often emerge unexpectedly. This is often due to customization, training and consulting. These unpredictable costs alone imply that decisions regarding ERP must be made with more caution. In addition, ERP is not simply a larger scale equivalent to other larger scale IT applications. ERP affects the organizational reengineering process that results in a major organizational change. This change is the source of considerable benefits and unmanageable costs. Failure to identify the full costs and benefits of ERP investment can have serious problem for ERP investment (Stefanou 2001). Secondly, given the rapidly changing world, the long investment process for ERP gives rise to uncertainties. ERP is significantly more time-consuming to invest than ordinary IT applications, often taking two to five years to get into operation (Hitt et al. 2002). When implementing technology spans years, a revolution in standards can produce an entirely new paradigm, making a discontinuous gap from the old. Doubling the investment time can more than double the uncertainties.

Another unique characteristic of ERP projects is the multiple-phase feature. ERP investments are in three steps (Markus et al. 2000a): The first is the pre-investment phase, during which the company selects the ERP system vendor to match their business vision and working process. The second is the shakedown phase during which the ERP system is starting be adopted into the business. The third is the onward phase during which the company onward upgrades the ERP adoption. Companies do not start to invest ERP systems until the pre-investment phase is ready, during which the management makes their ERP system selection process that can take 20 employees and for 14 months (Hecht 1997; Wei et al. 2005). Therefore, before the investment of ERP projects, there is a deferral decision with which the management decides when to invest the ERP project. Evaluation of ERP investments should take the above unique ERP characteristics as well as concerning the postponement of ERP into account (Ginzberg et al. 1988).

The most serious problem in applying the NPV rule to ERP investment is the implicit static worldview held by NPV. NPV assumes that ERP investments are reversible, and non-deferrable. However, ERP projects are irreversible, deferrable and undertaken in conditions of uncertainty. Adopting pinpoint now-or-never evaluation by the NPV rule leads companies to give up the managerial flexibility to defer a ERP investment which is critical in successful ERP investment, can results in a huge opportunity cost for the company.

Options theory (Black et al. 1973; Myers 1974; Trigeorgis 1993), which addresses the uncertainties of a risky underlying asset, aims to deal with uncertainties. A financial option is a contract, the value of which is dependant upon volatile underlying assets, such as stocks or interest rates. It gives a privilege to an investor, for sunk costs, who may buy a stock at the strike price when the stock price is favorable, but does not obligate the investor to buy the stock at an unfavorable price. Just as a financial option is a derivative of underlying financial assets, the options value is determined by the underlying real assets. It provides a dynamic view in project evaluation that it recognizes that in an uncertain and changing world it is important to take flexible plans into account. This capability enables the option holder to exercise the option when the uncertainties resolve in a favorable manner, but does not obligate him to do so in an unattractive market. Research into the application of options to the information systems field is still in its infancy. Some information system/information technology (IS/IT) researchers have noticed options theory (Dos Santos 1991; Kambil et al. 1993). They noted that besides used in the finance field, options theory can be used in the IS/IT field. Taudes (1998) used options theory to evaluate software growth options as a sequential exchange option within a system upgrade problem. He argued that IT benefits include flexibility and responsiveness, both of which can be evaluated with real options. Other research emphasizes that it is important to understand and hedge risks in IT projects based on options (Kumar 2002). He noted that when evaluating IT investments, the flexibility in IT must be addressed. Finally, Benaroch (2002) illustrates how the options approach can be applied to an information systems investment that entails the establishment of point-of-sale debit services systems.

Most of the previous works use the Black-Scholes formula; however, the formula is specific to European options, for which the option may be executed only on the expiration date. Moreover, the formula was developed to valuate financial assets, but is not suitable for valuation of real assets. Some researchers make the argument that it is not reasonable to use the formula on a real asset (Hull 2000; McDonald et al. 1986). Therefore, the differences between the two kinds of assets must be distinguished, and the valuation model must be used carefully, since the underlying assets in options, i.e., the ERP investments, are not traded in the market.

3. TIMING OPTIONS IN THE ERP INVESTMENT

Timing is crucial to ERP investments (Aladwani 2001; Oliver et al. 2002; Upton et al. 2000). Waarts et al. (2002) noted that the strategy used by some companies was postponement of the adoption rather than face disadvantages induced by failure to adopt the ERP. Consider a illustrate case that a big company, which is considering the investment of an ERP system. Costs of the investment are estimated at $60 million, including the cost of various ERP modules, training fees, consultation fees, workforce costs, and rewards for project. The company estimates that by investing the ERP system, the company can obtain competitive advantages by reducing headcount, improving cash management and achieving additional valuable flexibility in management. The estimated cash flows of these advantages are estimated to be $10 million, $ 15 million, $ 20 million, $ 15 million, and $ 10 million in the next five years, respectively. the volatility of future benefits, σ, equals 20% and the opportunity cost of a wait, δ, is 10% by survey of the average industry. The interest rate, ρ, is 4% according to the most recently two year average T-bill interest rate. For the company that investment in ERP, the first question is how to justify the costly and risky ERP investment. In addition, since the investment involves major risks including (Kumar 2002; Markus et al. 2000b):

1. The staff lacks necessary technical skills
2. Internal parties are uncooperative
3. The response by the competition may eliminate the firm's advantage
4. The benefits derived from adopting ERP must be studied further
5. A new, superior technology may be introduced, rendering the current application obsolete
6. The technology may be immature and its capabilities may be exaggerated.

Therefore the other question is how can the company defer the ERP investment, i.e., how much time can they spend on the pre-investment phase? Considering these unknown future states, delaying ERP investment may allow for the accrual of necessary experience and knowledge that enables improved the success of ERP investment. Deferment of ERP investment may reveal important additional information and provides some advantages to the firm. Examples include hardware procurement (where a delay may permit investment at a lower price) and types of technical prototyping (in which a delay may allow for use of new technology). In addition, the company can continue to gather information, while delaying the acceptance of information that may change, and as a result they may attain a more complete specification. Furthermore, deferring the investment may allow for the use of state-of-the-art technology that may be used to economize or facilitate attainment of the desired technical performance of the system.

We use a continuous-time stochastic process model, developed by Dixit et al. (1994) and Pindyck (1988) to model the ERP investment. Compared to the Black-Scholes model, this model is more specific to a real asset while maintaining simplicity. The cash flow of the project, V_t , follows a geometric Brownian process, given by:

$$\frac{dV}{V} = \alpha_v dt + \sigma_v dz_v \qquad (1)$$

where α_v is the constant drift rate of future benefit, and dz the increment of a Wiener process. The company invests ERP at the time, T^* , with costs I to realize V, the present value of the uncertain stream of future cash flows generated by this investment.

$V(t)$ represents the market value of the ERP investment on the stream of net cash flows that arises from the investment subsequent to time t. When $V^* > V(t)$, the company will not invest ERP right away. i.e., they wait. The value of the option to defer is $V_0(C^*)$, and the value of executing the option is $V_1(C^*)$ (See Figure 1).

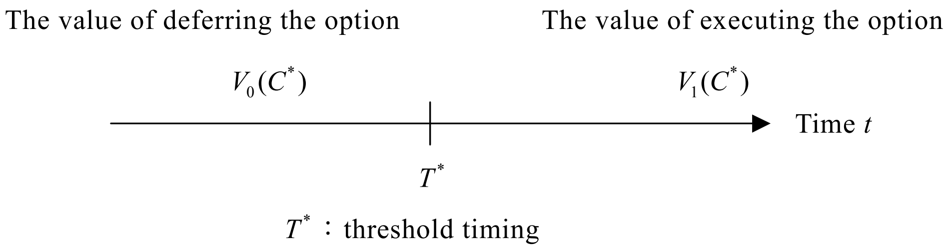

Figure 1: The threshold to invest ERP

At a point, the value of the option is equal to $Max(0, C_1^* - I)$. When the value of the option is below the critical value at some threshold C^*, the value of the option is 0. If the value of the option exceed the value at the threshold, the value of the option is then $C_1^* - I$. Whether the manager chooses to invest immediately or to wait to do so at a later time, the manager aims to reap the maximum of available benefits. When the value of the project is higher than the value at the threshold, the managers make the decision to invest the ERP project without delay. Otherwise, they decide to delay the ERP investment until a proper time arises. Formula 2 expresses decision-making policy as it is seen by managers:

$$V_i(C) = Max[V_0(C), V_1(C)] \quad (2)$$

The company is aware of the present value of future net cash flows for investment of ERP. However, there may be volatility σ_v in knowing in which ways the company may benefit. Let $F(V)$ be the market value of the ERP investment, where the expected project value is $F(V_t)$. The partial differential equation for the value of the ERP investment is:

$$\frac{1}{2}\sigma^2 V^2 F''(V) + (\rho - \delta) V F'(V) - \rho F = 0 \quad (3)$$

The partial differential equation must satisfy the following boundary conditions:

$$F(0) = 0 \quad (4)$$

$$F(V^*) = V^* - I \quad (5)$$

$$F'(V^*) = 1 \quad (6)$$

Equation (4) indicates the project value in a valueless situation within which the managers will decide not to invest as long as the investment value remains at 0. The value matching equation (5) follows that when the option is exercised, the value lost should be equal to the value gained at the critical point. The investment costs are denoted by I . The smooth-pasting condition (6) determines the trigger point of exercise for the adoption of ERP. At the trigger point V^*(See Figure 2), the graph of the option value touches the payoff function and the two function are tangent to each other. On the one hand, ERP may be adopted at a time which is a little too early (when the underlying is below its trigger value). On the other hand, it may be invested a little too late (when the underlying is above its trigger value). In short, at the trigger point, superior investment possibilities will not exist. For an intuitive proof of the boundary conditions see Dixit and Pindyck (1994).

We can calculate the value for the investment:

$$F = (V^* - I)(\frac{V}{V^*})^{\beta_1} \qquad \text{when V} < V > V^* \qquad (7)$$

$$F = V - I \qquad \text{when V} > V^* \qquad (8)$$

where F represents the value of the opportunity to invest in ERP. V^*, the critical value, means the lines between two regions. If $V < V^*$, the value of investing ERP is not sufficient to support the costs, so the project will be postponed. If $V > V^*$, positive benefits may be generated by investing ERP without further delay.

$$V^* = \frac{\beta_1}{\beta_1 - 1} I \qquad (9)$$

$$\beta_1 = \frac{1}{2} - \frac{\rho - \delta}{\sigma^2} + \sqrt{(\frac{\rho - \delta}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}} > 1 \qquad (10)$$

4. NUMERICAL ANALYSIS

Traditional NPV analysis would lead the managers to adopt ERP immediately, since NPV analysis of the situation for Company A reveals positive NPV, i.e. \$2.3 million. But the results arrived by options analysis is quite different. Applying the parameters to Formula (11), β_1 is 4.45 and V^* is \$77.4 million. Because the project value (\$62.3 million) is less than the threshold (\$77.4 million) ($V < V^*$ in Figure 2), i.e., the value with flexibility at point C is greater than the now-or-never NPV value at point D. Therefore the company delays the project. The difference between the two values signifies the value of the option to defer to the manager. With that information, the manager will choose to wait until the project value approaches the critical value \$77.4 million. The V^* is actually a trigger that the company will change its strategy between the two alternatives (wait and adopt). The value of the opportunity presented by the project is \$6.63 million. The value of the option to delay is thus \$6.63 million less \$2.3 million (project value without managerial flexibility, i.e., the NPV value) = \$4.32 million, amounting to nearly 7% of the total investment cost. That is the value of the managerial flexibility that the company has, with which it may take its strategic move.

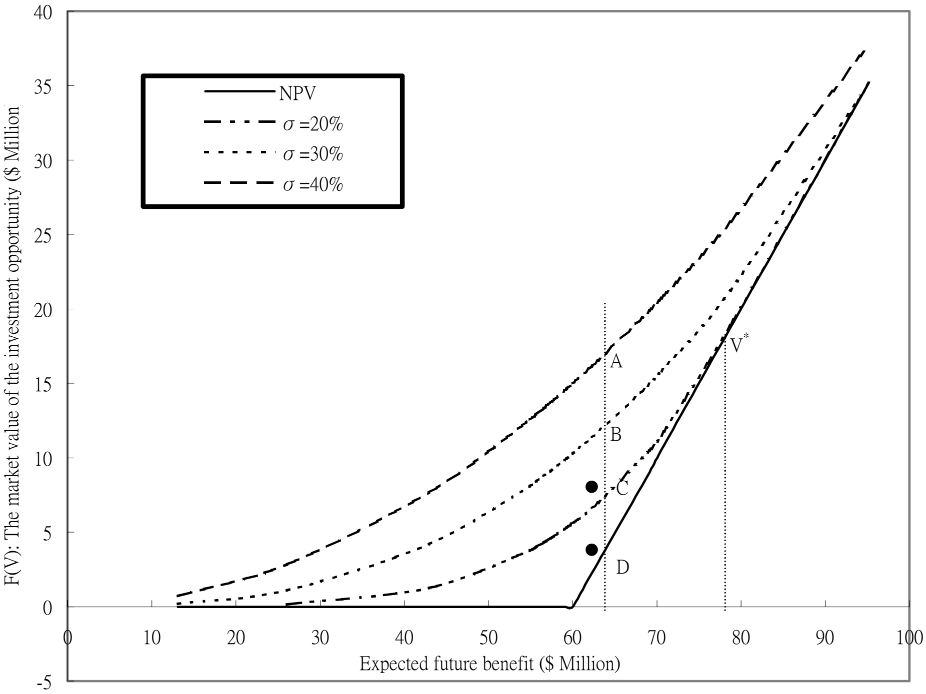

Figure 2: The impact of the volatilities

According to Formula (11), if σ is equal to 0, the value of the investment is equal to that made by an NPV rule. For a higher σ, there is a more uncertain value inherent in the project. Thus a firm will ask for a greater risk-premium with which it may cover the projected risks. A higher σ makes the β_1 approach 1, leading to a greater value of $\frac{\beta_1}{\beta_1 - 1}$. Since $V^* = \frac{\beta_1}{\beta_1 - 1} I$, $\frac{\beta_1}{\beta_1 - 1}$ stands for the multiple factors of investment that the company is willing to start the investment under investment uncertainty. The higher the opportunity cost δ rises, the lower that $\frac{\beta_1}{\beta_1 - 1}$ falls, and means that the firm is more willing to execute the option due to the high opportunity cost. In Figure 3, we can see that as δ becomes larger, the critical value to investment becomes lower, means that if which means the opportunity costs to defer become higher, it is better for manager to investment as soon as possible to avoid the loss of late market-entry. The opportunity costs are more sensitive for a project with higher volatility in Figure 3. On the contrary, the higher the interest rate ρ, the larger the value of $\frac{\beta_1}{\beta_1 - 1}$, meaning that the firm is more unwilling to execute the option. As the future value of the project is unknown, there is an opportunity cost of investing ERP project today. Hence the investment rule is to invest when V is at least as large as a critical value V^* that exceeds I. This critical value is 1.29 times as large as I, which suggests the company to wait to invest until V is more than 1.29 times of initial investment costs. The analysis results are quite different from NPV rules. The threshold value to invest conducted by the NPV rule is merely \$60 million, while it is \$ 77.4 million conducted by options theory.

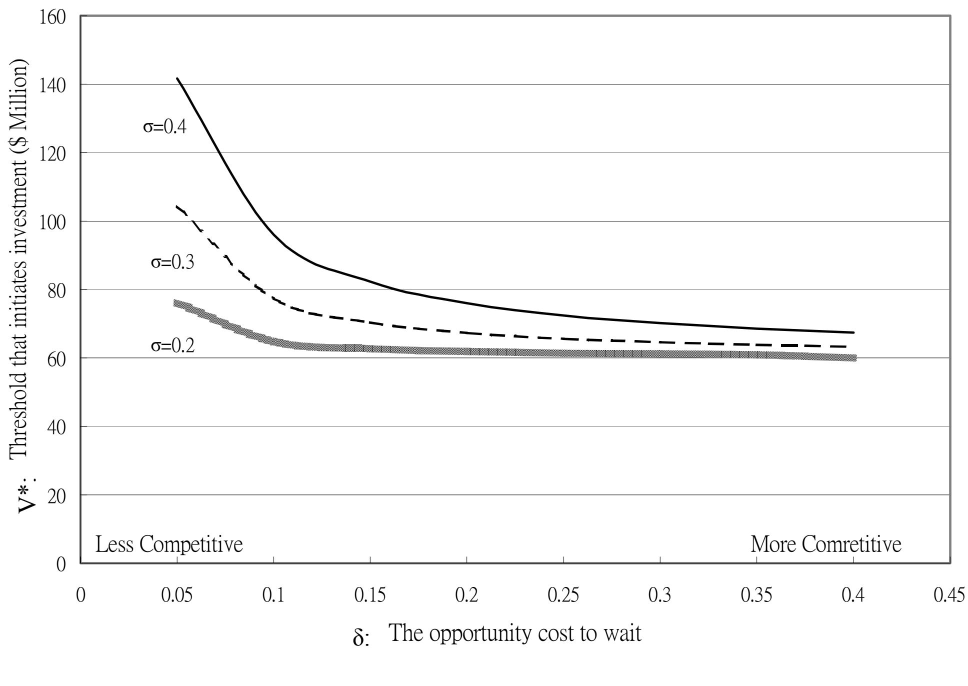

Figure 3: The opportunity costs of delaying the project

The volatility plays an important role by affecting the size of the "option premium". An increase in volatility increases total project value, while the associated opportunity cost, δ, has opposite effect. δ represents an opportunity cost of delaying investment. If δ is zero, then there is no opportunity cost to keeping the option alive. The two important driving variables in the analysis are actually tradeoff in determining the project value. They influence an ERP investment in an interact way that a company must realize the position it stands in the industry. Table 1 lists the effects of the two factors in investing an ERP.

Table 1: The Risk Factors

Change in variables	Project value	Implication
$\sigma\uparrow$	$F(v)\uparrow$	Increase in environment volatility actually increase the project value.
$\sigma\downarrow$	$F(v)\downarrow$	Decrease in uncertainty makes the value more equal to a “now or never” NPV value, and decrease the value of managerial flexibility.
$\delta\uparrow$	$F(v)\downarrow$	The more opportunity costs decrease the project value, which implies that, a company must enter the market as soon as possible. An extreme is the value of waiting eventually vanish in a complete compete market.
$\delta\downarrow$	$F(v)\uparrow$	A monopolist fully enjoys the value of waiting to make best use of the option premium before the investment opportunity expires.

In fact, to invest immediately may not be the best move, even when the NPV is positive. When ERP investment is taken under uncertainty there is an option value of delay. If the management has the option to wait and delay the pre-investment phase in the ERP project, i.e., to let the uncertainty unfold and make decisions according to the updated information, the value of the investment will be different from the value based on the invest now-or-never situation. The options perspective provides a richer ERP investment profile, which enables companies better understand the economics of ERP investment.

5. CONCLUSIONS & MANAGERIAL IMPLICATIONS

ERP investments are costly, lengthy, and risky, replete with complex organizational factors, such as initially unknown requirements, unexpected user adoption contingencies, and rapidly changing IT environments. Previous studies showed that ERP investment is a phased process. In other words, companies do not invest all their resources until the pre-investment phase is finished. For ERP investments under uncertainty, it is necessary to consider the value of the deferral option. Evaluating ERP investments by NPV creates a situation where companies are unable to respond to uncertainties; thus, important opportunities may be missed.

Given this background, we view ERP investments from a deferral options perspective, rather than as “now-or-never event”. Our contribution is twofold. 1) We evaluate costly and risky ERP investments under uncertainty. 2) We investigate the value of managerial flexibility offered by the deferral option, which is the unique feature of the pre-investment phase in an ERP investment. All calculations can be performed easily using widely available spreadsheet software. The results are quite different from those of traditional ERP evaluation approaches. This study has several managerial implications. For researchers, we extend prior ERP investment research by studying ERP investment evaluation under uncertainty. For practitioners, treating ERP investments as options allows companies to have flexible plans that can be adjusted to meet current conditions. The ability to defer ERP investment under uncertainty is a great asset to managers; however, this factor is neglected by the NPV method. The deferral option also gives the companies the flexibility to manage the pre-investment phase of the ERP project. Future research will include case studies. More ERP characteristics will be incorporated into the model and their effects examined to facilitate successful ERP investment.

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