Evaluate IT Investment Opportunities Using Real Options Theory

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ABSTRACT

In this paper, we discuss the real options theory and its applications in IT investment evaluation. We provide a framework within which the appropriateness of using real options theory in strategic IT investment evaluation is systematically justified. In our framework, IT investment opportunities are classified into four categories based on two criteria: the technology switching costs and the nature of competition. We point out that different real options models should be adopted for each category. The electronic brokerage's investment decision in wireless technology is discussed as a real world case within the framework. Our study also provides some insights about the relationship between technology standardization and IT investment decisions.

Keywords:

INTRODUCTION

Today's fiercely competitive environment means that every player in the real business world must be pro-active. However, limited financial resource and many uncertainties require business practitioners to maximize their shareholders' equity while controlling the risks incurred at an acceptable level. As the unprecedented development in information technology (IT) continuously produces great opportunities that are usually associated with significant uncertainties, technology adoption and planning become more and more crucial to companies in the information era. Karahama et al. (1999) point out that the value-adding potential of the new technology in question is a critical factor in IT adoption. Raghunathan and Madey (1999) develop a firm-level framework for electronic commerce information systems (ECIS) infrastructure planning. In this study, we attempt to evaluate IT investment opportunities from a new perspective, namely, the real options theory. Unlike the standard corporate resource allocation approaches, the real options approach acknowledges the importance of managerial flexibility and strategic adaptability. Its superiority over other capital budgeting methods like discounted cash flow analysis has been widely recognized in analyzing the strategic investment decision under uncertainties (Amram and Kulatilaka 1999, Luehrman 1998a, 1998b). In fact, some previous IS researches have recognized the fact that many IT investment projects in the uncertain world possess some option-like characteristics (Clemsons 1991, Dos Santos 1991 and Kumar 1996). Recently, Benaroth and Kauffman (1999, 2000) and Taudes, Feurstein and Mild (2000) apply the real options theory to real world business cases and evaluate this approach's merits as a tool for IT investment planning. For a general discussion of the link between real options theory and IT investment planning, readers are referred to Amram, Kulatilaka and Henderson (1999).

As all real options models inevitably depend on some specific assumptions, their appropriateness should be scrutinized under different scenarios. This study aims to provide a framework that will help IS researchers to better understand the real options models and to apply them more rigorously in IT investment evaluation. As the technology changes, the basic economic principles underlying the real options theory do not change. So we do not need a brand new theory, but we do need to integrate the IT dimension into the real options based investment decision-making process. Using electronic brokerage's investment decision in wireless technology as a real world example, we show the importance of adopting appropriate real options models in IT investment planning. By specifically focusing on the uncertainties caused by IT innovation and competition, our study also gives some intriguing results about the dynamics between IT adoption and the technology standard setting process.

REAL OPTIONS THEORY

The seminal works of Fischer Black, Robert Merton and Myron Scholes offer us a standard pricing model for financial options. Together with their colleague at MIT, Stewart Myers, they recognized that option-pricing theory could be applied to real assets and non-financial investments. To differentiate the options on real assets from the financial options traded in the market, Myers coined the term "real options" that has been widely accepted in academic and industry world. It is generally believed that the real options approach will play a more important role in the highly uncertain and technology driven digital economy. Before reviewing the real options literature body that is growing very rapidly, we use two examples to give readers an intuitive illustration of the values of real options and their significance in financial capital budgeting.

Example 1. This Year or Next Year?

$$NPV = -100{,}000 + \sum_{t=1}^{\infty} \frac{(15{,}000 + 7{,}000)}{2 * (1.1)^t} = 10{,}000$$

A software company is facing a new investment opportunity. It plans to spend \$100,000 to make its best selling database system compatible with an emerging Operating System (OS) in the market. But as the new OS is still in its infancy, the company is not sure whether it will be widely accepted in the near future. Suppose that the uncertainty about the new OS can be totally resolved next year, the company is trying to maximize its expected return form the $100,000 investment project. According to the company's estimation, the new OS has 50% chance to be widely accepted next year. In this case, the expected increased cash inflow from this investment is estimated to be $15,000 a year. In the case that the OS is not popular next year, the expected annual net cash inflow from this project will be $7,000. Suppose that the discount rate for this investment project is 10%, the NPV (Net Present Value) of this project can be calculated as:

$$NPV' = \frac{0.5}{1.1}\left[\sum_{t=1}^{\infty}\frac{15,000}{(1.1)^t} - 100,000\right] = 22,727$$

Since the NPV of this project is positive, it seems that we should go ahead with this project. However, the conclusion is incorrect because it does not count the value of the option of deferring the investment to the next year. Suppose that the company waits one year to watch the market reaction to the new OS, if favorable situation occurs, it proceeds to invest, otherwise it gives up the project. This time the NPV of this project turns out to be:

Obviously, it is better to defer the investment to the next year, and the value of this option is $22,727-$10,000= $12,727. Someone may argue that the investment costs will increase in the next year. In fact, further calculation shows that the option is still valuable even the costs are as high as $127,000 in the next year. Basically, this simple example shows the value of an option of deferring investment. In the next example, we discuss the value of a growth option.

Example 2. Pioneer Venture: The Value of a Growth Option

In this example, the management of a large pharmaceutical company wants to decide whether to acquire a young biomedical lab. If they decide to acquire it, they should provide $100,000 funding to cover the initial costs for the pioneer venture. Five years after the initial funding, the management will decide whether to stop the pioneer venture or to expand it significantly according to the market situation at that time. If they choose to expand it, additional $1,000,000 is needed. The cost of capital is assumed to be 15%. Five years after acquisition of the lab, the management will face two scenarios. The good scenario will occur with 60% while the bad one will have 40% to happen. All expected future cash flows during the next 10 years are given in Table 1.

Using standard capital budgeting method, we can find that the NPV for the pioneer venture is -$15,215. For the period of large-scale production, the NPV is -$71,873. As the NPVs for both periods are negative, it seems that the management should give up the acquisition. However, the acquisition will be a good investment if we consider the growth option associated with it. By acquiring the lab, the company also buys a growth option that enables it to expand the lab when the conditions are favorable five years later. In this case, the good scenario will occur with 60 percents. After simple calculation, it is easy to find that the growth option has a value of $28,965. Combining its value with the negative NPV during the pioneer venture period, the adjusted NPV of the acquisition is $13,750, which means this investment is

Table 1: Projected Cash Flows in the Example of Pioneer Venture Project

Year	Pioneer Stage	Larger Scale Stage	Total Cash Flows	Discount Rate
0	-$100,000		-$100,000	15%
1	$10,000		$10,000	
2	$10,000		$10,000	
3	$50,000		$50,000	
4	$50,000		$50,000	
5	$20,000	-$1,000,000	-$980,000	
6		$100,000	$100,000	
7		$100,000	$100,000	
8		$500,000	$500,000	
9		$500,000	$500,000	
10		$200,000	$200,000	
	Large Scale Stage	Good Scenario	Bad Scenario	Prob (good)
5	-$1,000,000	-$1,000,000	-$1,000,000	0.6
6	$100,000	$130,000	$55,000	
7	$100,000	$130,000	$55,000	
8	$500,000	$650,000	$275,000	
9	$500,000	$650,000	$275,000	
10	$200,000	$260,000	$110,000	
	NPV Pioneer Stage	-$15,215.42		
	NPV Large Scale Stage	-$71,872.54		
	NPV with Growth Option	$13,749.98		
	Value of the Option	$28,965.40		

strategically plausible.

In both of the above examples, we can easily calculate the values of the real options. The reason is that we make stringent assumptions on the distribution of future cash flows to simplify the calculation. In the real business world, option pricing is far more complicated. Fortunately, we can adopt some standard tools and concepts from option-pricing theory to evaluate real world investment opportunities.

An option is the right, but not the obligation, to buy (a call) or sell (a put) an asset by a pre-specified price on or before a specified date. For financial option contracts, the underlying assets are usually stocks. Until late 1960s, people had failed to find a rigorous method to price the options. Based on the Ito Calculus and the concept of dynamic portfolio hedging, Black and Scholes (1973) and Merton (1973) successfully found the fundamental partial differential equation that must be satisfied by the value of the call option and gave the analytical solution known as the Black-Scholes formula. Following their seminal works, many later studies extended the model or proposed other option pricing approaches. Cox, Ross and Rubinstein (1979) propose a simplified option pricing approach based on a multiplicative binomial process that approximates a geometric Brownian motion in its continuous-time limit. For non-technical introduction to options and option pricing theory, see Brealey and Myers (1996).

Following the revolution in option pricing theory, many researchers recognized the potential of this theory in capital budgeting because traditional DCF (Discounted Cash Flows) technique has its inherent limitation in valuing investments with strategic options and many uncertainties. Myers (1977) shows that a firm's discretionary investment options are components of its market value. Mason and Merton (1985) discuss the role of option pricing theory in corporate finance. Kulatilaka and Marcus (1988) also discuss the strategic value of managerial flexibility and its option like properties. Table 2 gives a comparison between an American call option on a stock and a real option on an investment project.

Despite the close analog, some people may still question the applicability of option pricing theory on real options that are usually not traded in a market. However, Cox, Ingersoll and Ross (1985) and McDonald and Siegel (1984) suggest that a contingent claim on a non-traded asset can be priced by subtracting a dividend like risk premium from its growth rate.

Based on the solid theoretical foundation, many researchers have investigated the valuation of various real options in the business world. One of the most basic real option models was developed by McDonald and Siegel (1986). In their model, they discuss the optimal time for a firm to invest in a proprietary project whose value evolves according to a geometric Brownian motion. Their results suggest that the option to defer an investment may be very valuable under some circumstances. Ingersoll and Ross (1992) also discuss the option of waiting to invest and its relation with uncertainty. Brennan and Schwartz (1985) examine the joint decisions to invest and abandon a project. Kulatilaka and Trigeorgis (1994) adopt the real option theory to value the managerial flexibility to switch inputs and outputs. Grenadier (1995) discusses how to value lease contracts by real options theory.

Recent development in real option theory focuses on the valuation of more complicated real options like shared options, compounded options and strategic growth options. Dixit and Pindyck (1994) examine the dynamic equilibrium in a competitive industry. Their model suggests that a firm's option to wait is valuable when uncertainty is firm specific. For industry wide uncertainty, there is not value to wait because of the asymmetric effects of uncertainty. Smit and Ankum (1993) apply real option theory and game theory to corporate investment decision under competi-

Table 2: Comparison Between an American Call Option and a Real Option on a Project

AMERICAN CALL OPTION ON STOCK	REAL OPTION ON A PROJECT
Current Stock Price	Present Value of Expected Cash Flows
Option Exercise Price	Investment Cost of a Project
Right to Exercise the Option Earlier	Right to Invest in the Project at Any time Before the Opportunity Disappears
Stock Price Uncertainty	Project Value Uncertainties
Option Price	Value of Managerial Flexibility Associated with the Project
Expiration Time	Time Window of the Investment Opportunity
Traded in Financial Market	Usually not Traded
Easy to find a Replicating Portfolio	Hard to find a Replicating Portfolio

tion. Trigeorgis (1996) extends the analysis to value the impact of random competitive arrivals. In the real world, a company usually faces a set of real options that may interact with one another. Trigeorgis (1993) examines the interaction between several options and argues that subsequent options can influence the value of earlier options. Grenadier (1996) discusses the strategic exercise of options in the real estate market. Sahlman (1997) shows how investors evaluate the growth options embedded in start-up ventures. Grenadier and Weiss (1997) apply the option-pricing approach to investigate the investment behavior of a firm facing sequential technological innovations. Huchzermeier and Loch (2001) critically evaluate the strategic value of managerial flexibility in R&D projects. Kulatilaka and Perotti (1998) quantitatively show that the gains of strategic preemptive investment sometimes overweight the loss from early commitment to a project with many uncertainties. Their results suggest that strategic considerations sometimes play a dominant role in investment timing.

A typical IT investment project requires significant initial outlay and is generally irreversible or at least partially irreversible. In addition, IT investments usually have huge business and technological uncertainties. All these characters make real option theory an appropriate approach in evaluating IT investment projects. As pointed out by Amram, Kulatilaka and Henderson (1999), real options in IT investments can create shareholder value in demonstrable ways.

FOUR CATEGORIES OF IT INVESTMENT OPPORTUNITIES

Recognizing the potential of real options in capital budgeting, many major companies are beginning to apply it in a variety of contexts. Amram and Kulatilaka (1999) give a portfolio of real options applications including new venture valuation, infrastructure investment, land valuation, R&D and strategic investment planning. Paddock, Siegel and Smith (1988) value offshore petroleum lease and subsequent exploration options. Luehrman (1998a) shows how to simplify real options theory and apply it to real business operations. Bulan (2000) reports some new empirical evidence that is consistent with real options theory. Capozza and Li (1994) argue that the true value of a vacant urban land should include the option value of alternative future development. Teisberg (1994) performs an option valuation analysis of investment choice by a regulated company. Recently some studies of real options theory have been done in valuing IT investment projects. For example, Benaroth and Kauffman (1999, 2000) conduct a case study to analyze a financial service industry IT project in the framework of real options. Using real options analysis, Taudes, Feurstein and Mild (2000) critically justify a corporation's investment decision in SAP R/3 system.

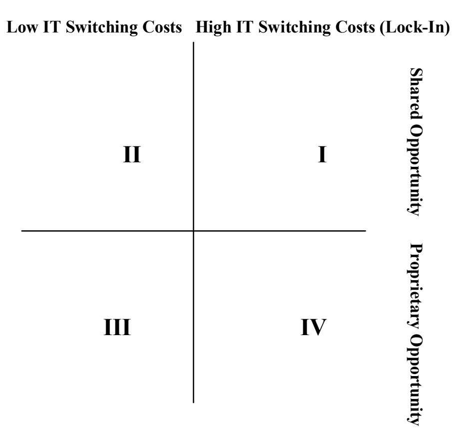
Like most theories, real options theory is not a panacea. Its applicability should be scrutinized under different investment scenarios. Although some IS researchers have begun to use real options theory as a tool in IT investment evaluation, they did not provide a framework where the issue of applicability could be addressed. The major goal of our paper is to establish such a framework. To achieve the goal, we classify IT investment opportunities into four categories based on two criteria: the technology switching costs and the nature of competition. As shown in Figure 1, we have four types of IT investment opportunities based on the two criteria:

i). Shared opportunities with high IT switch-

ing costs
ii). Shared opportunities with low IT switching costs
iii). Proprietary opportunities with low IT switching costs
iv). Proprietary opportunities with high IT switching costs.

It is worth noting that each category has distinctive requirements on the application of real options models. We use the continuous-time model developed in McDonald and Siegel (1986) as a benchmark to show why we differentiate IT investment opportunities based on the two criteria. Their model suggests that the investment opportunity is equivalent to an American call option- the right but not the obligation to invest the project at a known cost. Without intermediate cash flows and competitive erosion, this model has an explicit closed form solution. This analytical solution possesses many important characteristics. It basically suggests that the option to defer uncertain investment is very valuable and should be taken into account when a company makes investment decisions. A major assumption of this model is that there is no competitive erosion; in other words, the investment project is a proprietary opportunity. Without this assumption, the value of the project should not follow the symmetric geometric Brownian motion described in their model. The reason is simple: the existence of potential competition makes the distribution of future project value asymmetric with high project value less likely to occur. It is worth noting that the well-known Black-Scholes option pricing formula also base on the assumption that the underlying asset price follows the geometric Brownian motion. So even direct application of this formula is inappropriate when several competitors share the investment opportunity. In the real business world, most investment opportunities are shared or at least partially shared. Especially in the IT business sector where intensive competition is pervasive, those real options models assuming symmetric uncertainty in investment opportunity value are generally inappropriate. Intuitively, competition pressure will decrease the value of the option to defer an investment. There are usually two approaches to deal with this issue. One approach is to model the competitive entries as exogenous shocks. For examples, Dixit and Pindyck (1994), Trigeorgis (1991,1996) use a Poisson Jump process to describe the competitive arrivals. Their studies show that the effect of the competitive erosion can be expressed as the following equation

Figure 1. Four Categories of IT investment opportunities



Strategic NPV= NPV+ (Value of Option to Wait - Competitive Loss).

In other words, strong competition will restrict managerial flexibility if the investment opportunity is shared. To extend real options to value investment opportunities with random competitive arrivals, Trigeorgis (1996) suggest that the competitive arrivals can be viewed as have an impact analogous to a continuous dividend payout. The other approach is to endogenize the competitive interaction and to combine the real options valuation with game theoretical principles. Readers interested in this approach are referred to Smit and Ankum (1993). As we mentioned before, most IT investment are shared by several competitors. So before reach a conclusion, we must carefully compare the benefit of early preemptive investment and the value of the option to defer the investment. Applying those real options models that assume symmetric uncertainty on investment payoff is justified only when the opportunity is proprietary or at least not under competitive pressure in the foreseeable future. Some types of IT investment opportunities like Internal IT system procurement and upgrade may possess this character. However, we must evaluate the strategic effect of early investment before applying real options models to most IT investment projects. As suggested by Kulatilaka and Perotti (1998), the benefits of early preemptive investment may strategically dominate the benefits of waiting when the competition is very intensive. In fact, we can treat the strategic effect of preemptive investment as the value of a growth option. So we still evaluate the investment opportunity in the context of the real options theory by considering the growth option and the waiting option simultaneously. Alternatively, we can incorporate the preemptive effect into the standard real options models. For example, Li(2001) proposes a real options model with strategic consideration based on the model in McDonald and Siegel (1986).

The other criteria we used to categorize different IT investment opportunities is the IT switching cost. We all know that future uncertainty makes the options embedded in an investment opportunity valuable. Theoretically, there is no need to single out technology uncertainty from all other uncertainties in the real options model. All these uncertainties have same effect: they make the future payoff of an investment project less predictable. However, we will concentrate on the technology uncertainty in this study because it plays a pivotal role in affecting IT investment payoff. Perhaps the most important question that management faces before committing an IT investment is whether the technology adopted is the right choice. More specifically, will the adopted technology be the best solution to maximize the expected investment payoff? Clearly there is not a simple answer to this question because there are so many uncertainties involved. Some very promising or popular IT solutions may become obsolete in a few years. In some other cases, some neglected IT solutions may evolve to be the standard solution. Nevertheless, most technology uncertainties can be resolved as the process of technology competition goes forward. A typical process of technology competition includes:

1. Problem identification: An important problem is identified and new technology is sought to solve it.
2. Technology solutions proposition: Several technology developers/vendors propose different solutions to solve the problem.
3. Solution testing and comparison: Different technology solutions are competing in the market and their effectiveness is tested and compared.
4. Technology standardization: The best solution will flourish over time. Based on it, the technology to solve the problem will be standardized.

For many IT investment projects, decision makers face an uncertain technology environment where several IT solutions are competing in the market. Obviously, the future successes of these projects will to some extent depend on whether the IT solutions adopted will win the technology competition. Consequently, decision makers do have an incentive to use the deferring option to let more technology uncertainties be resolved. Under this scenario, many option-to-wait models can be easily extended to find the optimal investment strategy. However, to apply these real options models we must presume that there are significant technology switching costs once an IT solution is adopted. Otherwise, the uncertainties in technology competition will not make the option to wait valuable because the decision makers can easily switch to other IT solutions after they implement the investment project. As pointed out by Shapiro and Varian (1998), the IT switching costs are very significant in many cases. They use the term "technology lock-in" to describe the situation where management has little flexibility to switch to other technology solutions once they adopted one IT solution.

Now it should be clear why we use IT switching cost as the second criterion to classify different IT investment opportunities. When the IT switching cost is significant (technology lock-in), the option to wait is valuable. Therefore, real options analysis should concentrate on the managerial flexibility in deferring an IT investment to let more technology uncertainties be resolved. When the switching cost is low, high IT uncertainties can not be used to justify the wait-and-see policy. On the contrary, we should use real options analysis to quantify the value of the option to switch that usually makes an investment opportunity more appealing to the management.

To summarize our discussion, let us look at the four categories of IT investment opportunities based on the two criteria.

Category I: Shared investment opportunity with high IT switching cost.

For this type of IT investment opportunity, we must consider both the strategic benefit of early preemptive investment and the valuable option to wait. Potential competitive pressure forces investors to be proactive. However, preemptive investment will incur the loss of the valuable option to wait. So for this type of IT investment opportunity, the key in the real options analysis is to consider the strategic growth option and the option to wait at the same time. By balancing the two contradictory effects, we can find the optimal investment point at which the expected investment payoff will be maximized.

Category II: Shared investment opportunity with low IT switching cost.

For this type of IT investment opportunity, early preemptive investment is usually the best strategy. As we discussed before, it is beneficial to invest early to preempt potential competitors. Moreover, IT uncertainties will not make the wait-and-see strategy more appealing because the IT switching cost is low. Therefore, real options models should be used to quantify the values of the growth option and the switching option embedded in the IT investment opportunity.

Category III: Proprietary investment opportunity with low IT switching cost.

It is worth noting that the option to wait is a very valuable component of a proprietary investment opportunity. However, technology uncertainty will not contribute a lot to the value of the option to wait because the IT switching cost is low for investment opportunities in this category. So in the real options analysis we should pay attention to other business uncertainties that may increase the value of the option to wait.

Category IV: Proprietary investment opportunity with high IT switching cost.

Wait-and-see is the dominant strategy for this type of IT investment opportunity. So real options analysis should concentrate on the option to defer an investment. With the presence of technology lock-in, decision makers should be more patient before they commit a proprietary investment.

In the real business world, an IT investment opportunity may dynamically evolves from one category to other ones. So decision makers should be very cautious when they conduct real options analysis. In the next section, we use a real world case to show the importance of adopting appropriate real options models as the IT investment opportunity evolves.

A REAL WORLD CASE

With the phenomenal growth of World Wide Web (WWW) and the emergence of other communications technologies, the Internet-based brokerage business is reshaping many aspects of the way we trade securities. The most prominent and appealing characteristic of online brokerage is that it provides individual investors a fast, economical and easily accessible channel of trading. In recent years, advances in encryption and other networking technologies make online investing more secure and dependable, which in turn spurs further development in online brokerage business.

With the dramatic increase in the number of online brokerages, the competition of Internet-based brokerage business becomes more and more intensive. Consequently, the average commission investors paid per trade falls continuously and more customer services are available to online investors. The latest telecommunications technology makes it possible for online investors to leave their PCs alone and trade via wireless networks. So many electronic brokerage companies face an investment opportunity to build their wireless Internet trading infrastructure. Actually, the technology that enables high-speed wireless data access has been available for more than a decade. Several wireless Internet access solutions including Phone.com's UP.broswer are available as early as 1996. However, no electronic brokerage company rolled out wireless trading service before late 1998. From 1998 to 2000, nearly 70% of top 20 electronic brokerage firms began to provide some kinds of wireless trading services.

It is obvious that the investment opportunity in building wireless trading infrastructure is a shared opportunity. It means that every electronic brokerage company has an incentive to invest earlier to preempt its competitors. But why did these brokerage companies not start to build their wireless trading services as early as 1996? Why did most companies commit the investment within the time period from late 1998 to 2000? We try to answer the questions based on real options analysis and our discussion in the previous section. Before 1998, several wireless Internet access solutions were competing in the market and different wireless service providers were promoting their favorite solutions. It was very hard to tell which solution would be the future industry standard. Moreover, there was not a protocol or specification that could ensure the interoperability among these competing solutions. As a result, the switching costs among different solutions were very high. If a brokerage company decided to build its wireless trading service at that time, it would inevitably be locked in a solution. This situation was exactly what we described as Category I – shared opportunity with high IT switching cost. So an electronic brokerage company must consider both the strategic benefit of early preemptive investment and the valuable option to wait. Because of the lock-in situation, electronic brokerage companies adopted the wait-and-see strategy. This strategy is the best one when the value of the option to wait overweighs the strategic benefit to invest earlier. Sometimes too aggressive investment strategy ignoring the technology risks may lead to disasters. A recent example is the failure of Iridium project-a global satellite communications system. Several industry giants including Motorola committed millions of dollars to build a network of low orbit satellites to provide global portable phone service when there were many uncertainties surrounding the competition between satellite system and terrestrial cell phone system. The project turned out to be a disaster when the cell phone system became the standard global wireless communications channel. Iridium officially shut down its network and declared bankruptcy in early 2000.

The situation surrounding the wireless trading project changed in May of 1998. The WAP Forum, co-founded by Phone.com, Ericsson, Nokia and Motorola published WAP 1.0 (Wireless Application Protocol 1.0) that is basically an open industry standard aims to integrate mobile telephony and the Internet technologies. A major function of WAP is to ensure the interoperability among various wireless Internet solutions. As a result, different technology vendors can still compete in the market, but they volunteer to develop their products subject to the technical specifications set in WAP. Because WAP makes the competing technology solutions more interoperable and compatible, the switching costs among different solutions significantly decrease. Electronic brokerage companies have more flexibility in building their wireless trading platform because the chance of being locked in one solution is very small. With the presence of an open technology standard like WAP, the investment opportunity of electronic brokerage firms evolves from Category I to Category II, namely, shared investment opportunity with low IT switching cost. As we discussed above, early preemptive investment is usually the best strategy for this category.

In Table 3, we conduct a real options based discounted cash flow analysis to demonstrate how the dynamics of technology competition may affect an electronic brokerage company's investment timing decision.

We assume that an electronic brokerage company needs to decide whether to build a wireless trading platform at the beginning of 1996. In our analysis, we use 01/01/1996 as the benchmark starting time toward which all future cash flows are discounted. If the company decides to invest immediately, it needs to spend C=\$4,000,000 to cover the investment cost. It expects that the first year cash flow is CF_0=\$500,000 and this number will grow at an annual rate g=20% thereafter. However, the company knows that it faces the possibility of getting locked in a potentially failing technology because several incompatible technologies are competing in the market. It estimates that the technology competition process will end after 2000. The annual cash flow growth rate after 2000 will become 0% if the technology adopted loses in the competition. Based

Table 3: Real Option Based Discounted Cash Flow Analysis of the Wireless Trading Project

Investment Cost C	**$4,000,000**		**Growth Rate g**	**Discounted Rate r**			
			20%	**30%**			
Projected Cash Flows Assuming Technology Competition Ends in 5 Years							
p=60%	(1/1/96)			**p=70%**	(1/1/97)		
0	Win	Lose		1	Win	Lose	
1996	$500,000	$500,000		1997	$500,000	$500,000	
1997	$600,000	$600,000		1998	$600,000	$600,000	
1998	$720,000	$720,000		1999	$720,000	$720,000	
1999	$864,000	$864,000		2000	$864,000	$864,000	
2000	$1,036,800	$1,036,800		2001	$1,036,800	g=0%	
2001	$1,244,160	g=0%		2002	$1,244,160		
…g=20%		$4,492,800	**Expected NPV**	…	g=20%	$3,744,000	**Expected NPV**
DCF	$1,000,000	-$1,420,083	**$31,967**	DCF	$769,231	-$1,247,505	**$164,210**
p=80%	(1/1/98)			**p=90%**	(1/1/99)		
2	Win	Lose		3	Win	Lose	
1998	$500,000	$500,000		1999	$500,000	$500,000	
1999	$600,000	$600,000		2000	$600,000	$600,000	
2000	$720,000	$720,000		2001	$720,000	g=0%	
2001	$864,000	g=0%		2002	$864,000		
2002	$1,036,800			2003	$1,036,800		
2003	$1,244,160			2004	$1,244,160		
…g=20%		$3,120,000	**Expected NPV**	…g=20%		$2,600,000	**Expected NPV**
DCF	$591,716	-$1,088,897	**$255,593**	DCF	$455,166	-$945,345	**$315,115**
p=100%	(1/1/00)						
4	Win						
2000	$500,000						
2001	$600,000						
2002	$720,000						
2003	$864,000						
2004	$1,036,800						
2005	$1,244,160						
…g=20%			**Expected NPV**				
DCF	$350,128		**$350,128**				
Introduction of WAP 1.0-An Exogenous Shock to Technology Competition Process							
p=90%	(1/1/98)			**p=100%**	(1/1/99)		
2	Win	Lose		3	Win		
1998	$500,000	$500,000		1999	$500,000		
1999	$600,000	$600,000		2000	$600,000		
2000	$720,000	g=0%		2001	$720,000		
2001	$864,000			2002	$864,000		
2002	$1,036,800			2003	$1,036,800		
2003	$1,244,160			2004	$1,244,160		
…g=20%		$2,600,000	**Expected NPV**	…g=20%			**Expected NPV**
DCF	$591,716	-$1,228,949	**$409,650**	DCF	$455,166		**$455,166**

on the information available and the company's best knowledge at that time, it estimates that the possibility of adopting the right (potentially winning) technology is p=0.6. We assume that the annual discounted rate is r=30%. There are two reasons why we use a relatively higher discounted rate. First, most electronic brokerage companies have high costs of capital because they are in a very competitive and risky business. Second, this investment opportunity is nonproprietary, which suggests that the cost of waiting is high. Now suppose the company implements the project immediately, the expected NPV can be calculated as

$$ENPV = p\sum_{t=0}^{\infty}\frac{CF_0(1+g)^t}{(1+r)^t} + (1-p)\left[\sum_{t=0}^{3}\frac{CF_0(1+g)^t}{(1+r)^t} + \sum_{t=4}^{\infty}\frac{CF_0(1+g)^3}{(1+r)^t}\right] - C$$

Given the specific parameter values, Table 3 shows that ENPV is equal to \$31,967. Since \$31,967>0, the company should commit the investment immediately based on traditional discounted cash flow analysis. However, the company knows that it has the option to wait to let more technology uncertainties be resolved. For example, it can defer the investment until 2000 when the technology competition is expected to end. At that time, the brokerage is 100% sure that it can adopt the right technology. We assume that the brokerage expects that p will grow from 0.6 to 1 with an annual increment of 0.1. In other words, the predictability of the future technology competition outcome grows linearly from 1996 to 2000, which is consistent with the fact that future uncertainties are resolved gradually. Based on this assumption, the company is able to calculate the expected NPV of the project implemented at each subsequent year after 1996. Table 3 shows that the expected NPV increases from 1996 to 2000 and reaches its maximum at \$350,128. So under this scenario, the company should wait until all uncertainties are resolved in 2000. It is easy to prove that the expected NPV will decrease after 2000 when the technology competition ends. Without the presence of uncertainties, waiting can only incur costs due to the discounting effect.

Suppose that the technology competition process unfolds as the company expected, it adopts a wait-and-see strategy until 1998 in which the WAP 1.0 standard is established. We model the introduction of the WAP open standard as an exogenous shock to the technology competition process. More explicitly, the emergence of an open standard significantly reduces the uncertainties surrounding the technology competition process. In our analysis, we assume that p increases from 80% to 90% at the beginning of 1998 due to this shock. One year later, the uncertainties of the technology competition are fully resolved, that is p=100%. An alternative approach is to model the effect of WAP as an exogenous reduction in the switching costs among different competing technologies. The first approach is used in our analysis. However, the second approach should yield similar results because lower switching costs result to less technology uncertainties. Table 3 shows the expected NPV of the project after this shock. The brokerage company's best strategy is to invest in 1999 and the expected NPV is \$455,166 (Note: To facilitate comparison, we still use 01/01/96 as the benchmark starting time to calculate the expected NPV). So the introduction of WAP has two direct effects on the company's investment decision. First, it increases the expected investment payoff of the project because the outcome of technology competition is more predictable. Second, it makes the option to wait less valuable by reducing future technology uncertainties.

In the cash flow analysis, we do not consider other non-technology uncertainties that tend to further increase the value of the option to wait. It is also worth noting that the magnitude of NPV plays a very important role in determining investment timing. For some lucrative projects, the best strategy is to give up the option to wait and commit investment immediately. The reason is simple: The loss of NPV due to the discounting effect may dominate the value of the option to wait if immediate investment can generate significant NPV.

Our analysis of this real world case suggests that the dynamics of the technology competition process play an important role in IT investment decision. In a separate paper, we proposed a new real options model to further explore the interrelationship between technology competition and IT investment timing.

CONCLUSION

Although some recent studies recognized the potential of real options theory in evaluating strategic IT investment opportunities, we believe that the applicability of various real options models should be scrutinized under different scenarios. Standard real options models assuming symmetric uncertainty in future investment payoffs can not be directly applied to the shared opportunities because of the competitive erosion. With the presence of potential competitive entry, real options analysis should balance the strategic benefit of preemptive investment and the value of the option to wait. IT switching cost is another important factor we must consider when we conduct real option analysis. As high IT switching cost or technology lock-in is very common in the digital economy, decision makers should pay more attention to the technology uncertainties before committing early investment to preempt their competitors.

Since the dynamics of the technology competition and standardization play an important role in IT investment decision, more studies should be done to incorporate it into the real options based decision-making process. We also believe that further real options analyses should be conducted to explore the functions of open standard and technology interoperability in fostering IT investment.

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