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Exploring ERP-enabled Technology Adoption: A Real Options Perspective

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Abstract:

For decades, practitioners and scholars have focused on achieving optimal values in and benefits from enterprise resource planning (ERP) systems. Given that scholars have identified ERP systems as having option-like characteristics such as the capacity to create an information technology (IT) platform that enables the adoption of subsequent function-specific applications, we face a need to explore the linkage between post-ERP systems implementation and subsequent ERP-enabled technology adoption. We used real options theory to explore the underlying relationship between the initial ERP system implementation and subsequent technology adoptions. We surveyed 519 IT executives in the United States and found that the level of technology uncertainty, managerial flexibility, and formal real option analysis in ERP adoption decisions influenced the organizational relative advantage of subsequent non-ERP technologies. Our results also reveal that the level of uncertainty had a negative relationship with ERP-enabled technology adoption, while formal real option analysis in ERP adoption decisions positively influenced ERP-enabled adoption.

Keywords: ERP Systems, ERP-enabled Technology, Real Options Theory, Adoption Decisions.

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1 Introduction

ERP systems are an important element of the corporate information systems (IS) infrastructure that allows companies to enhance operational efficiencies and implement positive changes (Jones, Zmud, & Thomas, 2008). Organizations of all sizes and across the industrial spectrum continue to embrace ERP systems as solutions to fragmented information and inefficient business processes (Hong & Kim, 2002). Cao, Nicolaou, and Bhattacharya (2013) surveyed global chief information officers and found that ERP systems deployment and expansion continues to dominant IT investment. Although many organizations boast about successfully deploying and using ERP systems, post-implementation outcomes continue to vary among those companies that implement ERP. Furthermore, as more organizations view ERP implementations in a broader strategic context, they realize that an ERP system's benefits are limited if functional managers cannot identify, apply, and leverage the values and inherent opportunities in these underlying platform technologies. Indeed, a Forrester survey found that close to 30 percent of firms have invested in enhancements upgrades and third party ERP-enabled applications (Cao et al., 2013).

Researchers and practitioners alike have tried to understand and address the variation in ERP post-implementation outcomes by examining conditions that foster successful ERP implementation in companies (Hong & Kim, 2002). However, despite a large body of work on ERP systems that ranges from critical success factors of ERP implementation to investigations about ERP benefits realization (Mu, Kirsch, & Butler, 2015; Nwankpa & Roumani, 2015), little work has focused on understanding post-implementation adoption decisions that go beyond the initial ERP adoption (Nwankpa et al., 2013; Cao et al., 2013). However, at the core of an ERP implementation is having a system with organizational-wide impact that continues to drive success. To address this gap in the literature, we need to explore and determine post-implementation decisions. The initial ERP adoption decision may involve typical innovation and adoption factors, but the decision to extend the deployed ERP footprint beyond the core functionality may represent a strategic value-adding adoption decision with unique considerations (Nwankpa et al., 2013). Thus, the current information systems literature could benefit from a theory-driven inquiry into ERP post-implementation opportunities and ERP extension models that transcend the organizations' existing ERP systems.

IS literature has long advocated the concept of real options as a technique to evaluate IT investments, especially given their uncertainty and irreversibility (Benaroch, 2002; Fichman, 2004). Conventional discount cash flow (DCF) techniques fail to adequately capture future opportunities, managerial flexibility, the capability to benefit from uncertainty, and the dynamic nature of IT positioning investment (Benaroch, 2002; Fichman, 2004; Schwartz & Zozaya-Gorostiza, 2003) leading to undervaluation of IT projects. A real option, which is the right but not the obligation to undertake some business decisions and to obtain benefits from future opportunities, can serve as an investment appraisal capable of considering the risks and uncertainties associated with an investment while still recognizing active management's ability to intervene and act on the options created by this initial investment. DCF analysis, while accommodating cash flows, ignores the presence of options and the impact of managerial flexibility and interventions in response to environmental conditions.

Applying real options reasoning in the context of ERP implementation allows managers to recognize the associated options accompanying an ERP deployment. Thus, it provides managers with the right but not the obligation to exercise these embedded options through post-ERP implementation decisions. Such options include adopting subsequent ERP-enabled add-ons and function-specific applications. Few studies on real options and ERP systems have focused their attention on demonstrating that real options analysis presents a more complete picture of ERP investments because of the option-like characteristics that separate enterprise systems from other IS platforms (Taudes, Feurstein & Mild, 2000; Tiwana, Keil, & Fichman, 2006; Wu, Ong, & Hsu, 2008).

Against this backdrop, we used real options theory as a theoretical lens for understanding and exploring post-ERP implementation adoption opportunities created by ERP systems. Using real options theory, we examined how firms can identify the options embedded in an ERP system and how these options shape subsequent technology adoption as organizations attempt to exercise the optional values embedded in their ERP systems. We developed and empirically tested a model that worked to examine two central questions that the ERP literature has not adequately investigated:

1) What factors influence the adoption of ERP-enabled options?

2) How do real option factors in the ERP adoption decision affect subsequent ERP-enabled technologies?

We empirically tested our model using data collected through a survey of 519 IT executives from a diverse set of U.S. organizations.

Our focus on investigating ERP-enabled adoption using real options sets this study apart from existing literature, which has primarily examined IT valuation using real options and focused on how real options analysis can capture a complete picture of IT investment values (Panayi & Trigeorgis, 1998; Taudes et al., 2000; Fichman, Keil & Tiwana, 2005). Given that options are already part of the initial ERP investment for ERP implementing companies, this study extends the current literature by examining factors that influence the organizational relative advantage of these embedded options and its impact on ERP-enabled adoption. Furthermore, by examining ERP-enabled adoption, this study captures ERP implementation as a sequence of managerial decisions made over time rather than a one-shot view that previous ERP research has applied.

Moreover, this study furthers our understanding and contribute to the stream of research that examines IS successes. The IS success model suggests that technology adoption and innovation should be capable of creating an organizational impact in order to realize overall IS success (DeLone & McLean, 1992, 2003). ERP systems are enterprise-wide applications that can create a significant organizational impact; however, ERP-enabled adoption provides the mechanism through which organizations can further extend the systems overall impact in their organizations. We argue that understanding the factors that foster ERP-enabled adoption will enable organizations to extend ERP footprint across all their facets and lead to increased IS success.

This paper proceeds as follows. In Section 2, we discuss the background literature and associated real options factors; namely, level of uncertainty, managerial flexibility and real options analysis in ERP adoption, organizational relative advantage, and ERP-enabled adoption. In Section 3, we discuss the research model and hypotheses. In Section 4, we discuss the methodology we used. In Section 5, we discuss how we analyzed the data and report the empirical findings. Finally, in Section 6, we discuss our findings' implications for theory and practice, the study's limitations, and the potential avenues for future research.

2 Theoretical Background

2.1 ERP-enabled Adoption

ERP-enabled adoption refers to adopting and deploying subsequent technologies that occur after initially implementing an ERP system. Such adoption works to leverage an ERP system's information and integrated platforms with add-ons and function-specific applications. ERP vendors have recognized the importance of add-ons and third party applications and now provide platforms and interfaces that are friendly to integrating third party applications (Nwankpa et al., 2013). For example, SAP ERP 6.0 and Oracle e-business suites are built on a technical architecture that enables easier third-party application integration and package enhancement.

Many firms now view the initial ERP implementation as a base technology that permits firms to integrate such additional applications as data warehouse, data-mining solutions, and Web-enabled e-commerce applications (Willis & Willis-Brown, 2002). The initial adoption and implementation of an ERP system is equivalent to the option premium whereby a company invests in an amount—a sunk cost—that enables it to retain the ability to exercise the optional values at a later date. Recognizing these ERP options provides one with future opportunities to extend the reach and scope of the ERP system. Ignoring or not promptly taking steps to adopt subsequent technologies and capabilities could hinder one from realizing an ERP system's benefits. Managers who choose to defer or even ignore investment opportunities in technology platforms may not lay claim to the same future benefit since the investment's timing is a key consideration in maximizing its value (Dierickx & Cool, 1989). Thus, firms that extend their ERP systems beyond the core applications and capabilities are in a good position to optimize business processes, extend functionalities, and achieve higher returns on their ERP investment (Wu et al., 2008; Tiwana et al., 2006).

2.2 Real Options

Stewart Myers in 1977 pioneered the term “real options”. Myers recognized that one could apply option pricing theory to real assets and non-financial investments. Myers coined the term real options to differentiate the options on real assets from financial options traded in the market (Myers, 1977). A “financial option” refers to the right but not the obligation to buy a stock at a fixed price on or before a given date. When investors buy options, they spend a little to retain the flexibility of putting off decision making until a future date when they have greater certainty. The initial phase of an investment project is implicitly comparable to buying an option; as such, discretionary investment options should be the components of an investment market value (Myers, 1977). Thus, a “real option” refers to the right but not the obligation to take some action in the future in response to an event (Benaroch & Kauffman, 2000; Myers, 1977).

One establishes options by making initial investments such as creating a joint venture, developing a prototype, or implementing a technology platform (Krychowski & Quelin, 2010). The initial investment gives a firm the ability to partially commit to an investment and to defer certain decisions until information become clearer. The framework for real options is based on the understanding that, in the face of high uncertainty, one postpones the commitment until one knows a substantial part of the uncertainty (Song, Makhija, & Kim, 2015). Real options analysis explicitly accommodates uncertainty by making it possible for firms to adjust investment decisions during the course of the investment lifecycle as information becomes available (Krychowski & Quelin, 2010). In essence, real options are opportunities on real assets that can provide value in terms of operational flexibility and strategy.

Real options analysis gained popularity because of its ability to consider managerial flexibility, its recognition that investment projects can evolve over time, and its understanding that uncertainty can be beneficial. Flexibility encompasses the portfolio of options available to management as a result of investing in a project (Mason & Merton, 1985). Also, flexibility enables managers to apply real options embedded in an investment in such a way as to negate the potential unfolding of uncertainties (Benaroch, 2002). Thus, firms can use small initial investments to gain strategic flexibility to defer and scale investment decisions until uncertainty is reduced (Barnett, 2008; Bowman & Hurry, 1993). Li (2014) argues that, in an IT outsourcing relationship, two outsourcing partners start their outsourcing relationship with the understanding that the relationship comes with embedded options to expand operations based on future occurrences. Making an initial investment enables management to sacrifice a little while retaining the ability to exercise these options when information becomes clearer.

If properly applied, real options analysis allows one to more accurately evaluate investment decisions than previously available since it includes the values of the options embedded in the investment (Benaroch & Kauffman 2000; Taudes et al., 2000). Yet, not all investments are appropriate for real options analysis because four main conditions need to exist for one to evaluate an investment with real options logic: irreversibility, uncertainty, flexibility, and information revelation (Krychowski & Quelin, 2010). Irreversibility means that the IT investment is scarce and difficult to replicate in a timely way due to high learning costs, switching costs, and deployment costs (Kogut & Kulatilaka, 2001). Uncertainty means that the IT investment or technology has an unpredictable evolution (Fichman, 2004). Flexibility refers to the ability to choose among several alternatives as options expire (Krychowski & Quelin, 2010). Finally, information revelation refers to the possibility of reducing uncertainty associated with the option by obtaining additional information (Krychowski & Quelin, 2010). Such conditions give real options analysis superiority when compared to other valuation techniques; indeed, Fichman (2004) argues that real options analysis best suits innovative IT platforms with high uncertainty and high irreversibility.

Dos-Santo’s work (1991) pioneered the application of real options reasoning in the IS discipline. Using Margrabe’s model for exchanging options to determine the value of an option in a new technology, Dos Santos (1991) argues that a major portion of the value of a new IT investment derives from future use and new investment opportunities that the new technology creates. According to Dos Santos (1991), one should recognize the value of organizational knowledge and learning gained after the initial investment that subsequently results in future investments. Thus, recognizing these future investment opportunities as options could potentially increase the pre-investment valuation of a new IT investment. Dos Santos argues that recognizing only the user-oriented benefits of a new IT project without reflecting that the new IT investment could improve the organization’s technical ability in the future could significantly undermine the true value of such an investment. Connecting an initial IT investment benefit or value to only the system’s users ignores the flexibility of future valuable projects that such an initial IT project can enable as more information emerges. For instance, a certain IT investment may not be justifiable or worthwhile if the necessary baseline technology or technical architecture is lacking. In a rapidly evolving technological environment with a high degree of uncertainty, managers face the task of discerning new technologies and deciding which technology to adopt. Thus, investing in an IT project that enables the firm to undertake future projects accounts for a major portion of the value of the initial IT project (Dos Santos, 1991).

IT investments are indeed bundles of interconnected investment options (Panayi & Trigeorgis, 1998). Thus, failing to execute any of these options would lead to the loss of resultant options and subsequent investment opportunities. Taudes (1998), in establishing a framework for determining options value in software, reaffirms this view by observing that IS platforms have "software growth options" embedded in them that enable one to introduce new IS functions to them. Taudes posits that IS functions present in a software application represent a key proxy for evaluating it. McGrath (1997) extended the literature by developing a framework of factors that influence the value of a technology option. In her paper, she argues that factors outside the technology affect the options and potential values. Hence, to maximize the values of a technology position investment such as an ERP system, firms may need to understand the relationship between the boundary condition and uncertainty factors and to understand the appropriate time to exercise the options.

2.3 Real Options and ERP Systems

Research on ERP systems and real options has focused on valuation and justification issues that managers face prior to approving projects. Such research has focused on demonstrating that ERP systems, as technology positioning investments (Fichman, 2004), have option-like characteristics that make such systems unique and different from many IS platforms (Devadoss & Pan, 2007; Nwankpa et al., 2013). Furthermore, prior research has employed a case study approach and compared real options analysis with traditional discount-factor techniques such as net present value (NPV) and decision tree (DT). For instance, Taudes (2000), using real options analysis, reveals that the decision to either upgrade an existing version of an ERP system or to implement a new version is complicated and requires a valuation technique that can recognize future opportunities and benefits. The justification to implement the new SAP R/3 was that the new system would enable such subsequent investments as electronic data interchange-based purchasing and invoicing, workflow application, and Web-based e-commerce. In the same light, Wu et al. (2008) suggests that options embedded in ERP systems can mitigate a project's risk component. They conclude that, although ERP systems are risky projects, the options embedded in them create managerial flexibility that active management can exercise to minimize potential exposure to such risk.

Prior studies have attempted to develop a real options based methodology for evaluating and justifying an ERP-based hospital information system (Ozogul, Karsak, & Tolga, 2009). Using a case study, Ozogul et al. show that one can justify an investment if one applies the appropriate valuation technique capable of capturing both explicit and implicit values of the investment. They identify a multiple-phased approach that involves isolating the options in an investment, the interaction among them, and the nature of the flexibilities they offer and then evaluating the options. Furthermore, Ozogul et al. conclude that recognizing the options that investments enable can better equip managers to deal with uncertainties and the associated risk of such investments.

By their nature, ERP systems require a long and rigorous implementation process that involves a dynamic active management that can respond to the changing business environment (Wu et al., 2008). Hence, applying a real options perspective to ERP implementation allows management to not only recognize these associated options but also deal with uncertainties encountered during ERP deployment. These options enhance flexibility by providing managers with the right but not the obligation to make certain functionality implementation decisions such as adopting, scaling, deferring, switching, and abandoning during the implementation process (Benaroch & Kauffman, 1999; Wu et al., 2008; Tiwana et al., 2006).

2.4 Organizational Relative Advantage

Organizational relative advantage measures how much a firm perceives a technology or system to be valuable to the firm or how much better the technology is than the one being replaced (Rogers, 1995). Typically, organizations will not consider adopting an innovation if they do not see any relative advantage in doing so. Relative advantage is an important determinant of innovation diffusion because it captures the sum of values as perceived by the innovation's intended users (Moore & Benbasat, 1991). From an organizational perspective, managers are interested in the relative advantage that a specific ERP-enabled technology will bring to their firm. An initial investment in an IS platform, such as an ERP system, provides the right but not the obligation to exercise future deployment and growth opportunities embedded in the technology. These future opportunities are valuable options because they allow firms to build on the initial investment and make additional IT investments that may not have been possible without the initial investment (McGrath & Nerkar, 2004; Tallon, Kauffman, Lucas, Whinston, & Zhu, 2002). However, in making these decisions, managers may need to evaluate the relative advantage of the technology to establish the benefits associated with that adoption. Thus, the relative advantage of adopting technology after one has made an initial investment will depend on how well that initial investment facilitates and enables such applications with greater relative advantage to be implemented.

3 Research Model and Hypotheses Development

Building on the background literature discussed above, we develop a research model based on a theoretical rationale from real options framework. Application of the real options framework exist in multi-stage IT investments, risks, IT adoption, joint ventures (Pendharkar, 2010; Tiwana et al., 2006; Fichman, 2004). Consistent with the prior literature on real options, our model considers level of uncertainty, managerial flexibility, and formal real option analysis at the time one initially invests in IT as key elements one considers when choosing whether to adopt subsequent technology. Prior research on adoption has identified uncertainty as a barrier to adopting organizational technology (Grover & Goslar, 1993; Ulu & Smith, 2009; Chau & Tam, 2000). High uncertainty can obscure or deter adoption decisions for organizations. Uncertainties may arise due to one's difficulty in determining the adoption cost and complexities associated with replacing existing technology (Chau & Tam, 2000). Businesses and end user adopters attempt to reduce uncertainty by focusing on the innovation features or technology characteristics (Karahanna, Straub, & Chervany, 1999). Therefore, managers perceive innovation and technology adoptions as processes of reducing uncertainty and gathering information (Agarwal & Prasad, 1998). Organizations gather information to ensure that they reduce uncertainty to a minimum level prior to adopting technology. Extant literature suggests that using real options analysis as a formal valuation technique can foster conditions for adopting subsequent technologies (Tiwana et al., 2006; Nwankpa & Roumani, 2015). Applying formal real option analysis when initially deciding whether to invest in IT creates the awareness of potential options embedded in the investment, which results resulting in post-adoption behavior (Fichman, 2004). Prior studies and anecdotal evidence that suggest that managerial flexibility is vital precursor for the post-adoption activities of platform technologies such as ERP systems informed our choosing managerial flexibility as an antecedent for post-ERP adoption (Kauffman & Li, 2005; Fichman 2004). We also consider organizational relative advantage based on prior investigations as an important aspect of post ERP adoption decisions (Nwankpa et al., 2013). After one has already adopted an ERP, an additional technology's relative advantage is a key enabler of ERP-enabled adoption because such add-ons allow ERP-implementing companies to remain agile and strategically responsive to the evolving business climate (Nwankpa et al., 2013). Figure 1 provides a research model underlying our study. We discuss the specific hypotheses in Section 3.

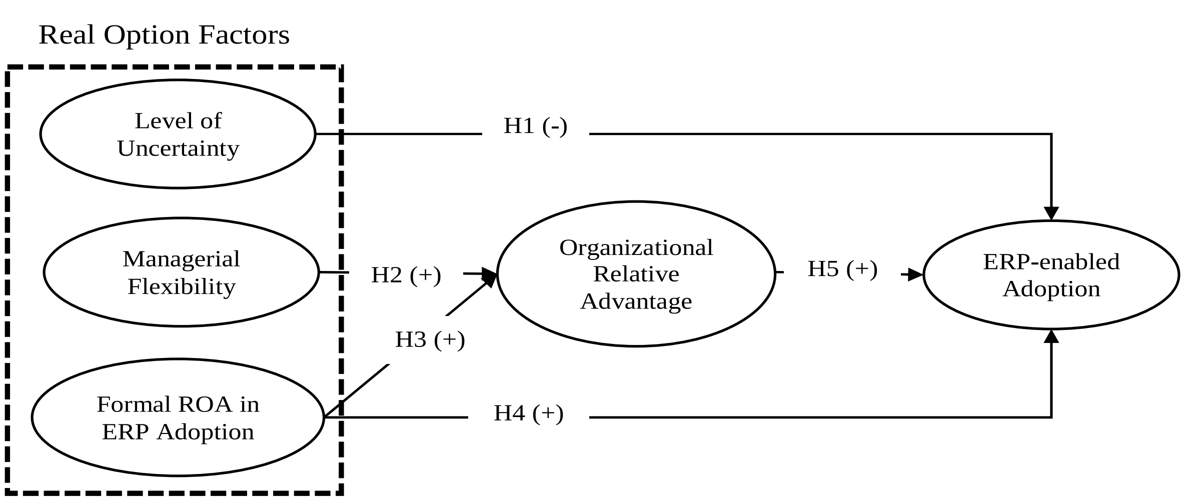

Figure 1. Real Option Factors

3.1 Real Options Factors

3.1.1 Level of Uncertainty

The level of uncertainty is an important parameter in a firm's IT investment and technology adoption decision making. Uncertainty refers to the unpredictability of possible outcomes. Uncertainty in IT investments arises due to the unpredictability in the evolution of technology and due to the path dependency that such technology imposes on the adopting enterprise's future technology path (Fichman, 2004). This unpredictability stems from inadequate information needed to assess, obtain, and implement IT investments (Stock & Tatikonda, 2008). Thus, IT investment uncertainty exists because of the gap between the information that managers need to obtain and implement technology and the information available at the time when deciding to or not (Stock & Tatikonda, 2008). Uncertainties may arise due to immature and complex technology, the unpredictability of its evolution (Fichman et al., 2005), and environmental uncertainties inherent in the technology (Benaroch & Kauffman, 2000). For example, environmental uncertainty can create unanticipated changes in circumstances that alter the project's anticipated outcome. Such environmental uncertainty may arises due to the volatility and unpredictability of changing business environment, emerging opportunities for growth and the complexity of entities within the business domain (Xue, Ray, & Gu, 2011).

Prior studies that have examined the impact of uncertainty on firms' investment decisions have found that investment and uncertainty have a negative relationship (Ghosal & Loungani, 2000). Anecdotal evidence has suggested that, in the face of high uncertainty and irreversibility, real options analysis better suits evaluating investment opportunities compared to traditional evaluation techniques (Benaroch & Kauffman, 2000; Fichman et al., 2005). The greater the technological uncertainty, the more likely firms will purchase option contracts for interventions (Ziedonis, 2007). Buying an option (e.g., a license) enables firms to retain the ability to benefit from these uncertainties (Fichman, 2004). Nevertheless, while option values increase with uncertainties, exercising these embedded options depends on the level of uncertainty's decreasing over time and on having the information necessary to make decisions. Thus, real options reasoning explores the uncertainty factor by providing the desirability of waiting for uncertainty to be resolved prior to making subsequent investment (Pindyck, 1991; McGrath & Nerkar, 2004). Hence, firms make adoption decisions about options only when uncertainty has diminished to an acceptable level and the decision makers can comfortably exercise these options (Ziedonis, 2007). From an options perspective, high uncertainty increases the value of a firm's investment opportunity but decreases its level of actual investment (Pindyck, 1991). For firms seeking to adopt specific ERP-enabled applications, their level of uncertainty with their current ERP system and the subsequent ERP-enabled technology will influence how well the subsequent technology will align and perform with the existing ERP. As such, we hypothesize:

> **Hypothesis 1:** Level of uncertainty negatively affects ERP-enabled adoption**.**

3.1.2 Managerial Flexibility

Managerial flexibility refers to managers' ability to take appropriate actions in response to the changing IT environment (Wu et al., 2008; Fichman, 2004). Since the business environment has much complexity and uncertainty, firms have embraced flexibility as a way of mitigating it. Prior studies on organization flexibility have argued that firms need to retain the capacity to respond to changing business conditions. Firms with such dynamic capacities can respond to changes. Flexibility results from an interaction between an organization's responsiveness and its management's abilities (Volberta, 1996). Such flexibility manifests in managers' actions as unanticipated events unfold.

The value of managerial flexibility has received a lot of attention in IS literature. Jorgensen and Wallace (2000) suggest that managerial flexibility's value lies in the difference between the expected value of a reactive approach and the expected value of a static approach. Furthermore, the real option literature has strongly advocated including managerial flexibility value in investment justification. For instance, Dos Santos (1991) argues that flexibility allows management to make considerable adjustments to how a project proceeds after the firm initially invests in it and that it should consider such ability when justifying whether to do so. The main thrust of real options analysis is the ability to recognize that project investment can evolve over time and that such flexibility is valuable (Krychowski & Quelin, 2010). In fact, real options theory does not dictate that one use any particular pricing model; rather, it recognizes the value of managerial flexibility in justifying investments (Benaroch & Kauffman, 2000; Benaroch & Kauffman, 1999). Thus, when faced with high uncertainty and irreversibility in making an initial IT investment, omitting the value of managerial flexibility can significantly understate that investment's value (Benaroch & Kauffman, 1999; Fichman, 2004; McGrath & Nerkar, 2004).

Recently, managerial flexibility has become a key factor in deploying technology in organizations as manager's grapple with an ever-changing competitive environment. In fact, Barnett (2008) argues that managerial flexibility enables managers to intervene in limiting losses and that these interventions have value and substantial upside potential. Thus, the inability of traditional project-evaluation techniques to account for this value has led firms' rejecting high-risk but potentially viable projects.

One can view managerial flexibility as management's ability to reshape strategies and respond to risks of an ERP post-implementation lifecycle (Wu et al., 2008). By having an active management, organizations can take appropriate actions and respond to environmental changes that will facilitate desired results.

Managerial flexibility and organizational relative advantage are two constructs that can be related. If managers are flexible and can respond to changes, then they are more likely to embrace the new technologies enabled by the ERP platform. Such a mindset on innovations and new technologies will typically increase the perceived organizational relative advantage of subsequent technology because organizations will put in place mechanisms that enable additional adoption of newer add-ons and applications. Organizations that have already institutionalized an environment that fosters agility and flexibility will view ERP-enabled technology adoption as a way to deal with an evolving climate and diminished uncertainty (Nwankpa & Roumani 2015). Thus, managerial flexibility can positively influence the relative advantage of ERP-enabled adoptions as managers are aware that they can actively respond to the changing conditions when implementing the technology and during projects' lifecycles. Adopting an ERP-enabled application is a form of change, and a flexible mindset is likely to discount the importance of change-based disruptions associated with subsequent technology adoption and would increase the perceived relative advantage of the technology. As such, we hypothesize:

Hypothesis 2: Managerial flexibility positively affects organizational relative advantage.

3.1.3 Formal Real Options Analysis in ERP Adoption

Real options analysis considers the potential opportunities and future options when evaluating an investment decision. Traditional valuation techniques (e.g. standard discounted cash flow) do not incorporate future opportunities (Benaroch, 2002; Dos Santos, 1991; Krychowski & Quelin, 2010; Taudes et al., 2000). Also, while one can use traditional techniques to evaluate stable and static investments, such techniques omit the value of future opportunities when used to evaluate investments with high uncertainties and potential growth. Such investments require active and flexible management to unlock these future opportunities (Taudes et al., 2000). In contrast, real options analysis captures the total value of potential investments by computing an option's potential value against its potential cost. Thus, real options analysis enables managers to identify favorable opportunities that arise from a particular IT investment decision (Fichman, 2004). The ability to have such a tool is vital, especially to IT managers who repeatedly face difficult investment decisions involving high uncertainty and incomplete information (Tallon et al., 2002). Real options can provide managers with the appropriate lens to make a current investment while retaining the ability to explore potential opportunities. Indeed, viewing an IT investment in isolation can negate the potential benefits that one can derive from such an investment because managers may lack the innovative mindfulness and agility to recognize an opportunity that can provide a firm with competitive advantages. According to Tallon et al. (2002), real options analysis can assist one in setting organizational goals prior to implementing an IT investment. Tallon et al. (2002) further argue that applying real options when evaluating a project can assist one in identifying the expected goal with the investment life. With real options, decision makers can specify the benefits their firm can realize in the short and long term and the likelihood the firm will achieve them.

While organizations have embraced real options reasoning for its ability to accommodate uncertainties and to allow managers to gain insight into future possibilities enabled by IT investments, the formal process of arriving at the options value depends on the organization. Researchers have proposed two basic models for pricing financial options: the Black-Scholes model (Hull, 1993), and the binomial model (Benaroch & Kauffman, 2000). The Black-Scholes model is typically associated with valuing options on financial securities, but IT scholars and practitioners have since adapted it to value non-financial investments such as IT investments (Amram & Kulatilaka, 1999). The Black-Scholes model calculates the price of a call option by using five key determinants: stock price, strike price, volatility, time to expiration, and short-term interest. In contrast, the binomial model breaks down the time to expiration of the options into potential large number of time intervals and assumes that the stock price will move up or down by an amount calculated using volatility and time to expiration. Some studies have also attempted to validate these models for valuing IT investments. Kambil, Henderson, and Hohsenzadeh (1993) used a binomial option pricing model to determine whether to execute a pilot project in a handheld technology. They found that, while NPV-based analysis rejected the idea, the binomial options model found that the options value exceeded the cost of the project and, hence, recommended executing the project.

However, managers rarely use these models because they involve complex computational variables, and some managers hesitate placing numerical values on future opportunities (Tallon et al., 2002). Even without complex mathematical computations, managers tend to identify future opportunities and attempt to value the benefits that such applications can bring to their organization (Taudes et al., 2000). This approach, while informal, can allow managers to identify potential future benefits and make conservative estimates based on current trends and the environment. A firm's preferred quantitative model needs to capture two distinct values: the value of the underlying asset and the value of specific future implementation opportunities enabled by the underlying asset.

Thus, real options allow managers to identify future opportunities by recognizing and deferring such opportunities to a time when adequate information is available. Moreover, formal real options analysis employs quantitative models to gain insight into potential risks and deal with the high level of uncertainty associated with new additional technologies. In addition, formal real options analysis when initially implementing a technology gives organizations the ability to enhance flexibility by making the underlying technology more generic, multi-purpose, scalable, and interoperable (Fichman et al., 2005). Hence, formal real option analysis can moderate the organizational relative advantage of the follow-up technology As Fichman et al. (2005) note, one cannot preordain the flexibility associated with an IT platform; thus, real options analysis enables organizations to put in place the measures needed to influence the relative advantage of subsequent technology Recognizing at the initial stage of ERP implementation that there will be follow-up projects are likely to set a stage that facilitates smoother adoption of such future applications. As such, we hypothesize:

Hypothesis 3: Formal real options analysis in ERP adoption positively affects organizational relative advantage.

Hypothesis 4: Formal real options analysis in ERP adoption positively affects ERP-enabled adoption.

3.1.4 Organizational Relative Advantage

Organizational relative advantage measures how an organization perceives a technology to be valuable. Arguably, firms that apply formal real options analysis during an initial ERP adoption decision can identify subsequent beneficial technologies they can adopt during the ERP lifecycle. Real options analysis builds on the premise that the value of such add-ons and ERP-enabled technologies are significant components of the overall ERP investment. Thus, recognizing and incorporating such options can have a strategic and beneficial implication (Nwankpa et al., 2013).

However, the relative advantage of the subsequently adopted technology will depend on how well the initial investment facilitates and enables other applications. The value of a software platform lies in the options it creates to build more applications (Taudes et al., 2000). Thus, the options embedded in an initial investment will be high if the investment allows one to build several applications with relative advantage in the platform. Exercising these options and building on the platform is a function of how well the intended technology supersedes the existing one. Prior literature has argued that one can use IS functions present in a software platform as a proxy for evaluating the potential growth options of the initial investment (Taudes et al. 2000).

A real options perspective enables one to preserve choices that allow a firm to take a variety of actions such as scaling up, abandoning, changing direction, or delaying as information becomes available (McGrath & Nerkar, 2004). Research has identified growth options and operational growth as the key options embedded in an IT platform such as an ERP system (Tiwana et al., 2006). The operational options give managers and decision makers flexibility during the implementation process. Such options include the deferral option, the stage option, the abandon option, and the option to change scale.

While options embedded in an IT investment provide future opportunities for follow-up investments (Tiwana et al., 2006; Trigeorgies, 1995), managers make such follow-up decisions based on the perceived benefits and advantages of the subsequent technology or add-on applications. Indeed, such follow-up investments can be both strategic and non-strategic in nature. The non-strategic adoptions are those potential growth options that add value but do not strategically affect the firm. For instance, an ERP system platform may provide opportunities to implement operational third party applications that enhance process efficiency in a business operation. In fact, the operational growth option provides opportunities for add-ons and investments that may not be anticipated during the initial investment. These expansion activities are valuable because they give firms the flexibility to take advantage of favorable opportunities and future benefits. The strategic growth option exists when an IT investment or one of its parts opens up future opportunities that allow firms to respond favorably to long-term business goals. Strategic growth options lead firms to create new investments that relate to the old one but that go beyond those that the base technology creates (Benaroch, 2002). Implementing an ERP system as a baseline investment would enable additional investments such as electronic data interchange-based purchasing and invoicing, workflow applications, and Web-based e-commerce (Taudes et al., 2000). Similarly, an ERP system might provide the baseline for supply chain management systems in the future (Tiwana et al., 2006). However, while initially investing in an ERP system creates options to adopt EDI and workflow applications, the system's relative advantage (as an organization perceives it) will influence its decision to adopt these specific applications at a later date. As such, we hypothesize:

Hypothesis 5: Organizational relative advantage positively influences ERP-enabled adoption.

3.1.5 Control Variables

To minimize the confounding effect of spurious correlation, we included firm size and time elapsed since ERP system implementation (duration) as control variables in this study. We included firm size because research has found it to determine firm performance and innovativeness (Rai, Patnayakuni, & Seth, 2006; Kim & Lee, 2010). Larger firms can benefit from economies of scale that arise from available human capital and financial resources. In addition, we included the length of time that had elapsed since the firm implemented the ERP system as a control variable.

4 Research Methodology

4.1 Construct Operationalization

We operationalized constructs by developing and, in some cases, using validated items from prior research with minor modifications in words to fit the investigation context. Following Petter, Straub, and Rai's (2007) recommendations, we operationalized these constructs using multiple reflective measurement items. We derived the measures of organizational relative advantage from Moore and Benbasat (1991). We used multiple item measures for most variables to increase their reliability and validity (Churchill, 1979; Nunnally, 1978). Furthermore, we adapted validated measures from usefulness constructs to enhance confidence. Researchers have argued that usefulness and relative advantage are the same constructs (Carter & Belanger, 2005, Venkatesh, Morris, Davis, & Davis, 2003). For instance, Venkatesh et al. (2003) combined the two constructs as one in their united theory of acceptance. In total, seven items measured organizational relative advantage using a seven-point Likert-type scale (1 = strongly disagree; 7 = strongly agree). Measuring the variables using a seven-point Likert-type scale is consistent with prior literature (Venkatesh & Davis, 1996).

We measured managerial flexibility based on a four-item measure that we developed based on prior literature (Huchzermeier & Loch 2001; McGrath, 1997; Fichman, 2004). These managerial flexibility measures reflect management's ability to reverse, delay, alter, and expand on its ERP capability through ERP-enabled additional technologies. Furthermore, we measured level of uncertainty with four items that reflect the newness and unpredictability of the additional technology outcomes at the time of the adoption decision. We adapted three of the items measuring the level of uncertainty from Ragatz, Handfield, and Petersen (2002), while we developed one item based on real option literature (Fichman, 2004; Taudes et al., 2000). Given the absence of established measures for formal real options analysis, we developed multiple item measures based on prior literature. We measured formal real option analysis using a three item seven-point Likert-type scale that reflected organizational ability to recognize future growth opportunities (Taudes et al., 2000; Fichman, 2004). We derived these measures from theoretical statements made in the literature (Taudes, 1998; Taudes et al., 2000).

Finally, we operationalized the dependent variable, ERP-enabled adoption, as a percentage of adoption, which Innovation and technology adoption research commonly uses (Grover & Goslar, 1993; Nwankpa et al., 2013). Appendix A provides further details about each construct and its measurement items.

4.2 Sample and Procedures

The firm is the unit of analysis in this study. Hence, for our subjects, we focused on IT decision makers such as chief information officers (CIO), the chief technology officers (CTO), and vice presidents of IT operations. When using perceptual measures and single respondents, one needs to solicit data from the most qualified and well-informed individual in an organization (Huber & Power, 1985). As such, we chose IT executives as the key informants. These executives typically deal with the decision making processes of their organizational technology needs. We used the directory of executives from Dun and Bradstreet's Million Dollar database (Cooper & Schindler, 1998; Tiwana et al., 2006) to identify a random sample of IT executives. This database provided contact information for executives in various positions in firms in the United States. We applied two qualifying factors in the sample selection: 1) that the IT executives' firms used ERP systems in their operations and 2) that the firms had adopted an additional application or technology that their existing ERP system supported or enabled. Prior to conducting the survey, we administered a pilot study of the survey questionnaires. Appendix A provides further information about the pilot study.

Table 1. Sample Characteristics

Classification	Number of respondents	Respondents (%)
Firm's size (market capitalization in USD)		
Less than $250 million	127	24%
251- 500 million	112	22%
500 - 999 million	119	23%
1 - 4.9 billion	99	19%
5 - 9.9 billion	31	6%
10 billion or more	31	6%
Industry		
Construction	67	13%
Education	5	1%
Financial	31	6%
Information technology	36	7%
Manufacturing	125	24%
Retail	78	15%
Service	145	28%
Telecommunication	16	3%
Other	16	3%
Time elapsed since ERP implementation		
1 - 3 years	124	24%
3 - 6 years	133	26%
6 - 10 years	125	24%
More than 10 years	137	26%
Job title of respondents		
Chief information officer	359	69%
Chief technology officer	88	17%
Vice president of IT operation	46	9%
IT director	26	5%

We contacted each IT executive through an email communication that included a Web-based link containing the survey instrument. The randomly selected sample from Dun and Bradstreet's Million Dollar database comprised 4,337 IT executives, 575 of whom returned responses. However, we discarded 29 responses due to incomplete questionnaires and found an additional 27 responses unusable. Out of 575 responses, 519 were usable, which resulted in an actual response rate of 12 percent. Table 1 provides sample characteristics. To reduce the likelihood of single source bias that typically occurs due to self-promotion and exaggeration, we assured all IT executives that the results would be completely anonymous.

5 Data Analysis and Results

We analyzed and empirically validated our hypotheses with partial least squares (PLS) analysis. We selected PLS because it enables one to specify and test path models with latent constructs and because it places minimal restrictions on measurement scales, sample size, and residual distribution (Chin & Newsted, 1999). Further, PLS allows one to model latent constructs as reflective indicators as was the case with our data. We used SmartPLS 2.0 (Ringle, Wende & Will, 2005) software for the analysis. SmartPLS 2.0 performs bootstrapping analysis to assess the statistical significance of the loading and path coefficients (Ringle et al., 2005). Consistent with prior research that has used PLS models (Hull, 1999; Chin 2001; Gefen & Straub, 2005), we analyzed the research model in two stages. The first stage involved assessing the reliability and validity of the measurement model, and the second stage involved assessing the structural model (Hull, 1999).

5.1 Assessment of Potential Response Bias and Common Method Bias

To ensure that the responses were free from non-response bias, we followed the approach that Armstrong that Overton (1997) suggest and compared early and late responses. Early respondents were those who responded to the initial email, while late respondents were those who responded after the second email reminder and appeal. Results of the t-tests of the mean differences for each of the constructs did not reveal any significant differences ($p < 0.05$, two-tailed), which suggests that non-response bias was not a serious threat to this study.

Given that a single respondent completed each of survey questionnaire, we needed to assess the potential of common methods bias. Following Podsakoff, MacKenzie, Lee, and Podsakoff (2003), we applied the Harman's one-factor test on the constructs by simultaneously loading all items from the combined dataset in factor analysis with no rotation. Results showed that the most covariance explained by one factor was 29.22 percent, which suggests that common method bias was not likely present in the study. Furthermore, we applied the Liang, Saraf, Hu, and Xue (2007) procedure to test the common method bias in PLS. The results revealed that method loadings were insignificant and that indicators' variances were considerably greater than their method variance. Thus, we concluded that common method bias was not a serious threat to this study.

5.2 Measurement Model

We assessed the adequacy of the measurement model by evaluating the results of content validity, criterion-related validity, convergent validity, construct validity, and reliability tests (Boudreau, Gefen & Straub, 2001; Straub, 1989). Content validity refers to the degree to which the items in an instrument represent the construct being measured. One can assess content by using domain experts and thoroughly reviewing prior literature (Straub, Boudreau, & Gefen, 2004). We established content validity by examining prior literature, developing and adapting existing scales, and using a panel of IT professionals and researchers in the area to judge the quality of the instrument (Cooper & Schindler, 1998). Criterion-related validity is the extent to which the survey instruments relate to concrete criteria. We accessed the expected cross validity index (ECVI), which indicates how well our structural model fits a cross-validated sample. The ECVI value of our model was 0.297 compared to 0.283 for the saturated model. We conducted confirmatory factor analysis for all of the latent constructs in the model (see Table 2). All item loadings were greater than 0.70 as Hair, Sarstedt, Ringle, and Mena (2012) recommend. Thus, the items represented their respective constructs. Furthermore, we evaluated the reliability of the scales and measurement items. The composite reliability (CR) and Cronbach's alpha values in Table 3 indicate the scales' reliability. All values were above the acceptable 0.70 threshold (Nunnally, 1978); thus, all measures had adequate levels of reliability.

5.3 Using Convergent Validity and Discriminant Validity to Assess Construct Validity

Researchers achieve convergent validity when scores of items they use to measure a construct correlate with or relate to scores of other items designed to measure the same construct. We tested convergent validity using two criteria (Fornell & Larcker, 1981): 1) all indicator loadings should be significant and exceed 0.70 and 2) each construct's average variance extracted (AVE) should exceed the variance due to the measurement error for that construct. As Table 2 shows, all of the items exhibited a loading higher than 0.70 on their respective construct, and as Table 3 shows, were greater than 0.70, which satisfies the two conditions for convergent validity. The variance inflation factor (VIF) examined the existence of multicollinearity among latent constructs. All VIF measures were below the 3.0 recommended minimum (Kline, 1998); the highest VIF value was 2.76.

Table 2. Item Loadings and Cross Loadings

	EEA	LOU	MF	FROA	ORA
EEA	1	-0.141	-0.231	0.399	0.463
LOU1	0.075	**0.841**	-0.187	0.116	-0.112
LOU2	0.275	**0.909**	-0.121	-0.056	-0.171
LOU3	0.147	**0.821**	0.043	0.143	-0.152
LOU4	0.269	**0.905**	0.354	0.112	-0.202
MF1	0.214	0.376	**0.886**	0.109	0.407
MF2	0.209	0.389	**0.871**	0.224	0.303
MF3	0.341	0.479	**0.901**	0.107	0.449
MF4	0.297	0.331	**0.907**	-0.128	0.421
FROA1	-0.077	-0.354	0.318	**0.901**	-0.067
FROA2	-0.142	-0.266	0.462	**0.899**	0.085
FROA3	0.019	-0.059	0.316	**0.907**	0.023
ORA1	0.218	-0.314	0.371	-0.024	**0.901**
ORA2	-0.017	-0.243	0.354	0.078	**0.767**
ORA3	-0.021	-0.272	0.202	-0.016	**0.854**
ORA4	0.242	-0.041	0.175	0.051	**0.886**
ORA5	0.217	0.025	0.226	0.072	**0.909**
ORA6	0.271	0.076	0.141	0.101	**0.911**
ORA7	0.167	0.369	0.156	-0.075	**0.898**

Table 3. Descriptive Statistics, Validity and Reliability

	No. items	Mean	SD	AVE	CR	α	EEA	LOU	MF	FROA	ORA
EEA	1	86.15	1.05	0.99	0.93	0.92	**0.99**				
LOU	4	-4.43	1.09	0.89	0.96	0.94	-0.23	**0.94**			
MF	4	5.12	1.11	0.87	0.95	0.93	0.27	-0.22	**0.93**		
FROA	3	4.65	1.13	0.85	0.94	0.92	0.41	-0.19	0.51	**0.92**	
ORA	7	5.77	1.09	0.86	0.94	0.91	0.39	-0.32	0.39	0.33	**0.92**

EEA: ERP-enabled adoption, LOU: level of uncertainty, MF: managerial flexibility, FROA: formal real option in ERP, ORA: organizational relative advantage. Note: we show square root of AVE figure in bold along the diagonal

Discriminant validity examines the degree to which a measure correlates with measures of constructs that differ from the construct one intends the measure to assess (Barclay, Higgins & Thompson, 1995). Discriminant validity implies that a construct does not share much variance with other constructs rather than with its own measures. We assessed discriminant validity using three tests. First, an examination of cross-factor loadings (Table 2) indicated good discriminant validity because the loading of each item on its assigned construct was greater than its loadings on all other constructs (Chin, 1998). Second, the correlations among the constructs were below the 0.85 threshold (Kline, 1998), which suggests discriminant validity. Third, the square root of the AVE from a construct was greater than the correlations among the construct and all other constructs in the model (Table 3) (Fornell & Larcker, 1981). Furthermore, we analyzed the effect size to determine the dominant path between the constructs in the model. See results in appendix B.

5.4 Structural Model Testing

In PLS analysis, examining the structural paths and the R-square scores of the endogenous variables assesses the explanatory power of the structural model. Figure 2 shows the results of the structural path analysis. Overall, all of the five paths were significant with a p-value of less than 0.05.

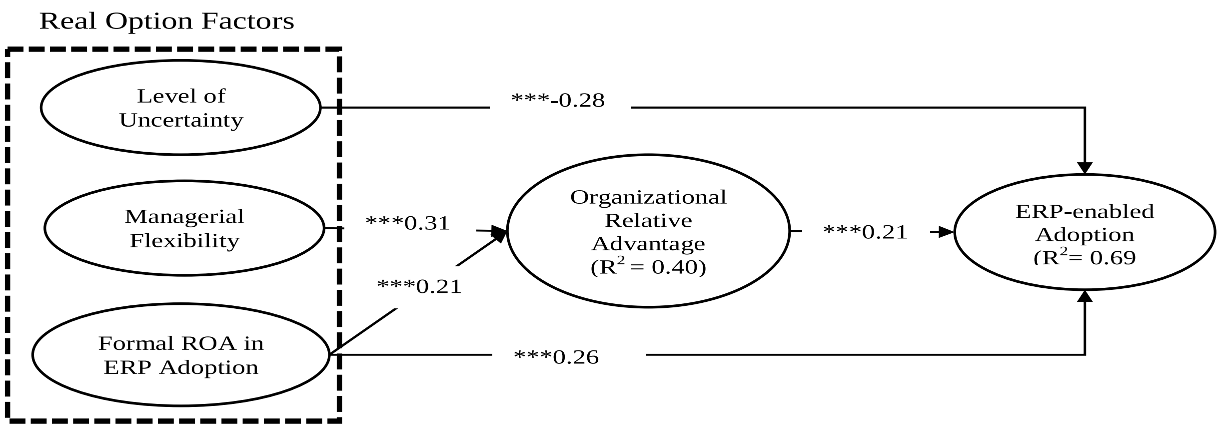

Figure 2. Real Option Factors

The model explained 69 percent of the variance in ERP-enabled adoption. Level of uncertainty (H1, β = -0.28, p < 0.001), organizational relative advantage (H5, β = 0.21, p < 0.001) and formal real options analysis in ERP adoption (H4, β = 0.26, p < 0.001) all influenced ERP-enabled adoption as hypothesized. Similarly, the model explained 40 percent of the variance in organizational relative advantage of subsequent technology being adopted. Managerial flexibility (H2, β = 0.31, p < 0.001) and formal real options analysis in ERP adoption (H3, β = 0.21, p < 0.001) influenced organizational relative advantage as hypothesized. In testing our model, we evaluated the effect of the control variables (i.e., firm size and time elapsed since ERP implementation). Results showed no significant influence on organizational relative advantage or ERP-enabled adoption. This result indicates that the independent variables in the research model better explained the organizational relative advantage of ERP-enabled technologies and ERP-enabled adoption than the difference among the respondents.

6 Discussion and Implications

In this paper, we examine the factors that influence the adoption of ERP-enabled technology options and how real option factors in ERP adoption decisions affect the adoption of subsequent ERP-enabled technologies. We provide empirical evidence that the level of uncertainty has a negative association with ERP-enabled adoption. We find this result revealing because it demonstrates that, for firms to exercise these ERP-enabled options, the uncertainties associated with these additional technologies has to diminish to an acceptable level. This finding is consistent with Pindyck (1991) who argues that high uncertainty increases the value of future investment opportunities (options) but decreases the level of actual investment. Thus, for firms to optimally maximize ERP-enabled options and adoption, they need to be mindful and actively monitor the level of uncertainties of emerging technologies and functional-specific applications and how these uncertainties will impact the overall ERP-enabled adoption. Consistent with anecdotal evidence from prior research, firms may decrease uncertainty and benefit themselves by developing the ability to learn more about additional technology during the option period (Ziedonis, 2007).

Similarly, we found that managerial flexibility is an important predictor of subsequent technologies' organizational relative advantage. It appears that managers and IT executive relish the ability to delay, adopt, reverse, and, if necessary, abandon an additional technology or capability. Given that adopting additional functional-specific applications to an ERP systems comes with some degree of uncertainty, having the managerial flexibility to temporarily abandon, reverse, and delay the decision to adopt is critical, and it impacts how firm managers perceive the overall organizational relative advantage of the technology.

Several researchers have argued that real options analysis provides a comprehensive valuation technique for IT investment because of its ability to factor in future investment opportunities and managerial flexibility associated with the investment (Benaroch & Kauffman 2000; Fichman et al., 2005; Krychowski & Quelin, 2010). Our study suggests that applying formal real options analysis in an initial ERP adoption is positively associated with the ERP-enabled additional technology's organizational relative advantage. It appears that, by applying real options analysis in the early stages of implementing an ERP system, firms become aware of and can recognize future options and growth opportunities and implement place measures that would foster follow-up projects. A firm can implement these measures that they capture by applying formal real options analysis when initially deploying an ERP system, and they can positively impact the additional option technology's organizational relative advantage. Thus, applying real options reasoning and analysis may guide managers to the right path of recognizing and exercising options and future investment opportunities embedded in their ERP systems. Indeed, prior studies have argued that real options reasoning and analysis can allow firms to more rapidly discover and execute future investment opportunities embedded in their initial IT investments (Fichman, 2004; Krychowski & Quelin, 2010; Nwankpa & Roumani, 2015).

Furthermore, we found that the level of uncertainty has a strong negative influence on ERP-enabled adoption, which is particularly important because it reveals that an organization's ability to adopt subsequent ERP-enabled technology may lie in part in recognizing when technology uncertainty has diminished to an acceptable level. For instance, organizations at the point of implementing an ERP system may want to integrate data mining solutions and Web-based e-commerce applications during the post-ERP implementation phase, but they may be uncertain how the ERP system will integrate these additional applications. Recognizing that uncertainty can create value in the ERP system is just one step in the process. Understanding that one can apply these potential values over time when managers have the necessary information to make decisions can have strategic implications for ERP firms.

Our results show that the managerial flexibility and formal real options analysis in adopting ERP systems are key enablers of organizational relative advantage of subsequent ERP-enabled technology. Thus, for managers to leverage the options embedded in their ERP systems, they need to perceive that such technology will benefit their organization. Organizational relative advantage of this ERP-enabled technology will be based on the availability of adequate information regarding the technology characteristic, management's ability to take appropriate action in response to changing environment, and whether formal real option analysis was applied during the initial ERP investment decision. Our findings suggest that formal real options in ERP adoption decisions and managerial flexibility positively influence management's ability to recognize the relative advantages that subsequent technologies bring to the organization. This finding is consistent with the existing literature that argues that managerial flexibility is an important predictor of organizational relative advantage of subsequent technology (Nwankpa & Roumani, 2015).

6.1 Theoretical Contributions

This research makes several theoretical contributions to the literature. First, the current literature contains many case studies and much anecdotal evidence of the role of real options analysis and ERP systems. To the best of our knowledge, this research is the first to apply and empirically examine ERP-enabled adoption from a real options lens. As such, it extends theory in a study area important to both researchers and practitioners. The current study advances the theory-building process by developing and validating a model of ERP-enabled adoption that can help explain why some organizations have benefited and strategically built on their ERP platform through add-ons and function-specific applications while others have continued to struggle.

Second, this study directs researchers' attention to the important yet ignored issue of ERP-enabled adoption. We shift the focus from prior literature that has examined ERP adoption and deployment in the boundaries of an initial ERP system (Mu, Kirsch, & Bulter, 2015; Law & Ngai, 2007) by investigating adoptions enabled by the existing ERP platform. ERP-enabled adoption offers a potentially insightful area of research that can help unlock the discrepancy in the literature on realizing ERP benefits. Our study demonstrates how real options analysis, as a valuation technique, can be used to explain the related but different phenomenon of ERP-enabled adoption.

Third, this study builds on existing ERP-enabled adoption literature (Nwankpa & Roumani, 2015) and uses its organizational relative advantage construct to predict ERP-enabled adoption of additional technologies, a dependent variable that can unlock firms' ability to achieve overall ERP benefits. The findings are largely consistent with Nwankpa et al. (2013) who found that, in the context of ERP-enabled adoption, organizational relative advantage has a significant direct impact on the overall ERP-enabled adoption. In addition, we applied real options factors in our model and found that level of uncertainty has a direct negative relationship on ERP-enabled adoption and that managerial flexibility and formal real options in ERP adoption are important predictors of organizational relative advantage of the ERP-enabled technologies. Although anecdotal evidence has suggested that uncertainty about the benefit or technology or innovation may hinder adoption (Agarwal & Prasad, 1998; Lu, Yao, & Wu, 2005), we builds on the adoption theory by introducing and empirically testing the role of uncertainty as it relates to ERP-enabled adoption. Prior IS research has illustrated the role of organizational relative advantage in the adoption of technology (Kanter, 2000; Templeton & Byrd, 2003; Li, Troutt, Brandyberry & Wand, 2011; Nwankpa et al., 2013), but we know relatively less about the antecedent of these variables, especially when dealing with adoption decisions that go beyond the initial ERP deployment.

Finally, the study applies real options reasoning as a theoretical foundation for explaining the dynamic interplay wherein initial ERP systems create the platform for subsequent and additional function-specific adoptions. This study is one of the first to empirically test post-ERP implementation adoption decisions from a real options reasoning perspective. As we discuss earlier, prior adoption research has examined organizational adoption as a static process that views the adopting technology in isolation, which limits our understanding of the process. The empirical evidence presented in this study directly supports the contention that formal real options analysis can be useful when faced with investment decisions with a high level of uncertainty. Thus, this study can provide a revealing theoretical lens for further understanding ERP-enabled adoptions.

6.2 Practical Implications

This research makes several contributions to practice. The ERP-enabled adoption approach complements and extends the work done by many managers to successfully implement and generate the expected returns on their organization's ERP system. The ERP-enabled adoption approach goes beyond the conventional ERP critical success factors and standard operating procedure by emphasizing the need to view an ERP system as an IS platform with embedded options rather than as just another technology application. Therefore, managers need to understand that the ability to capture full ERP benefit may depend on firms' capabilities to deploy and adopt follow-up technologies or capabilities.

Moreover, from an evaluation perspective, viewing an ERP system as a foundation IS platform can help justify ERP system projects. We show that an ERP system can give an organization the ability to adopt emerging technologies and the capacity to extend values and benefits outside the parameters of the initial ERP system. This finding is in line with prior results that have found a positive effect between implementing subsequent ERP systems and firms' agility (Aburub, 2015) and the finding that firms can sustain agility through digital options embedded in their information technologies (Sambamurthy, Bharadwaj, & Grover, 2003). By incorporating ERP-enabled adoption into an organization's strategic plan, IT managers can leverage their ERP systems, extend these systems' functionalities, and keep pace with technological leaps and innovations. Therefore, the results should encourage managers to develop in-house mechanisms that continuously examine ways to unlock opportunities for future follow-on ERP-enabled adoptions. Even without the formal real option analysis when adopting an ERP system, managers can still retroactively seek for options embedded in their ERP platform while evaluating the factors that will bolster ERP-enabled adoption.

Furthermore, executives and managers who want to increase the potential of their ERP systems should find this study practically important. When considering adopting subsequent ERP technologies, IT managers and management need to focus on three important factors: level of uncertainty, formal real option in the ERP adoption, and organizational relative advantage of the subsequent technology. More specifically, management should gather all the necessary information and details to be aware of any issues and reduce uncertainties concerning the subsequent technology. Also, by providing the organizational support needed to foster perceived relative advantage, management can further influence what subsequent technologies the firm adopts. Indeed, ERP vendors are already supporting the technical aspects of ERP-enabled adoption. Firm management should also remember that uncertainty (lack of information) about subsequent technologies can negatively affect relative advantage since it creates doubt regarding users' experience with the technology. Also, firm management should consider managerial flexibility and formal real options as factors that can help them make the right decisions during the course of the investment lifecycle that would positively affect the organizations relative advantage of subsequent technologies.

6.3 Limitation and Future Research

This study has several limitations. First, we collected empirical data from one key respondent from several different firms in one country, which limits our study's generalizability. This limitation could potentially lead to the percept-percept inflation problem, which refers to artificially inflating estimates of co-variance (Crampton & Wagner, 1994). However, several factors partly alleviate this concern in our context for several reasons including the depth of involvement of these respondents in management responsibilities and the operations of their respective firms. Also, the results from Harman's single-factor test suggest that common-method bias did not influence our results. Given that respondents came from a single country, future research needs to analyze ERP benefits and national and cultural particularities. For instance, one could introduce organizational culture as a moderator in the influence of ERP benefits.

Second, the parsimonious nature of our model limits our choice to three real options factors: level of uncertainty, managerial flexibility, and formal real options analysis. Although these factors are consistent with prior literature and are based on anecdotal evidence in the literature that suggests that level of uncertainty, managerial flexibility, and real options analysis are important considerations to executing options (Benaroch 2002; Benaroch & Kauffman, 2000; Fichman, 2005; Kauffman & Li, 2005), our model may not exhaustively cover all factors. Future research may benefit from examining other factors and studying their influence on ERP related constructs.

Moreover, this study adopts a cross-sectional view in measuring the constructs, and such a design may not adequately capture the interactions among the constructs and cannot establish causality. Future researchers might find it useful to conduct a longitudinal study from the time a firm implements the ERP system to the time it revises the option or adopts future technological capabilities. Such a study may enrich the findings of our results and establish the causality of argument. Nonetheless, the theory in this study suggests that the relationships tested in the research model are causal in nature.

Future research can examine how one can apply formal real options analysis to other technology platforms and to different adoption models and contexts. For instance, one could examine the effect of options as they apply to mobile platforms such as android operating systems. Another possibility might be to examine whether users at individual level consciously or unconsciously integrate real options reasoning during adoption decisions. In addition, we need to further examine how managers capture options embedded in an ERP system in detail. While the current study goes a step further to indicate that formal real options analysis has adoption implications that transcend the initial adoption, we need to examine how the interplay between real options and technology uncertainties can help managers implement ERP systems more successfully. Furthermore, future research should consider how ERP-enabled adoption succeeds or fails over time as firms attempt to address uncertainties associated with these adoption decisions.

7 Conclusions

In this paper, we identify gaps in extant literature on ERP systems and better our understanding of ERP-enabled adoption by integrating the real options framework. In particular, we answer two research questions: 1) "What factors influence the adoption of ERP-enabled options?" and 2) "How do real option factors in the ERP adoption decision affect subsequent ERP-enabled technologies?". Using survey data and structural equation modeling, our research confirmed that the level of uncertainty negatively influences ERP-enabled adoption while formal real option analysis in ERP adoption and organizational relative advantage of subsequent ERP-enabled technology influence ERP-enabled adoption. As for the second question, we found that managerial flexibility and formal real options in ERP adoption were important antecedents of organizational relative advantage of subsequent technologies. Clearly, these findings provide a foundation for managers who must decide how to extend and integrate add-ons and other function-specific ERP-enabled applications to their existing ERP systems. Option thinking requires embracing a management style that promotes flexibility and agility while explicitly identifying and tracking uncertainty. Firms can benefit from their ability to learn more about the technology or additional capability during the option period. Firms that recognize and apply real options thinking will better position themselves to transition from having an ERP system to having ERP platform technology and ERP-enabled strategic functional applications.

Finally, this study advances and furthers our understanding in the research stream that examines IS success and business performance. An innovation's or a system's impact in an organization remains a key measure of IS success (DeLone & McLean, 1992). ERP-enabled technology adoption can provide the mechanism for firms to dynamically extend ERP's footprint in the organization. In an era of emerging digital technologies and innovations, ERP-implementing companies that seek to optimize and extend their ERP system benefits and success would be better served if they aggressively and cautiously identified, pursued, and adopted ERP-enabled emerging technologies and functional-specific applications that could support and extend the specific activities of their business units.

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Appendix A: Measures

Three faculty members in the information systems field, three doctoral students actively involved in ERP systems research, and five IT managers reviewed our preliminary survey. We provided respondents with a comment box and asked them to provide feedback and comments on the items. These steps ensured face and content validity of the measurement items. After incorporating suggested modifications, we pilot tested the modified questionnaire with 45 IT executives. We modified the questionnaire a final two times before using it in the final survey we report in this paper. Using perceptual measures and a single informant requires obtaining the response from experienced and knowledgeable individuals (Huber & Power, 1985). Prior literature suggests using CIO as respondents for questions on the use of IT win the organization (DeLone & McLean, 1992). Single source respondents can lead to common source bias; thus, we advised respondents that results would be completely anonymous. Furthermore, we applied Nunnally's (1994) recommended questionnaire design strategies to minimize common source bias. In framing the responses, we avoided implying that one response was more acceptable than the other. Moreover, we made all the responses of equal effort, paid attention to item wording, and tried to avoid socially desirable responses to ensure that common source bias does not occur.

To minimize the problems of inattention and acquiescence, we used randomly mixed items together, which helps avoid unintended question order effects (Dillman, Smyth, & Christian, 2014). Also, we used a page-by-page construction to ensure that certain questions appeared on their own page (Dillman et al., 2014). We mailed a small scale pretest of the questionnaire to a random sample of 200 IT executives. We instructed the respondents to indicate their level of agreement with a statement using multiple indicators coded on a seven-point Likert scale. Due to time constraints, we received a total of 45 responses. Although there is considerable debate and no universal method for determining sample size of a pilot study (Hertzog, 2008; Lackey & Wingate, 1998), the recommended sample size is generally 10 percent of the regular sample size; the sample size of our pilot study was 8.7 percent. Preliminary confirmatory factor analysis indicated a clear factor loading and internal consistency on the hypothesized dimensions. Thus, we did not further modify the final questionnaire before mailing it. We present the final version of the items we used in Table A1.

Table A1. Measures

Construct name	Item code	Item	References
ERP-enabled adoption	EEA	On a scale of 1-100 please provide your best estimate of the percentage of implementation of this ERP-enabled technology or capability.	Adapted from Nwankpa et al. (2013) and Grover & Goslar (1993)
Level of uncertainty		**At the time of considering the adoption of this additional technology or capability, we concluded that:**	Adapted from (Ragatz et al., 2002)
	LOU1	Forecasting for the IT changes and requirements of this additional technology or capability was difficult.	
	LOU2	How well this additional technology or capability would work was difficult to predict.	
	LOU3	It will be difficult to determine whether the additional technology or capability would be subject to obsolescence quite rapidly.	
	LOU4	The additional technology or capability may require frequent changes.	
Managerial flexibility		**At the time of considering the adoption of this additional technology or capability, we concluded that:**	Developed based on Huchzermeier & Loch (2001) and McGrath (1997).
	MF1	The additional technology or capability could be temporarily abandoned if necessary during its adoption, implementation and post-implementation process.	
	MF2	The decision to adopt and implement the additional technology or capability could be reversed.	
	MF3	We could delay the decision to adopt this technology.	

Table A1. Measures

	MF4	The additional technology or capability could be expanded or contracted.	
Formal real options analysis	FROA1	During the initial ERP justification, our organization used a valuation technique that recognizes future the ERP system growth opportunities.	Developed based on Fichman (2004), and Taudes et al. (2000)
	FROA2	During the initial ERP justification, our organization used a valuation technique that recognizes that managers can alter the ERP investment course of action.	
	FROA3	During the initial ERP justification, our organization used a valuation technique that recognized that the ERP System provides foundation for developing future IT capacity.	
Organizational relative advantage		**At the time of considering the adoption of this additional technology or capability, we concluded that:**	Adapted from Moore & Benbasat (1991)
	ORA1	The adoption of this additional technology or capability would be advantageous to the organization.	
	ORA2	The adoption of this additional technology or capability would increase productivity.	
	ORA3	The adoption of this additional technology or capability would improve the quality of work.	
	ORA4	The adoption of this additional technology or capability would allow us to accomplish tasks more quickly.	
	ORA5	The adoption of this additional technology or capability would make our organization more competitive.	
	ORA6	The adoption of this additional technology or capability would make our organization more efficient.	
	ORA7	The adoption of this additional technology or capability would improve our organizational decision-making.	

For the dependent variable ERP-enabled adoption, we asked respondents if their organization had adopted or implemented an additional technology or capability that their initial ERP system facilitated. Furthermore, respondents provided the name or description of this additional technology or capability (See Table 4). Finally, we asked respondents to estimate the percentage of implementations of ERP-enabled technologies.

Table A2. ERP-enabled Technologies

Type of ERP-enabled technologies/capabilities	Frequency (%)
Web-based application/technology	16%
Warehouse management application	14%
Logistic/distribution/order-tracking application	11%
Business intelligence applications	9%
Subscription billing application	9%
Transport management system	9%
Retail application	9%
Budgeting and forecasting application	8%
Electronic healthcare application	6%
Mobile applications	5%
Email management systems	4%

Appendix B: Summary of Effect Size

Table B1. Summary of Effect Size

	ORA		
	Path coefficients	f^2 effect size	q^2 effect size
LOU		LOU	
MF	0.29	MF	0.29
FROA	0.19	FROA	0.19
ORA		ORA	
EEA		EEA	
	EEA		
	Path coefficients	f^2 effect size	q^2 effect size
LOU		LOU	
MF		MF	
FROA		FROA	
ORA	0.22	ORA	0.22
EEA		EEA	

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