PAPERS

Does Real Options Reasoning Support or Oppose Project Performance? Empirical Evidence From Electronic Commerce Projects

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ABSTRACT

There is a consensus among scholars that real options reasoning is crucial for improving project performance but there has been little empirical support thus far; hence, we explore how real options reasoning may influence project timeliness, efficiency, and effectiveness. Our longitudinal analysis of 110 electronic commerce projects, drawn from new technology ventures, indicated the differential effects of real options reasoning on project performance. We find that higher uncertainty does not always lead to a greater use of real options reasoning. Although perceived environmental state uncertainty is positively linked to real options, perceived environmental effect and response uncertainty are not.

KEYWORDS: perceived environmental uncertainty; real options reasoning; electronic commerce investment; project performance; flexibility

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INTRODUCTION

Real options reasoning provides a fruitful framework for project managers to better account for the different types of uncertainties that impact investment decisions (Avadikyan & Llerena, 2010) and helps limit downside risk and simultaneously capture potential opportunities. In recent project management research there has been considerable interest in understanding how real options reasoning might usefully affect project performance (Fichman, Keil, & Tiwana, 2005; Tiwana, Wang, Keil, & Ahluwalia, 2007). Real options reasoning presents a rational survival strategy for project managers to use flexibility in order to cope with environmental uncertainty. The usefulness of real options logic highly depends on the amount of uncertainty perceived by project managers (Dixit & Pindyck, 1994). In other words, a real option has no value whenever there is low level uncertainty (Kogut & Kulatilaka, 2001).

Drawing on an extensive body of past research on strategic management, we first tested how perceived environmental uncertainty influences the usage of real options reasoning and then how greater use of real options may impact e-commerce project performance, a state that has received scant attention in strategic management research (Swamidass & Newell, 1987). Our work has two specific aspects. First, in line with recent real options reasoning studies (Huchzermeier & Loch, 2001; Tiwana et al., 2007; Fichman, 2004), we conceptualized real options reasoning at the project level rather than at the firm level (Podoynitsyna, Song, van der Bij, & Weggeman, 2013). This approach helps gain a finer understanding of the usability of real options reasoning from the viewpoint of project outcome (Klingebiel & Adner, 2014).

Second, in contrast to some environmental uncertainty–strategy research, which considers environmental uncertainty as a unidimensional construct, we use it as a distinct set of constructs. In a seminal article, Milliken (1987) unfolded the construct of perceived environmental uncertainty in the management interpretation process into three types: (1) Management can be uncertain about what is happening (state uncertainty), (2) how it will impact their organization (effect uncertainty), and (3) what they are going to do about it (response uncertainty). Given that decisions about how many real options should be created and when to exercise them are taken at the managerial level, and the managerial action is highly determined by subjective perception (Child, 1997; Priem, Love, & Shaffer, 2002), the study of real options reasoning has to be based on managers' perceptions (Verdu, Tamayo, & Ruiz-Moreno, 2012).

By breaking down perceived environmental uncertainty into Milliken's (1987) typology, the following question arises: How do various types of uncertainty perceptions influence the number of real options used at the project level? A complementary research question yet to be answered in this context is the following: Can project performance be guaranteed when real options are used in greater numbers? These two questions are fundamental to enriching our understanding of real options reasoning in strategic management and the answer is a key to progress in research on this topic (Tong & Reuer, 2007). By answering the first question, we challenge well-accepted beliefs in the real options context of "the higher uncertainty, the greater use of real options" (Dixit & Pindyck, 1994; Kogut & Kulatilaka, 2001). We highlight that the higher usage of real options is highly contingent on the type of perceived environmental uncertainty.

Despite a growing body of research that emphasizes the prominent role of real options reasoning on firms' performance by reducing different types of uncertainties (Bloom & Van Reenen, 2002; Podoynitsyna et al., 2013), little is known about the effect of real options on project performance (Klingebiel & Adner, 2014). We extend the real options theory by adapting it to the electronic commerce context and examining the possibility that real options reasoning at the project level may both promote and impede performance.

Furthermore, we contribute to upper echelons theory by showing how individuals' perceptions may influence their actions and consequently how their actions may impact the firms' level of performance.

This article is organized as follows. First, we outline the key literature on real options reasoning, perceived environmental uncertainty, as well as project performance. Then we present our five hypotheses, our methodology and sample, as well as our key results. The discussion leads to our implications for further research, and finally, our limitations.

Literature Review

Real Options Reasoning

Real options reasoning has its roots in financial options theory, which was introduced by Black and Scholes (1973) and received notable attention in the contexts of entrepreneurship (Miller & Folta, 2002), innovation (Verdu et al., 2012), networks (Podoynitsyna et al., 2013), information technology (Fichman et al., 2005), and capability development (Kogut & Kulatilaka, 2001). At the project level, real options reasoning has been used as an appropriate organizational strategy or behavior to reduce environmental uncertainty in supply chains (Hult, Craighead, & Ketchen, 2010), information technology (Fichman et al., 2005; Tiwana, Keil, & Fichman, 2006), innovation (McGrath & Nerkar, 2004), and strategic investment decisions (Krychowski & Quélin, 2010).

Real options reasoning offers six types of possible actions to project managers in the face of environmental uncertainty: *unlocking, switch use, scale, stage, deferral,* and *abandonment* (Fichman et al., 2005; Hult et al., 2010; Tiwana et al., 2007; Zhang & Babovic, 2011, 2012). An *unlocking* or *growth* option is present when an electronic commerce project creates the possibility of pursuing upcoming strategic opportunities (Hult et al., 2010). The *stage* options refers to the possibility of completing an electronic commerce project with a series of incremental investments (Majd & Pindyck, 1987) that allow the project manager to terminate the investment if unforeseen changes later on warrant doing so (Tiwana et al., 2007). A *scale* option is present in electronic commerce projects when there is a possibility to contract or expand the allocated resources (financial and human, logistic systems, hardware, and software in electronic commerce projects) (Fichman, 2004). The *defer* option exists when the initiation of an electronic commerce project can be delayed or postponed to a later point in time, without the risk of foregoing a valuable opportunity (Benaroch & Kauffman, 1999; Tiwana et al., 2007). According to Trigeorgis (1993), a *switch* use option allows for electronic commerce investments to be redeployed to another application. Finally, an *abandonment* option is present when an electronic commerce investment or project can be terminated prior to completion, freeing up remaining resources to be used in another project (Hult et al., 2010).

Using these six types of real options not only provides a considerable amount of flexibility to project managers in order to meet project objectives in the face of environmental uncertainty (McGrath, Ferrier, & Mendelow, 2004), but these real options also enable them to seize upside opportunities more effectively. However, a wait-and-see strategy such as real options *did not* always appear to be taken very seriously by project managers or to have been implemented in all strategic decisions (Zardkoohi, 2004), because it necessitates spending a considerable amount of time, which may reduce the possibility of completing a project on time. Furthermore, the probability of changing or stopping the project in terms of market and environmental conditions may erode the morale of project team members, which might ultimately degrade project efficiency and effectiveness. Project managers may squander the main goals of a project when there is great room for terminating, redeploying, and postponing the project.

Perceived Environmental Uncertainty

It appears to be widely accepted in the strategic management literature that environmental uncertainty significantly impacts new technology venture (NTV) strategies (Oriani & Sobrero, 2008; Liu, Shah, & Babakus, 2012; Beckman, Haunschild, & Phillips, 2004; Afshar Jahanshahi, 2016) and performance (McCabe, 1990; Podoynitsyna et al., 2013). The perception of uncertainty is

fundamental for management, because managers form the foundations for their strategic choices based on their perceptions (Child, 1997; Priem, Love, & Shaffer, 2002; Downey, Hellriegel, & Slocum, 1975).

In trying to handle uncertainties, first one needs to know the types of uncertainties one is facing (Grote, 2009). Milliken (1987) suggested that managers may perceive three distinct types of uncertainties as they seek to understand and respond to changes in a business environment: state uncertainty, effect uncertainty, and response uncertainty.

State uncertainty refers to the inability of decision makers to predict how the main components of a business environment might be changing. "For example, one might be uncertain both about the likelihood of deregulation and the likely behavior of competitors if deregulation occurs. Thus, in this case, one knows neither the probability of deregulation nor the probability of a price war if deregulation occurs" (Milliken, 1987).

Effect uncertainty refers to the inability of decision makers to predict the impact of changes in the business environment on their organizations. Milliken (1987) gave the example of "knowing that a hurricane is headed in the general direction of your house does not mean you know how it will affect your particular house." Finally, perceived response uncertainty is the inability to predict the likely consequences of a response choice. Milliken added: "Administrators would most likely experience response uncertainty in the course of either choosing from a number of possible strategies or formulating a response to an immediate threat in the environment" (Milliken, 1987). Following Milliken's typologies allowed us to gain a deeper understanding of how the perceptions of different types of environmental uncertainties may influence the usage of real options reasoning. State uncertainty arises from a lack of information about future changes and spreads uniformly across ventures in the same industry (Miller & Shamsie, 1999). Perceived effect uncertainty, however, is context-dependent and contingent on the project manager's analytical and creative capabilities of realizing cause–effect relationships (Aragón-Correa & Sharma, 2003). Perceived response uncertainty is related to the level of confidence of project managers in making decisive decisions with almost predictable outcomes (Lewis & Harvey, 2001; Milliken, 1990; Ashill & Jobber, 2009; Ashill & Jobber, 2014). The inability to distinguish between these three types of uncertainties may lead to inconsistent and noncumulative research findings (Ashill & Jobber, 2009; Miller & Shamsie, 1999; Doty, Bhattacharya, Wheatley, & Sutcliffe, 2006).

Project Performance

In uncertain environments, the performance of a project is the primary concern of project managers (Liu & Deng, 2015; Yazici, 2009). The project manager must balance tightening available budgets, time constraints, and quality requirements to meet a unique acceptable performance level (Aubry, 2015; Landoni & Corti, 2011). Ignoring one or the other may lead to project failure. The measurement items that have been used frequently by researchers to determine the performance of IT-related projects are project efficiency; the quantity in terms of both the amount produced and adherence to budget constraints; project effectiveness; the quality of work produced, and meeting project objectives and project timeliness, that is, undertaking tasks in a time-efficient manner and launching the project on time (Henderson & Lee, 1992; Liu, Chen, Chen, & Sheu, 2011).

Electronic commerce projects have always carried great risk and uncertainty (Bergendahl, 2005), which makes it difficult to predict their exact completion time. These uncertainties arise from many sources, such as unexpected problems in the underlying project hardware, programming languages, internet connection, database technologies, system software, and customer acceptance (Jahanshahi, Zhang, & Brem, 2013). The uncertainty inherent in electronic commerce investments results in the need for special strategies that provide adequate flexibility. Please see Figure 1 for a theoretical model of antecedents and consequences of real options reasoning in electronic commerce projects.

Research Hypotheses

According to Upper Echelons Theory, organizations are reflections of their top management teams (Hambrick & Mason, 1984). The main idea behind this theory is that there is a direct relationship among top management cognition (how they perceive and interpret the environmental changes), their strategic choices, and the resultant performance outcomes (Finkelstein & Hambrick, 1990). Following this theory, we propose that the project manager's perception of environmental uncertainty will explain the variance in real options usage in organizations (strategic choices) and subsequent project performance.

The rationale behind our arguments is based on two reasons. First, firms in the same industry experience environmental state uncertainty almost equally (Miller & Shamsie, 1999), yet they perceive environmental effect and response uncertainty differently (Ashill & Jobber, 2009; Ashill & Jobber, 2014; Lewis & Harvey, 2001; Milliken, 1990). One organization may see environmental changes as a significant threat and consider itself subject to a sharp effect uncertainty; simultaneously, the other organization may not see such a state. In this line of research, Miller and Shamsie (1999) showed that under a condition of high state uncertainty, firms prefer diversity; under effect and response uncertainty, they prefer simplicity in their strategic choices. It seems that differences in view, capability, or resources may yield to different reactions to unforeseen changes in the same situation. Second, the natures and sources of these three types of uncertainty are extremely

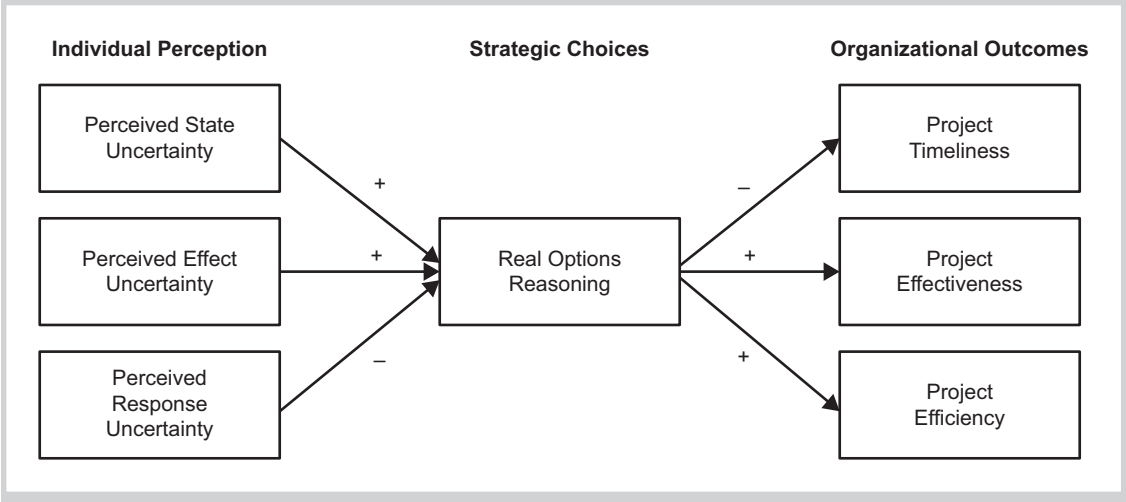

Figure 1: Theoretical model of antecedents and consequences of real options reasoning.

different (Milliken, 1987; 1990), and most likely have different effects in terms of decision outcomes; thus, the inability to distinguish between them may lead to numerous inconsistent and noncumulative research findings (Ashill & Jobber, 2009; Miller & Shamsie, 1999; Doty et al., 2006).

It is a well-accepted statement in the real options literature that higher uncertainty in the business environment increases the value of real options (Dixit & Pindyck, 1994; Driouchi, Leseure, & Bennett, 2009; Driouchi & Bennett, 2012). Project managers can be more certain about their strategic choices and actions in highly uncertain conditions when they have multiple alternatives (Eisenhardt, 1999). The possibility of investing in multiple stages, for example, gives project managers an opportunity to start a project with a minimum level of risk of losing. At a later date, when enough information about different aspects of the market is obtained, project managers will be in a better position to either scale investment or switch to another project. The project manager uses a greater number of real options because a flexible strategy such as real options increases the number of choices available to project managers and allows them to face upcoming environmental uncertainty more effectively (Podoynitsyna et al., 2013).

State uncertainty mainly arises from the lack of critical information about unexpected changes in key trends and events (Miller & Shamsie, 1999). In electronic commerce investments, these key events are unpredictable as to which technology will emerge to dominate the industry (Tegarden, Hatfield, & Echols, 1999) or be adopted as a standard in the near future (Krishnan & Bhattacharya, 2002); volatility in competitors' propensity to introduce new electronic services to the market (Ashill & Jobber, 2009); and lack of information about customer acceptance. Making a significant investment without knowing enough about these issues may eventually reduce the chance of project success. Thus, firms need to opt for a behavior or strategy that maximizes the receipt of novel information about project usefulness, customer acceptance, and market changes.

Generally, higher environmental uncertainty necessitates higher flexibility in investment decisions (Gerwin, 1993; Song, Makhija, & Kim, 2015). By buying time through real options, project managers can repeatedly quest for novel information about the market and the business environment (Mittendorf, 2004; Ziedonis, 2014). Using the updated information, project managers are able to change the project's course of action if the information is unfavorable (Huchzermeier & Loch, 2001). Thus, one way to face state uncertainty is using the wait-and-see strategy to gain a better understanding of the different unknown aspects of changes in the market (Sirmon, Hitt, & Ireland, 2007). In this regard, in the first hypothesis, we predict that the perception of high environmental state uncertainty increases the tendency of project managers to create and exercise a greater number of real options. Thus, we propose that:

> ***H1:*** *The higher the state uncertainty perceived by a project manager, the higher the use of real options reasoning in electronic commerce projects.*

In the second hypothesis, we suggest that when project managers are subjected to high environmental effect uncertainty, they may be more prone to creating multiple types of real options. A project manager with enough analytical capability and skills to evaluate the likely effects of key trends and events/changes in the environment on their projects will pay less attention to real options because he or she is in the position to complete all stages of the project

as quickly as possible (Iansiti, 1995). In contrast, the lower predictability of the effects of changes forces project managers to spend enough time and resources to analyze the project outcome from different perspectives.

Real options allow firms to make a small initial investment at an early stage (Majd & Pindyck, 1987). This initial investment is more appealing under conditions of effect uncertainty. Through this incremental investment, project managers may have the chance to learn about different facets of the market and the environment before making a significant commitment. They also have the possibility of expanding the investment if they receive favorable information over time or switch to another project if unfavorable information is received. Thus, similar to our first hypothesis we propose that:

> ***H2:*** *The higher the effect uncertainty is perceived by the project manager, the greater the use of real options reasoning in electronic commerce projects.*

Increased ambiguity about decision outcomes leads to increased inertia in firms' investing decisions (Illeditsch, 2011). In the context of action, perceived state uncertainty stimulates the frequency of need for action (McMullen & Shepherd, 2006), and response uncertainty represents the most impactful impediment to individuals' decisions to act (McKelvie, Haynie, & Gustavsson, 2011). Furthermore, perceived response uncertainty complicates the administration and use of existing capabilities and resources to pursue proactive strategies, such as creating a portfolio of real options (Aragón-Correa & Sharma, 2003). In addition, when managers experience high levels of ambiguity with regard to the consequences of each response option, the diversity in decision options is dramatically reduced (Miller & Shamsie, 1999). Creating a greater number of real options complicates the prediction of the consequence of each decision option. Managers may prefer to concentrate on available options. A project manager cannot be expected to exercise a growth option, for example, when he or she is unable to predict the expected outcome of such a decision to a satisfactory extent. Because project managers are not highly sure about their decisions, they may prefer to focus on existing projects rather than creating multiple types of real options. Thus, we hypothesize that:

> ***H3:*** *The higher the perceived response uncertainty by the project manager, the less the use of real options reasoning in electronic commerce projects.*

A real options reasoning embodies defensive possibilities (for example, delay, defer, and abandon), as well as proactive possibilities (for example, unlocking, switch use, and scale (Driouchi & Bennett, 2012). This gives project managers an excellent opportunity to take some flexible actions in the future without any obligation. In order to reduce environmental uncertainty, project managers should spend some time learning more about a given situation before taking a specific action. They may rely highly on defensive and conservative real options (for example, delay, defer, and abandon options), which, in turn, may create constraints that make it particularly difficult to complete an electronic commerce project in a timely manner. Thus, we propose that:

> ***H4:*** *The higher the usage of real options reasoning by project managers will be negatively related to project timeliness.*

Through real options, project managers are able to postpone a given commitment (hold and phasing options) until a substantial portion of environmental uncertainty has been resolved by the passage of time or by receipt of updated information (Adner & Levinthal, 2004a). The quality of work produced should be higher when project managers are not under pressure to continue to commit resources without enough understanding of the outcome. Informed decisions and actions by the project manager could make a big difference.

Overall, investment based on real options gives project managers not only enough time to search for new information from the market and environment (McGrath & Nerkar, 2004; Janney & Dess, 2004), it also creates an excellent opportunity for them to appropriately exploit their resources in order to meet project objectives. Thus, we suggest that the higher usage of real options reasoning by project managers helps meet project objectives more effectively:

> ***H5:*** *The higher usage of real options reasoning by project managers will be positively related to project effectiveness.*

In the last hypothesis we predict that the higher usage of real options reasoning by project managers will enhance project efficiency. Project efficiency includes quantity in terms of both the amount produced and adherence to budget constraints (Peters & Karren, 2009). Real options reasoning provides a dynamic framework for project managers to modify their tangible and intangible resources in accordance with market, technology, and environmental changes without strict guidelines.

Furthermore, decreasing the number of available scenarios for a given investment (by creating fewer real options) puts firms in inflexible positions, and firms are forced to continue the project even if they are hesitant about its outcome. This may reduce the possibility that a firm elects to exercise only those options that are "in the money" and allows the remainder of the options to expire (McGrath & Nerkar, 2004). Thus:

> ***H6:*** *The higher usage of real options reasoning by project managers will be positively related to project efficiency.*

Methodology

Sample and Data Collection

Our study sample comprises 377 new technology ventures (NTVs) in Iran. We

drew the sample from the Science & Technology Parks database, the most comprehensive database on technology ventures in Iran. Iranian new technology ventures provide the ideal context for this study owing to their extraordinarily high level of environmental uncertainty. The environmental uncertainty in Iran was particularly high during our study period owing to sanctions and policy volatility (due, in part, to sanctions). These sanctions and volatilities greatly increase environmental uncertainties, including (1) financial uncertainty, such as fluctuation in currency; (2) market demand uncertainty affecting the export of products and services; and (3) supply uncertainty, such as the availability of critical raw materials due to trade embargoes. Although all of these uncertainties affect new technology ventures operating in Iran, new technology ventures perceive these environmental uncertainties to varying degrees and have different perceptions about how they may affect their venture and what they should do to deal with said uncertainties.

In order to collect data, first we asked respondents whether they had recently undertaken (or completed) electronic commerce projects. We identified 126 project managers (126 of 377 new technology ventures) who have been involved in electronic commerce investments in the past year and were willing to participate in our study. The sampling frame comprises a wide range of industry segments, including electronics (28%), computer equipment (23%), chemicals (16%), telecommunications equipment (10%), pharmaceuticals and medicines (9%), agriculture (7%), and others (7%).

The measurement items were translated into Persian using the double-back-translation method to ensure accuracy (Brislin, 1970). In doing so, first we hired two independent expert translators to translate the items into Persian and asked two bilingual strategic management professors to translate it back into English. Second, we conducted a meeting with the individuals who were involved in the translation process (we conducted a meeting with the four translators) to compare the original items with the translated ones to check for conceptual equivalence. Third, to ensure face validity of the scales and confirm appropriateness of the questionnaire, we conducted five in-depth interviews with project managers in new technology ventures, wherein we asked them to identify ambiguity and wording format. These project managers were asked to first complete the survey and then provide detailed feedback. To refine the questionnaire measures, a pre-test study with ten project managers (not included in the main sample) was conducted using our Persian survey. To enhance the clarity of questions, we asked the respondents to review the items carefully. Any confusing words were revised before we began launching the questionnaire.

We collected data in three different phases. First, telephone notifications were executed before the initial mailing to identify key informants, verify mailing addresses, and solicit cooperation. In the second step, we sent surveys with independent and control variables in mid-2013. We addressed the survey strictly to the project managers. In order to increase the response rate, after three weeks of initial distribution, we made telephone calls and requested those from whom we had not yet received feedback to complete and return the survey. Finally, in the first wave of data collection, 114 usable survey responses were received, resulting in a response rate of 41%. Given that the average project duration was 11 months, approximately one year later, we distributed our second survey containing dependent variables to the same ventures and managers (one new technology venture had ceased operations). In this phase, we received 110 completed surveys.

We checked for the non-response bias effect in our findings. It was assumed that late respondents were more similar to non-respondents than to early respondents. By using the time trend extrapolation test (Armstrong & Overton, 1977), we compared the early respondents (first 25%) with the late respondents (late 25%). This test provided evidence that the data are not subject to non-response bias.

Furthermore, the Harman one-factor test was conducted to check for common method variance; no single factor emerged nor did a single factor account for the majority of the variance (Podsakoff, 1986). In addition, we sent the project performance items to the firms' CEOs. Eventually, we received 22 responses from CEOs. The comparison of both groups of respondents (project managers versus CEOs) showed a high and statistically significant correlation. The correlation of respondents for project timeliness was 0.818, for project efficiency 0.884, and for project effectiveness 0.864 ($p < 0.001$), respectively. A strong correlation between the two responses indicates that the original assessments are not susceptible to bias (James, Demaree, & Wolf, 1984).

The average new technology venture age was 8.21 years (S.D. = 3.15), the average number of employees was 57 (S.D. = 32.31), the average project team size was 8.16 (S.D. = 4.11), and the average project duration was 10.99 months (S.D. = 4.57).

Measurement

Project Performance

In the present research, electronic commerce project timeliness, effectiveness, and efficiency were measured in terms of nine items adopted from Henderson and Lee (1992). Cronbach's alpha values of project timeliness, effectiveness, and efficiency were 0.940, 0.868, and 0.887, respectively.

Real Options Reasoning

In the present study, we focus our analysis on the project level rather than the firm level. The independent variable that we included in the study is real options reasoning. We used 19 items ($\alpha = 0.97$) to measure the existence

of real options reasoning in electronic commerce investment based on the works of Tiwana et al. (2007). All 19 items were loaded onto one factor, so we used real options aggregately in our modeling.

Perceived Environmental Uncertainty

We assessed perceived state ($\alpha = 0.89$), effect ($\alpha = 0.79$), and response ($\alpha = 0.82$) uncertainties using nine items (Ashill & Jobber, 2009). Examples of items include: "You have the information to understand how your business environment will change in the future" (state uncertainty); "You fully understand the effect of the environment factor on your decision making" (effect uncertainty); and "You can accurately anticipate the consequences/outcomes of decisions before implementing them" (response uncertainty) (Ashill & Jobber, 2009). In the current study, multi-item Likert scales were used to measure the dependent and independent constructs (see the Appendix for items and factor loading).

Control Variables

Some variables not considered in the hypotheses are presented herein, and these variables may still influence real options reasoning and project performance. At the individual level, we controlled project manager age, education, and gender. At the firm level, we controlled new technology venture size (logarithm of number of employees) and age (logarithm of years of operation). At the project level, we controlled project net present value (NPV), team size (logarithm of number of individuals involved in the project), complexity, duration (logarithm of number of months required for project completion), and direct responsibility of project managers (whether respondent had direct personal responsibility for initiating the project). All project level control variables were adapted from Tiwana et al. (2007).

Results

In Table 1, we summarize the descriptive statistics and correlations of all variables in the study. To test the hypothesized relationships meaningfully, it was first necessary to establish that the types of uncertainty were, in fact, differentiable. An exploratory factor analysis (EFA) revealed that the factors grouped themselves according to the theory (Kaiser-Meyer-Olkin = 0.932; Bartlett's = 0.000).

To reduce the threat of multicollinearity, dependent variables were centered before conducting regression analyses. In addition, we checked variance inflation factors (VIF) to exclude multicollinearity. The results of VIF testing of all our variables were significantly below 5, suggesting that our model of study did not have a serious multicollinearity problem (Cohen, Cohen, West, & Aiken, 2013).

To test the study hypotheses, we performed a hierarchical multiple regression analysis. In the first step, we entered the control variables with real options reasoning as dependent variables. In the second step of each regression equation, we entered the independent variables (state, effect, and response uncertainty). Table 2 and Figure 2 list the direct effects of the three types of uncertainties on real options reasoning.

We first address Hypothesis 1, which deals with the direct and positive relationship between perceived environmental state uncertainty and real options reasoning. As can be inferred from Table 2, the relationship between perceived environmental state uncertainty and real options reasoning is positive and statistically significant ($B = 0.318$, $p < 0.05$). Thus, hypothesis 1 was fully supported. This means that under higher state uncertainty, project managers use greater numbers of real options.

Our second hypothesis indicated that there is a positive and significant relationship between perceived effect uncertainty and real options reasoning. As can be inferred from Table 2, the path from perceived environmental effect uncertainty to real options reasoning is positive but non-significant ($B = 0.031$, $p < 0.05$). Thus, Hypothesis 2 was not supported by our results.

In the third hypothesis, we predicted that perceived response uncertainty was negatively related to real options reasoning. As summarized in Table 2, the perceived environmental response uncertainty is significantly negatively related to real options reasoning ($B = -0.503$, $p < 0.01$). Hypothesis 3 was fully supported by our results. This means that under higher environmental response uncertainty, project managers prefer to consider fewer real options.

The results of testing Hypotheses 4, 5, and 6 by hierarchical multiple regression analysis are summarized in Table 3 and Figure 2.

The fourth hypothesis predicted that real options reasoning would be negatively associated with project timeliness. As predicted, our results demonstrated that higher usage of real options reasoning decreases the project timeliness ($\beta = -0.632$; $p < 0.001$). Thus, Hypothesis 4 was supported by our results.

Hypothesis 5 proposed that real options reasoning would be positively associated with project effectiveness. As predicted, our results confirmed that the higher usage of real options reasoning leads to higher project effectiveness ($\beta = 0.393$; $p < 0.001$). Hypothesis 5 was fully supported. And finally, consistent with Hypothesis 6, we found that real options reasoning significantly and positively relates to project efficiency ($\beta = 0.393$; $p < 0.001$).

Among the control variables, surprisingly, education was negatively related to project timeliness ($\beta = -0.389$; $p < 0.05$) and positively related to project effectiveness ($\beta = 0.434$; $p < 0.05$) and efficiency ($\beta = 0.381$; $p < 0.05$). Consistent with the argument of Tiwana, Wang, Keil, and Ahluwalia (2007), we found a negative relationship between project net present value (NPV) and the usage of real options ($\beta = -0.376$; $p < 0.001$). This means that project managers associate real options reasoning with perceived project value in ecommerce projects with low NPV.

	Mean	S.D.	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00
1. Firm Age®	8.21	3.15	1.00																	
2. Firm Size®	56.94	32.31	.420**	1.00																
3. Manager Age®	36.99	6.97	.221**	0.05	1.00															
4. Gender	1.24	0.43	0.05	−0.06	0.08	1.00														
5. Education	4.79	1.32	0.04	−0.06	0.04	−0.12	1.00													
6. Net Present Value	4.81	2.18	0.15	0.03	−0.05	.230*	−.535**	1.00												
7. Direct Responsibility	1.15	0.36	−.189*	−0.14	−0.09	−0.11	.208*	−0.08	1.00											
8. Project Complexity	3.94	1.47	−0.10	−0.12	0.00	0.07	−.206*	0.14	−0.02	1.00										
9. Project Duration	10.99	4.57	−0.11	−0.10	0.13	−0.04	0.00	−0.01	−0.03	−0.05	1.00									
10. Project Size	8.16	4.11	−0.17	−0.04	−0.19	0.00	0.17	0.06	−0.02	−0.03	0.11	1.00								
11. Market Opportunity	1.40	1.51	−.252**	−0.02	0.18	0.06	0.05	−0.09	−0.11	0.09	.214*	0.01	1.00							
12. State Uncertainty	3.31	1.40	−0.07	0.09	−0.03	−0.05	.403**	−.440**	0.13	−.296**	0.08	0.08	0.05	1.00						
13. Effect Uncertainty	2.80	1.40	0.05	0.06	−0.16	−0.06	−0.08	0.14	−0.03	−0.04	0.03	0.16	−0.11	0.16	1.00					
14. Reponse Uncertainty	3.00	1.21	−0.06	−0.06	0.00	0.08	−.417**	.512**	−0.05	.205*	−0.01	−0.04	0.04	−.622**	−.196*	1.00				
15. Real Options	4.31	1.76	−0.08	−0.02	0.01	−0.11	.386**	−.515**	0.13	−0.18	0.00	0.12	−0.05	.677**	0.13	−.635**	1.00			
16. Timeless	3.69	1.98	0.10	−0.08	−0.01	.211*	−.516**	.603**	−0.08	0.14	0.04	−0.02	−0.11	−.546**	−0.04	.634**	−.593**	1.00		
17. Efficiency	4.13	1.91	−0.12	−0.15	−0.01	−0.03	.498**	−.641**	0.14	−0.12	0.07	0.00	0.02	.655**	0.05	−.697**	.722**	−.663**	1.00	
18. Effectiveness	4.30	1.66	−0.01	−0.07	0.06	−0.04	.505**	−.506**	0.14	−.219*	0.01	−0.01	−0.08	.655**	0.02	−.619**	.622**	−.649**	.630**	1.00

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

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Table 1: Descriptive statistics and correlations.

	Real Options Reasoning	
	Control Variables	**Main Effects**
Firm Age	−0.395	−0.266
Firm Size	0.34	−0.07
Manager Age	1.631	2.079
Gender	−0.262	−0.332
Education	0.149	−0.04
Direct Responsibility	0.491	0.261
Project Complexity	−0.083	0.044
Project Duration	−0.038	−0.037
Market Opportunity	−0.016	−0.012
Net Present Value	−0.376**	−0.246*
Project Team Size	0.093*	0.042
State Uncertainty		0.318*
Effect Uncertainty		0.031
Response Uncertainty		−0.503**
R^2	0.408	0.630
Adj. R^2	0.321	0.554
F	4.206***	7.832***

+p < 0.10; *p < 0 .05; **p < 0.01; ***p < 0.001

Table 2: Regression analysis with real options reasoning as criterion variable.

	Project Timeliness		Project Effectiveness		Project Efficiency	
	Control Variables	**Main Effects**	**Control Variables**	**Main Effects**	**Control Variables**	**Main Effects**
Firm Age	1.044	0.944	−0.434	−0.45	0.344	0.626
Firm Size	−0.642	−0.329	0.289	0.055	−0.731	−0.742
Manager Age	1.306	2.238	0.984	0.524	−1.764	−1.984
Gender	−0.025	−0.158	0.47	0.553	0.391	0.696*
Education	−0.389*	−0.307*	0.434**	0.386**	0.381*	0.275*
Direct Responsibility	−0.199	0.117	0.37	0.174	−0.08	−0.294
Project Complexity	0.001	−0.036	−0.022	−0.01	0.028	0.065
Project Duration	0.013	−0.011	0.014	0.028	0.008	0.022
Market Opportunity	−0.066	−0.061	−0.183*	−0.191*	−0.034	0.001
Net Present Value	0.435***	0.185*	−0.277**	−0.119	−0.534***	−0.381***
Project Size	−0.016	0.046	0.011	−0.028	0.029	−0.01
Real Options Reasoning		−0.632***		0.393***		0.502***
R^2	0.449	0.629	0.395	0.505	0.546	0.704
Adj. R^2	0.371	0.569	0.309	0.425	0.481	0.656
F	5.232***	10.319***	4.199***	6.17***	7.352***	13.79***

*p < 0.05, **p < 0.01, ***p < 0.001; †p < 0.10

Table 3: Regression analysis with project timeliness, effectiveness, and efficiency as criterion variables.

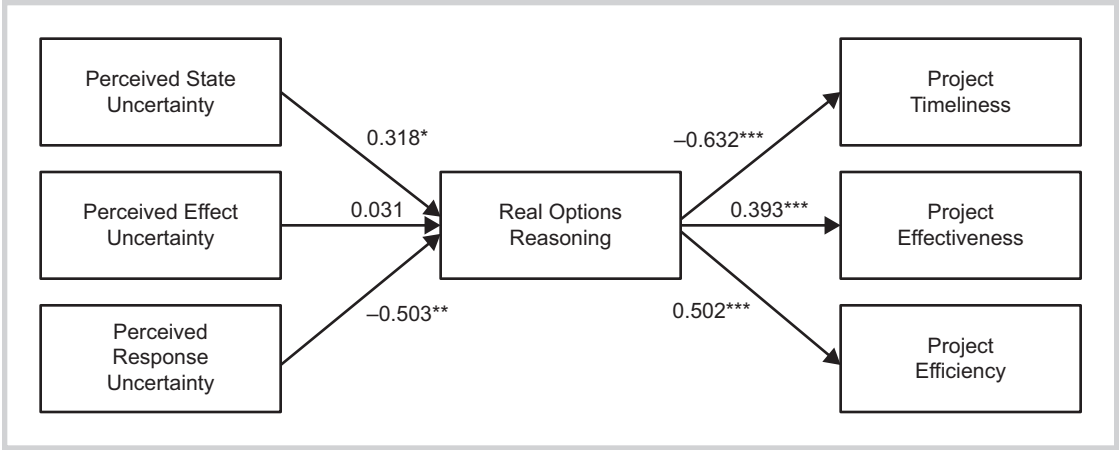

Figure 2: Overview of the results of the study.

Discussion

Despite the growing recognition of the importance of real options reasoning, little is known about the major antecedents and consequences of this phenomenon on the project level. Our research addresses this gap by focusing on the relationship between the perception of environmental uncertainty and real options reasoning and the resultant project performance. In support of our expectations, the results indicate that:

(1) The perception of state increases and the perception of response uncertainty decreases project managers' tendency to consider real options in electronic commerce projects. Under conditions of response uncertainty, the accepted tenet of greater uncertainty leading to more real options reasoning usage is not valid. In fact, under response uncertainty conditions, project managers would reduce their real options reasoning usage.
(2) The use of greater numbers of real options decreases project timeliness.
(3) The use of greater real options increases project effectiveness and efficiency.
(4) In contrast to our prediction, we didn't find a significant relationship between perceived effect uncertainty and real options reasoning.

The findings of our study challenge a common belief in the context of real options literature, which is "the higher the uncertainty, the greater is the real options usage." Higher or lower use of real options in investment decisions is contingent on the type of uncertainty faced by a project manager. The result of this study reveals that when project managers are less certain about the outcomes of their decisions (response uncertainty) they prefer to use fewer real options. They use greater numbers of real options when they are faced with an unpredictable environment (state uncertainty).

Although real options reasoning is widely considered a promising line of research (Trigeorgis, 1996; Zardkoohi, 2004) with important practical implications (Fichman, 2004), its actual use at the project level has not been smooth (Adner & Levinthal, 2004b; Barnett, 2008). The possible reasons for this are varied, such as the impact of differing managerial perceptions of option-based decisions and difficulty in managing abandonment options (Adner & Levinthal, 2004a; Adner & Levinthal, 2004b). Our research extends the real options literature by empirically testing real options in electronic commerce investments, a context that presents high levels of uncertainty to project managers and drives much of the competitive activity in the current economy. However, our work highlights that the application of real options reasoning does not always enhance project performance under conditions of higher uncertainty. Greater use of real options is essential to meeting project efficiency and effectiveness, but it decreases project timeliness. Moreover, when project managers use fewer real options, it may reduce the quality of the work produced and affects the completion of electronic commerce project objectives, yet it helps to complete the project in a time-efficient manner.

The findings of this study are worthwhile because they emphasize the need to treat environmental uncertainty as a distinct set of constructs as opposed to a unidimensional concept (Sutcliffe & Zaheer, 1998). Previous empirical studies on real options reasoning and investment decisions (Fichman et al., 2005; Tiwana et al., 2007) have partially neglected the important roles of different types of perceived uncertainties on real options reasoning decision endeavors and efforts. This fact is insofar surprising that the different types of uncertainties may have distinct effects on real options reasoning based decisions.

Anchored in the Upper Echelons Theory (Hambrick & Mason, 1984; Hambrick, 2005; Carpenter, Geletkanycz, & Sanders, 2004), the results of this study provide a clearer picture of the

general relationship among top managers' perceptions, their actions, and the subsequent outcomes than was previously available. Furthermore, we advanced the current understanding of how Upper Echelons Theory applies in non-western contexts (Hambrick, 2007).

Even though it is not part of our main hypotheses, we found a negative relationship between the net present values of projects and real options reasoning. This finding is in line with Tiwana et al. (2007), who showed that project managers are less likely to use real options reasoning when they estimate the net present value of a project to be high. Our finding is in contrast with the Bowman and Moskowitz (2001) argument, which asserts that investments in based of real options reasoning make economic sense only when the value of the option exceeds the cost of the option.

An important implication of the findings of the present study is that project managers in new technology ventures need to clearly prioritize their objectives for each electronic commerce project so that they can adopt the appropriate strategy to facilitate the achievement of their objectives. If project time efficiency is the main goal under the condition of uncertainty, for example, our findings reveal that project managers need to create and exercise fewer real options. In contrast, under such a condition, if the priority of project managers is to produce high quality work that ensures the satisfaction of project objectives, the greater use of real options is suitable.

Limitations and Directions for Future Research

Our work has some limitations. Because our project performance measures are subjective and we are unable to prove that the perceptual measure of study is a valid predictor of more "objective" project performance measures, one could argue that different results might be obtained for other project performance measures. Thus, future work in the context of project performance may include more objective project performance measures to provide confidence in their robustness. Our results concern young and high technology based ventures, which may limit their applicability to other sectors. It might be worthwhile to consider firms in low-technology environments and older firms to reinforce the generalizability of our findings. Finally, national culture is an influential factor in risk and uncertainty perception (Weber & Hsee, 1998), which was not assessed herein. Iranian culture exhibits a high preference for avoiding uncertainty. This feature makes it difficult to generalize our findings disregarding of cultural background. The research results could be generalized into other national cultures via cross-cultural comparisons in future studies.

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Does Real Options Reasoning Support or Oppose Project Performance?

Ziedonis, A. A. (2014). Real options in technology licensing. *Management Science*, *53*(10), 1618–1633.

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Appendix: Construct measures.

	Factor Loading
Perceived environmental state uncertainty (Adapted from Ashill and Jobber, 2009) How often do you feel and believe that:	
• You have the information to understand how your business environment will change in the future.	0.674
• Your information about your business environment is adequate for your decision making.	0.859
• You are unable to get the necessary information about your business environment for your decision making (R)	0.773
Perceived environmental effect uncertainty (Adapted from Ashill and Jobber, 2009) How often do you feel and believe that:	
• You are unable to predict the impact of your business environment on your project (R)	0.538
• You fully understand the effect of the environment factor on your decision making.	0.887
• Please indicate your "sureness" (level of certainty) as to how each environmental factor affects your decision making? (Not at all sure about how it will affect my decision making/completely sure about how it will affect my decision making).	0.825
Perceived environmental response uncertainty (Adapted from Ashill and Jobber, 2009) How often do you feel and believe that:	
• You can accurately anticipate the consequences/outcomes of making decisions before making them.	0.618
• You know how to respond to changes in the external environment.	0.767
• You are able to determine what the response options should be in light of changes in the external environment.	0.666
Real options reasoning (Adapted from Tiwana et al., 2007) For our organization, this project is:	
• Necessary for unlocking future project opportunities	0.683
• Necessary for developing future capabilities	0.784
• First in a chain of interrelated follow-on projects in the future	0.83
This project could be easily:	
• Funded incrementally in stages	0.767
• Managed in incremental stages	0.86
• Completed as a series of smaller projects	0.769
• Decomposed into smaller independent sub-projects	0.859
This project could easily:	
• Use a set of different resources (e.g., new technologies, new suppliers) to produce the same product	0.872
• Be reconfigured to produce different products to satisfy emerging market needs	0.788
• Serve a different strategic purpose	0.874
It would be very easy to expand or contract the following resources initially allocated to this project	
• Budget	0.894
• Personnel	0.866
• Other resources	0.851
If this project were postponed by two years	
• Project requirements would be clearer	0.882
• Many technical uncertainties would be resolved	0.877
• Uncertainty around the business model would be reduced	0.867
To what extent could the following resources be put to other uses if this project were abandoned prior to completion?	
• Allocated budget	0.894
• Personnel	0.882
• Other resources	0.867

(continued)

	Factor Loading
Project Timeliness (Adapted from Henderson and Lee, 1992)	
• The team's adherence to schedules	0.762
• The speed at which the team did its work given the level of quality	0.81
• The team's ability to meet the goals as quickly as possible	0.773
Project Efficiency (Adapted from Henderson and Lee, 1992)	
• The efficiency of team operations	0.785
• The team's adherence to budgets	0.806
• The amount of work the team produces	0.682
Project Effectiveness (Adapted from Henderson and Lee, 1992)	
• The quality of work the team produces	0.653
• The effectiveness of the team's interactions with people outside the team	0.892
• The team's ability to meet the goals of the project	0.742