RESEARCH NOTE

The Bounded Rationality Bias in Managerial Valuation of Real Options: Theory and Evidence from IT Projects

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ABSTRACT

Although real options theory normatively suggests that managers should associate such real options with project value, little field research has been conducted to test whether they suffer from systematic biases in doing so. We draw on the notion of bounded rationality in managerial decision making to explore this understudied phenomenon. Using data collected from managers in 88 firms, we show that managers exhibit what we label the bounded rationality bias in their assessments: They associate real options with value only when a project’s easily quantifiable benefits are low, but fail to do so when they are high. The study also contributes the first set of empirical measures for all six types of real options. The study contributes to managerial practice by identifying the conditions under which managers must be vigilant about inadvertently neglecting real options and by providing a simple approach for assessing real options in technology development projects.


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INTRODUCTION

Managers are often faced with the challenging task of assessing the value of pursuing prospective project opportunities (Shepherd, 1999; Bharadwaj & Tiwana, 2005). Many such decisions are shrouded in considerable uncertainty and require managers to consider a variety of ill-structured information in their decision making (Walsh, 1988; Simon & Houghton, 2003; Brousseau, Driver, Hourihan, & Larsson, 2006). Rationally-acting managers often rely on discounted cash flow (DCF) techniques (Fichman, Keil, & Tiwana, 2005), which recent thinking on real options has cautioned fail to account for the flexibility through which managers actively create and exploit future strategic opportunities (Perlitz, Peske, & Schrank, 1999; Balasubramanian, Kulatilaka, & Storck, 2000; Bowman & Moskowitz, 2001).

Real options exist in a project when managers have the opportunity without the obligation to take some action in the future. Such flexibility buffers project risk while retaining entrée to the future upside opportunities created by a project (Sullivan, Chalasani, Jha, & Sazawal, 1999; Fichman et al., 2005). Although empirical tests of real options are few and far between, preliminary field studies show that managers do intuitively recognize them (Fichman et al., 2005; Tiwana, Keil, & Fichman, 2006).

An assertion in real options theory is that managers should account for the real options created by a project—beyond its net present value (NPV). However, no research currently exists regarding whether managers exhibit systematic biases in how they ascribe value to such real options, a gap that this study seeks to empirically address.

An independent, larger stream of research on cognitive biases in managerial decision-making has consistently demonstrated that managers are boundedly rational, not perfectly rational (Simon, 1979; Chaiken, 1980; Hammond, Keeney, & Raiffa, 1998). They cope with decision-making complexity by using only a subset of the available information, leading to biases in a variety of decision making contexts (March & Shapira, 1987; Bukszár & Connolly, 1988; Hammond et al., 1998; Hilary & Menzly, 2006; Smith & Winkler, 2006). While these developments in managerial cognition and real options have contributed important insights into managerial decision making under uncertainty, the two streams coexist in relative isolation and offer partially conflicting prescriptions.

We draw on Simon’s notion of bounded rationality to develop the idea that managers will exhibit systematic biases in how they value real options. Building on his concepts of selective search and satisficing, we hypothesize that managers are less likely to associate real options created by a project with perceived project value when the project exhibits adequate value by the traditional NPV metric (i.e., quantifiable project benefits largely exceed costs). We label this phenomenon the bounded rationality bias in real options valuation. By drawing on project-level data from 88 firms, the research reported here provides support for the bounded rationality bias.

The article’s key contributions to managerial decision-making theory are two-fold. First, integrating insights from real options theory and bounded rationality, we show that managers associate real options with project value in projects with low NPV but systematically downplay their value in projects with high NPV. The
second and more modest contribution of the article is the development of the first set of project-level measures for all six types of real options. The cross-sectional nature of our data, however, does not permit testing how real option value changes across different stages of a project.

The rest of the article is structured as follows. In the next few sections, we develop our hypotheses. Then we describe the research methodology and present our analyses and results. Finally, we discuss the implications of these results, and conclude with a summary of the key insights offered by the study.

THEORY AND HYPOTHESES

In this section, we build on bounded rationality and real options theory to develop the idea that managers associate real options with project value only when the net present value of a project is low. This leads managers to undervalue real options when they are optimistic about a project’s quantifiable value, leading to a systematic bounded rationality bias in real options valuation.

Real Options Theory

A real option refers to the opportunity without an obligation to take some action in the future in response to endogenous or exogenous developments (Benaroch & Kauffman, 1999; Taudes, Feurstein, & Mild, 2000; Benaroch, 2002). At the project level, real options often exist in bundles wherein a project can create multiple distinct real options (McGrath, 1997; McGrath, 1999; Benaroch, 2002). Prior research has identified six real options based on the type of flexibility that is associated with each option (Trigeorgis, 1993; Fichman, 2004): (i) growth, (ii) stage, (iii) scale, (iv) switch use, (v) defer, and (vi) abandonment (summarized in Table 1).

<table>
<thead>
<tr>
<th>Option</th>
<th>Option exists in the project if...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>A project unlocks opportunities for future follow-on IT investments, many of which can be foreseen at the time of initiating the project (Benaroch &amp; Kauffman, 1999; Kogut &amp; Kulatilaka, 1994; Kogut &amp; Kulatilaka, 2001; Trigeorgis, 1993).</td>
</tr>
<tr>
<td>Stage</td>
<td>A project is structured as a series of incremental investments in a project that allow the project to be terminated if unfavorable business conditions later warrant (Majd &amp; Pindyck, 1987; Myers &amp; Majd, 1990).</td>
</tr>
<tr>
<td>Scale</td>
<td>The allocated resources—budgets, personnel, hardware, and software in IT projects—to be contracted or expanded (Fichman, 2004; Pindyck, 1988).</td>
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<tr>
<td>Switch</td>
<td>It can be put to a different application from the one for which it was originally intended (Taudes et al., 2000; Trigeorgis, 1993).</td>
</tr>
<tr>
<td>Defer</td>
<td>The initiation of a project can be delayed without risking foregoing a valuable opportunity (Benaroch &amp; Kauffman, 1999; Hubbard, 1994).</td>
</tr>
<tr>
<td>Abandon</td>
<td>Managers have the discretion to discontinue a project prior to completion and redeploy remaining project resources (Fichman, 2004; Hubbard, 1994).</td>
</tr>
</tbody>
</table>
Bounded Rationality in Managerial Decision Making

Traditional project valuation approaches use net present value (NPV) to estimate the extent to which the benefits of a project exceed its costs. The NPV decision heuristic guides decision making by recommending that only projects with a positive NPV are worth pursuing (Huchzermeier & Loch, 2001). Real options theory was developed to account for the value of managerial flexibility that is neglected by NPV. The option-adjusted NPV of a project is its traditional NPV plus the value of the embedded real options.

Options literature emphasizes that real options are more valuable under greater uncertainty based on the premise that the managerial flexibility provided by real options is of value when there is considerable uncertainty surrounding a project (Hubbard, 1994; Benaroch & Kauffman, 1999). Uncertainty can arise from technical sources and from evolving business needs related to a project. Technical uncertainty in IT projects (this study’s context) arises from unexpected problems in the underlying project hardware, system software, programming languages, and database technologies (Nidumolu, 1995; McGrath, 1997). Business uncertainty arises from unpredictable changes in a project’s business priorities during its implementation (Nidumolu, 1995; Tiwana, Bharadwaj, & Sambamurthy, 2003). Both might be present in the context of a given project, with the total uncertainty compounded when both are simultaneously present. The concept of parametric uncertainty, which is defined as the degree of technical and business uncertainty associated with a project, captures such uncertainty (Williamson, 1987; Vazquez, 2004). According to options theory, real options are more valuable under greater parametric uncertainty because managerial flexibility is more valued under greater uncertainty (Benaroch & Kauffman, 1999; Huchzermeier & Loch, 2001; Benaroch, 2002). Thus, we expect that managers will ascribe more value to the real options created by a project under greater parametric uncertainty. However, uncertainty is a necessary but insufficient condition for managers to ascribe value to real options because managers are likely to face a bounded rationality bias in their valuation of a prospective project.

Bounded rationality in managerial judgments

In order to make strategic assessments, managers must engage in cognitively demanding activities, in which they must integrate a variety of information to arrive at an overall assessment (Bukszar & Connolly, 1988). When facing a cognitively challenging assessment task, managers arrive at their conclusions by considering a broad range of facts and then by conducting a detailed examination of a subset of facts (Etzioni, 1989). In doing so, they encounter the limits of their bounded rationality. Bounded rationality refers to the limits experienced by managers in their ability to process and interpret a large volume of pertinent information in their decision-making activities (Simon, 1979). Bounded rationality thus describes the process of how managers arrive at their assessments (Simon, 1979). This phenomenon is poorly appreciated in field studies of how managers value real options in their technology investment decisions.

Bounded rationality encompasses two central concepts: search and satisficing (Simon, 1979). Search refers to how extensively a decision maker searches for information to guide decision making. In IT projects, managers are likely to consider
the costs of a project, its perceived organizational benefits, and the technical and
business uncertainties that might affect its likelihood for successful completion.
The search scope is capped by what Simon describes as an aspiration level that
defines at the outset of the search process what constitutes a good enough solution.
As soon as this aspiration level is reached, individuals terminate the search process
and reach a tentative conclusion (Simon, 1979). Search is guided by heuristics that
are tacitly held but consistently used to simplify the cognitive decision-making
process (Simon, 1979; Chaiken, 1980; Hammond et al., 1998). Managers cope
with the potentially large volume of contextual information by focusing on a few
salient cues in forming heuristic-driven judgments under uncertainty (Kahneman,
2003; Simon & Houghton, 2003). Individuals consequently reach a preliminary
conclusion after assessing a salient subset of the available information that they
perceive as being most informative and terminate their search (Miller & Chen,
2004; Hilary & Menzly, 2006). In managers’ evaluation processes, empirical stud-
ies have also found that their perceptions are narrowly anchored on a reference
point they use to assess changes in wealth rather than the final states of wealth.
Managers’ evaluations tend to rely on narrow frames of reference that are relative to
a reference point to which they have become adapted (Kahneman, 1982; Kahneman,
2003). (For example, IT managers are often professionally trained to
use NPV as a project investment reference point (Fichman et al., 2005).)

This process of terminating information search without further considering a
broader realm of available information to form a judgment is known as satisficing
(Simon, 1979). Prior field studies on managerial decision making have shown that
satisficers are ready to act as soon as they have enough information to satisfy
their self-imposed informational requirements (Brousseau et al., 2006), which are
often heuristic-governed (Kahneman, 2003). Satisficing criteria therefore terminate
search. This satisficing process makes individual decision makers vulnerable to
cognitive biases, as also demonstrated by numerous empirical studies (March &
Shapira, 1987; Bukszar & Connolly, 1988; Hammond et al., 1998; Hilary & Menzly,
2006; Smith & Winkler, 2006).

Consider how such bounded rationality manifests itself in managers’ assess-
ments of prospective IT projects. Managers follow the satisficing principle, which is
governed by the widely-prescribed NPV rule that then becomes a salient judg-
ment heuristic (Kahneman, 2003). Such reliance on a limited number of heuristic
principles simplifies the complex task of project valuation to a simpler judgmental
operation (Kahneman, 2003). If the NPV of a prospective project is low, NPV in-
formation is unlikely to terminate the search process. If managers are expecting to
see value in a proposed project but do not see such value reflected in the traditional
heuristic of a high NPV (i.e., its quantifiable benefits are lower than its expected
costs), they are likely to expand their search scope by scrutinizing the project
more closely to assess whether it might have plausible justifications not reflected
in its NPV estimates. In contrast, if the NPV of a project is high, this information
should terminate managers’ search processes. Any additional information about a
prospective project—such as the real options that it creates—is less likely to enter
managers’ cognitive calculus. As a result, managers are more likely to consider
additional information beyond the project’s NPV in forming an assessment of value
in low-NPV but not in high-NPV projects. We hypothesize that this tendency will
systematically lead managers to associate real options with perceived project value in projects with low NPV but not in projects with high NPV.

We posit that boundedly-rational managers, facing high parametric uncertainty, are less likely to perceive value associated with the real options embedded in an IT project when the project is already perceived to have quantifiable benefits (i.e., high NPV), and vice versa. In the following sections, we develop this logic for each type of real option.

**Option to Grow**

A growth option exists in a project if it unlocks opportunities for future follow-on IT investments, many of which can be foreseen at the time of initiating the project (Trigeorgis, 1993; Kogut & Kulatilaka, 1994; Benaroch & Kauffman, 1999; Kogut & Kulatilaka, 2001). The growth option serves as a precursor to related projects and IT capabilities that can be used to exploit unforeseen future opportunities (Kim & Kogut, 1996; Taudes, 1998; Fichman, 2004). Initiating a project with an embedded growth option can also provide a firm technical skills that facilitate exploitation of future technologies (Kogut & Kulatilaka, 1994; Taudes et al., 2000; Loch & Bode-Greuel, 2001). For example, Starbucks, a Seattle-based chain of cafés, introduced its Starbucks card that used a magnetic data stripe in conjunction with card readers in its stores in 1999. In the following years, the card allowed Starbucks to implement a variety of customer intelligence software applications and a customer loyalty program that were not envisioned at the time of the introduction of the original card (Fichman et al., 2005). Thus, the initial project served as a platform for exploiting future opportunities.

The growth option is less likely to enter managers’ mental calculus of project value when a prospective project has high NPV, because the high NPV itself suffices to justify a given project. In other words, the identification of a high NPV terminates search. However, managers are more likely to recognize an embedded growth option as contributing to the value of a prospective project when its NPV is low (i.e., its costs cannot be justified based on its quantifiable net benefits alone). This follows from managers’ boundedly-rational behavior in which a high NPV satisficies the search for project valuation information but a low NPV triggers an expanded search. In summary, we expect that under high parametric uncertainty, managers will associate an embedded growth option with project value in projects with low NPV.

**H1:** Under conditions of parametric uncertainty, when projects are perceived to have a low net present value, managers are more likely to associate embedded growth options with the perceived value of a prospective project.

**Option to Stage Investments**

The option to stage investments exists when a project is structured as a series of incremental investments that allow the project to be terminated under adverse business conditions (Majd & Pindyck, 1987; Myers & Majd, 1990). Staging options can be embedded in a project if it is decomposed into a chain of smaller sub-projects, each of which can be viewed as a compound option on the value of the subsequent stages (Geske, 1979; Benaroch, 2002). An investment in an earlier
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project stage provides the real option to proceed to the subsequent stages if the preceding stages have favorable outcomes (Panayi & Trigeorgis, 1998; Huchzermeier & Loch, 2001). For example, a project plan that provides funding for the architecture design only after requirements elicitation has been completed has a stage option embedded in it. A staging option is valuable under high uncertainty because it lowers organizations’ exposure to risk by actively utilizing information produced at the end of each project stage: If the project outcomes of one stage are unfavorable, the losses are capped at the cost of the preceding stages (Sullivan et al., 1999; Fichman et al., 2005). Managers, due to their boundedly-rational behavior, are likely to value this option more highly when a project’s costs exceed its quantifiable benefits (i.e., its NPV is low relative to other comparable projects in an organization). In contrast, when its NPV is high, managers are more likely to terminate their search for additional information beyond the NPV heuristic in forming an assessment of a project’s value. This leads to the next hypothesis:

**H2:** Under conditions of parametric uncertainty, when projects are perceived to have a low net present value, managers are more likely to associate embedded staging options with the perceived value of a prospective project.

**Option to Change Scale**

The option to change scale exists in a project if the allocated project resources—budgets, personnel, hardware, and software in IT projects—can be contracted or expanded (Pindyck, 1988; Fichman, 2004). This option provides managers the opportunity to revise project resource allocations based on new information that emerges during a project. Managers can also free up resources that were initially allocated to a project if the intermediate project outcomes are unfavorable. Managers’ boundedly-rational behavior will lead them to terminate their search for information without associating significant value with the scaling option in projects with high NPV. However, in projects with low NPV, the absence of sufficient information to justify a project in terms of its quantifiable benefits will lead managers to expand the scope of their search to include the value of flexibility to change scale as a contributor to a project’s perceived value. Thus, we hypothesize that managers are more likely to associate an embedded option to change scale with project value in projects with low NPV.

**H3:** Under conditions of parametric uncertainty, when projects are perceived to have a low net present value, managers are more likely to associate embedded scale options with the perceived value of a prospective project.

**Option to Switch Use**

The option to switch use exists when a project can be put to a different application from the one for which it was originally intended (Trigeorgis, 1993; Taudes et al., 2000), potentially allowing managers to partially recoup expended project costs by repurposing it (Hubbard, 1994; Fichman, 2004). However, managers are more likely to associate switching options with project value in projects that have considerable uncertainty about future quantifiable benefits. In such cases, the value of managerial flexibility is inherently higher given the riskier nature of the project
(Copeland & Tufano, 2004). However, when the project has a high NPV, boundedly-rational managers will terminate their search for further project assessment information and are thus less likely to consider the switch use option as a source of added value. Thus, we hypothesize that managers are more likely to associate an embedded option to switch use with project value only in projects with low NPV.

**H4**: Under conditions of parametric uncertainty, when projects are perceived to have a low net present value, managers are more likely to associate embedded switch use options with the perceived value of a prospective project.

**Option to Defer Investment**

The option to defer investment exists when the initiation of a project can be delayed without foregoing a valuable opportunity (Hubbard, 1994; Benaroch & Kauffman, 1999). This option is valuable under uncertainty if the salient technical and business uncertainties can be resolved by simply waiting. An example of this option is illustrated by the case of the Yankee 24’s point-of-sale debit charging network system (Benaroch & Kauffman, 1999). In that case, the primary uncertainty was business uncertainty about how fast retailers would adopt such a system and whether the state of Massachusetts (its primary market) would revise banking regulations that discouraged merchants from adopting such a system. By simply waiting for three years, Yankee was able to resolve these uncertainties and observe the adoption rate for a similar system in the California market (where such a system was implemented earlier (Fichman et al., 2005)). Managers are likely to associate an embedded deferral option with project value when its NPV alone cannot justify initiating a project. However, due to their boundedly-rational behavior, they are unlikely to associate deferral options with project value in projects where a high NPV itself satisfies managers’ heuristic for project value. Therefore we expect managers to associate an embedded deferral option with project value in projects with low NPV.

**H5**: Under conditions of parametric uncertainty, when projects are perceived to have a low net present value, managers are more likely to associate embedded deferral options with the perceived value of a prospective project.

**Option to Abandon**

An abandonment option exists if managers have the discretion to discontinue a project prior to completion and redeploy the remaining project resources elsewhere (Hubbard, 1994; Fichman, 2004). While any project can be abandoned in theory, the resources allocated to any project cannot readily be reallocated to other uses. Furthermore, abandoning a project mid-course can also damage the reputation of the organization and the responsible project manager, making it non-trivial to simply abandon a project. The tendency to save face and avoid public embarrassment from canceling a project, coupled with such empirically observed phenomena as sunk-cost and completion effects situations (Keil, 1995; Keil, Truex, & Mixon, 1995; Drummond, 1996; Keil, Tan, Wei, Saarinen, Tuunainen, & Wassenaar, 2000; McNamara, Moon, & Bromiley, 2002) can discourage managers from exercising
the abandonment option in practice. Managers are more likely to associate an embedded abandonment option with project value in projects with low NPV and high parametric uncertainty the option it provides managers the ability to curtail further losses if the project goes awry. However, when the NPV of a project is high, managers are less likely to use this information due to their boundedly-rational evaluation heuristics. Thus, we hypothesize that managers will associate an abandonment option with perceived project value in projects with low NPV.

H6: Under conditions of parametric uncertainty, when projects are perceived to have a low net present value, managers are more likely to associate embedded abandonment options with the perceived value of a prospective project.

To summarize, the overarching idea developed is that managers are more likely to associate real options with project value for projects with low, but not high, NPV. This bias stems from boundedly-rational managers terminating searches for additional information to guide their assessment of a project if the quantifiable benefits of the project exceed its costs (i.e., high NPV). However, they are more likely to continue their search and recognize the value of embedded real options if a project’s NPV is low because information about a low NPV might fail to meet their satisficing criteria, thus precipitating a more extensive search process.

METHODOLOGY

A field survey was conducted in 2004 to collect data to test the hypotheses. Our sampling frame consisted of a random sample of MIS managers in 500 firms drawn from Dun and Bradstreet’s 2004 directory of corporate executives. The respondents were asked to provide project-level data for a project they had recently considered or were currently considering in their organization. Data on 88 IT development projects were collected. Sixteen of the contacted respondents declined to participate in the study due to company policies, and 61 mailings were returned as undeliverable, leaving 423 potential respondents. This yielded a response rate of 20.8% (88/423), which compares favorably with other studies involving mid-level managers. The firms in the sample represented a variety of industries including publishing, industrial, and consumer products manufacturing; electrical products; printing services; broadcasting; engineering, and retail. To assess non-response bias, post-hoc T-tests were used to compare the early (first 25) and late (last 25) respondents. This revealed no statistically significant differences in firm characteristics, project characteristics, or respondent demographics, suggesting that non-response bias is not a significant threat to the results.

Construct Operationalization and Scale Development

Multi-item Likert or semantic differential scales with seven-point anchors were used to measure all key constructs in the study (see Appendix). New scales were developed to measure the six types of real options in IT development projects based on a review of the real options literature. The informing sources in the literature
Table 2: Measures for the six types of real options.

<table>
<thead>
<tr>
<th>Real Option</th>
<th># Items</th>
<th>$\alpha$</th>
<th>Measurement items conceptually based on...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>3</td>
<td>.80</td>
<td>(Benaroch &amp; Kauffman, 1999; Fichman, 2004; Kogut &amp; Kulatilaka, 1994; Taudes, 1998; Taudes et al., 2000)</td>
</tr>
<tr>
<td>Stage</td>
<td>4</td>
<td>.87</td>
<td>(Benaroch, 2002; Huchzermeier &amp; Loch, 2001; Majd &amp; Pindyck, 1987; Myers &amp; Majd, 1990)</td>
</tr>
<tr>
<td>Scale</td>
<td>3</td>
<td>.74</td>
<td>(Fichman, 2004; Kim &amp; Sanders, 2002; Pindyck, 1988; Tiwana et al., 2006)</td>
</tr>
<tr>
<td>Switch</td>
<td>3</td>
<td>.92</td>
<td>(Fichman, 2004; Hubbard, 1994; Taudes et al., 2000; Trigeorgis, 1993)</td>
</tr>
<tr>
<td>Defer</td>
<td>3</td>
<td>.84</td>
<td>(Benaroch &amp; Kauffman, 1999; Fichman et al., 2005; Hubbard, 1994)</td>
</tr>
<tr>
<td>Abandon</td>
<td>3</td>
<td>.83</td>
<td>(Fichman, 2004; Hubbard, 1994; Keil et al., 1995; Tiwana et al., 2006)</td>
</tr>
</tbody>
</table>

for the measurement items used in this pool of manifest variables are summarized in Table 2.

The initial item pools were refined based on feedback from an expert panel consisting of five IT managers and eight academic experts. The purpose was to ensure that the wording of the items was unambiguous in an IT project context and to ensure the face validity of the survey items. The items were empirically refined using exploratory factor analyses using principal components analysis following the procedures outlined by Straub (1989). Several items from the item pool were deleted in this iterative scale refinement process to ensure convergent and discriminant validity.

The presence of the growth real option was assessed using three items that tapped into the degree to which the project was necessary for unlocking future IT project opportunities, provided a foundation for developing future IT capabilities, and represented a first in a chain of interrelated follow-on projects in the future (Kogut & Kulatilaka, 1994; Taudes, 1998; Benaroch & Kauffman, 1999; Taudes et al., 2000; Fichman, 2004). The staging real option measured four items that assessed the degree to which the project could easily be funded and completed in incremental stages, as a series on smaller projects, and decomposed into smaller independent sub-projects (Majd & Pindyck, 1987; Myers & Majd, 1990; Huchzermeier & Loch, 2001; Benaroch, 2002). The scale real option assessed the extent to which the initially-allocated project budget, personnel, and project resources such as hardware and software could easily be expanded or contracted (Pindyck, 1988; Kim & Sanders, 2002; Fichman, 2004). The switch use real option was assessed using three items that tapped into the ease with which the project could be redeployed for a different purpose from which it was intended (Trigeorgis, 1993; Hubbard, 1994; Taudes et al., 2000; Fichman, 2004). The deferral real option was measured using three items that assessed whether postponement of the project by two years would resolve and make clearer project technical uncertainties and requirements (Hubbard, 1994; Benaroch & Kauffman, 1999; Fichman et al., 2005). Finally, the abandonment real option was measured using three items that assessed the extent to which the project’s allocated budget, personnel, and other resources...
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The project’s net present value was measured as a single-item semantic differential scale that assessed the degree to which the measurable benefits of the project exceeded its costs, relative to other projects that had previously been completed in the organization. The middle point of the scale represents zero NPV, where the quantifiable benefits of the project equal its costs. The end points of the scale indicated where costs greatly exceed quantifiable benefits and where quantifiable benefits greatly exceed costs. Perceived project value was measured using a nine-item semantic differential scale that tapped into the value of the project to the respondent’s organization if it were pursued, following Tiwana et al. (2003). The bipolar anchors in the scale were worthless/worthwhile, unimportant/important, non-essential/essential, of no value/of great value, completely useless/highly useful, difficult to justify/easy to justify, unnecessary investment/critical investment, inappropriate/appropriate, and of no benefit/of great benefit. Parametric uncertainty was computed as a cross product of business and technical uncertainty associated with the project, following Vazquez (2004). Business uncertainty was measured using Nidumolu’s (1995) three-item scale for IT project business requirements uncertainty and technical uncertainty was measured using his four-item IT project technical unpredictability scale. Measures for the control variables are described in the Appendix. All scales exhibited discriminant validity and sufficient reliability (as demonstrated by Cronbach’s (1951) Alpha values of .74 and higher (Nunally, 1978)). Construct correlations, means, and standard deviations are summarized in Table 3.

Descriptive Statistics and Sample Characteristics

On average, the firms in our sample had $59.78 million (SD = $86.1 million) in revenues, 446 (SD = 690) employees, and had been in business for 23 years (SD = 18.79 years). The respondents were highly knowledgeable about IT projects, as evidenced by their average IT experience of 17.4 years (SD = 18 years). Approximately 89% of the respondents had direct personal responsibility for the reported project. Of the projects in the sample, 48.2% were of a strategic nature and the remaining were non-strategic (informational = 42.6%, transactional = 7.2%).

ANALYSIS AND RESULTS

The hypotheses were tested using a three-step hierarchal multiple regression model. In the first step, all control variables were entered, followed by the six types of real options, and finally, interaction effects between the six options and parametric uncertainty. The analyses were conducted for two subgroups, projects with lower and higher NPVs. This sub-grouping was based on a median split, chosen for two reasons. First, different firms are likely to use different hurdle rates as their internal norm. A median split then classifies a project as low NPV, not based on an arbitrary cutoff but rather on the extent to which the respondents in the study expect the NPV to be high or low. Since managers are likely to use prior comparable projects as a frame of reference for judging a prospective project’s benefits and
Table 3: Construct correlations and distributions.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean</th>
<th>SD</th>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
<th>6</th>
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<tr>
<td>1. Strategic importance dummy&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.2%</td>
<td>—</td>
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<td>15. Perceived project value</td>
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<td>0.96</td>
<td>0.05</td>
<td>0.05</td>
<td>−0.03</td>
<td>−0.18</td>
<td>0.12</td>
<td>−0.24</td>
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<td>−0.10</td>
<td>−0.15</td>
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<sup>a</sup>Percentage for dummy variable = 1
costs (Kahneman & Tversky, 1984), this approach accounts for managers’ relative frames of reference instead of using an arbitrary absolute negative and positive NPV cutoff. In addition to its consistency with how managers frame their assessments, this approach is consistent with the idea that IT projects might be highly strategic to the business of some firms, and projects with lower quantifiable benefits than costs (i.e., negative absolute NPV) might be common. In such organizations, a project with a moderately negative absolute NPV might still be viewed as being the acceptable norm. In other firms, a high hurdle rate might be the norm. In such organizations, a project that has a positive value in terms of its absolute NPV might still be treated as a low payoff project relative to the expectation of a much higher payoff that might be used as the norm. In other words, some firms might routinely initiate projects with negative absolute NPV or routinely reject projects when their NPV is positive but not positive enough to meet their investment decision norms and heuristics. Classification as high/low NPV relative to other projects in the respondent’s organization is a more appropriate and realistic anchor than a project’s absolute NPV. Second, a median split allows sufficient power for more robustly testing the hypotheses because of equal-sized subsamples that are used in the subsequent regression tests. Lance’s (1988) multicollinearity-reducing residual centering technique was used for all interaction terms. The results of the tests are summarized in Table 4 for high and low NPV subgroups.

The hypothesis tests appear in shaded highlighting in the last pair of columns for each subgroup. These correspond to step 3 of the regression tests involving the interaction terms between the six real options and parametric uncertainty. Consistent with our preceding theoretical arguments, the path coefficients and statistical significance for the interaction terms of the six real options with parametric uncertainty—not the main effects—provide tests for the hypotheses. Consistent with our hypotheses, positive and significant relationships between perceived project value and the six parametric uncertainty and real options interaction terms in the low NPV subgroup would provide support for the individual hypotheses.

As shown in Table 4, under high parametric uncertainty, the growth option had a significant relationship with perceived project value in low NPV projects ($\beta = .63$, T-value = 3.46, $p < .001$) but not in high NPV projects ($\beta = .07$, T-value = .20, ns). Hypothesis 1 was therefore supported. The staging option did not have a significant relationship with perceived project value in low NPV projects ($\beta = -.06$, T-value = -.29, ns) or in high NPV projects ($\beta = .22$, T-value = .94, ns), failing to support Hypothesis 2. The scale option had a high and significant relationship with perceived project value in low NPV projects ($\beta = .62$, T-value = 3.90, $p < .001$), supporting Hypothesis 3. However, this relationship was also significant in high NPV projects ($\beta = .38$, T-value = 1.87, $p < .05$). The switch use option had a positive and significant relationship with perceived project value in low NPV projects ($\beta = .78$, T-value = 3.51, $p < .001$) but not in high NPV projects ($\beta = .38$, T-value = 1.20, ns). Hypothesis 4 was therefore supported. The deferral option did not have a significant relationship with perceived project value in low NPV projects ($\beta = -.28$, T-value = -.28, ns) or in high NPV projects ($\beta = .21$, T-value = .69, ns), failing to support Hypothesis 5. The abandonment option had a positive and significant relationship with perceived project value in low NPV projects...
Table 4: Results.

<table>
<thead>
<tr>
<th></th>
<th>Low NPV</th>
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<th>High NPV</th>
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<tr>
<td></td>
<td>Control Variables</td>
<td>Step 1</td>
<td>Step 2</td>
<td>Step 3</td>
<td>Interaction Terms</td>
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<td>Interaction Terms</td>
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<td>Main Effects</td>
<td>Interaction Terms</td>
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<td>T stat</td>
<td>β</td>
<td>T stat</td>
<td>β</td>
<td>T stat</td>
</tr>
<tr>
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<td>0.26</td>
<td>1.30</td>
<td>0.22</td>
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<td>3.46</td>
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<td>(Scale option)</td>
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<td>(Abandon option)</td>
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<td>× (Par. uncertainty)</td>
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<td>R^2_adjusted</td>
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<td>28.7%</td>
<td>70.36%</td>
<td>32.56%</td>
<td>48.79%</td>
<td>71.39%</td>
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<tr>
<td>ΔR^2_adjusted</td>
<td>—</td>
<td>13.58%</td>
<td>41.63%</td>
<td>—</td>
<td>16.22%</td>
<td>22.60%</td>
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<tr>
<td>F-change (ΔR^2_adjusted)</td>
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<td>0.826</td>
<td>4.684***</td>
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<td>1.003</td>
<td>1.712***</td>
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</table>

*p < 0.05; **p < 0.01; ***p < 0.001; 1-tailed T-test; hypothesis tests are shaded in gray.

H_1 through H_6 indicate regression terms that test the individual hypotheses.

Bolded items in table represent statistically significant results.

Shaded areas represent results of hypothesis tests.
(β = .36, T-value = 1.88, p < .05) but not in high NPV projects (β = −.14, T-value = −.52, ns), supporting Hypothesis 6. Overall, the results support four of the six hypotheses.

The model explained 70.36% of the variance in perceived project value in the low NPV subgroup and 71.39% in the high NPV subgroup. The addition of the interaction terms involving real options contributed 41.63% and 22.6% to the explained variance in Table 4. The change in explained variance from the addition of these interaction effects to the model was statistically significant in both subgroups.

Control Variables: An Assessment of Rival Explanations

We controlled for rival explanations based on both project characteristics and respondent characteristics. For the former, we controlled for strategic importance, project complexity, project duration (measured in months expected to complete the project), and project team size (Tiwana & Keil, 2004). For the latter, we controlled for personal responsibility (i.e., whether the respondent had direct personal responsibility for initiating the project) and the respondent’s prior IT experience measured in years. Of these, project team size (β = −.194, T-value = −1.694, p < .05), personal responsibility (β = .208, T-value = −1.87, p < .05), and IT experience (β = −.197, T-value = −1.85, p < .05) were statistically significant and were thus included in the subgroup analyses. The control variables respectively accounted for 15.1% (low) and 32.56% (high) variance in the subgroups.

An Assessment of Validity Threats from Common Methods Bias

Two steps were taken to assess the threat of common methods bias, following the procedures outlined by Podsakoff and Podsakoff (2003): (i) the Harman one-factor test and (ii) triangulation of project value assessments at temporally distinct points. Harmon’s one-factor test was conducted by entering all independent and dependent variables in an exploratory factor analysis. The data would have a common methods bias problem if a single factor emerged that accounted for a large percentage of the variance in the resulting factors. However, a single factor did not emerge in our analyses, and the first factor accounted for 20.6% of the total 78.8% variance. The second mechanism for assessing the threat of common methods bias is to statistically triangulate IT managers’ assessments of project value with those of a manager from the department for which the project was primarily intended. We contacted all respondents from the first phase to collect perceived project value assessments from the manager of the primary client department. We received 19 responses for a 21.6% response rate in this follow-on step. A weak relationship between the two stakeholders’ responses would indicate that the original assessments are susceptible to bias (James, Demaree, & Wolf, 1984; James, Demaree, & Wolf, 1993). We found a high and statistically significant correlation of .738 (p < .001) between the two informants’ assessments of project value. This pattern of high inter-rater agreement and Harmon’s test provide some assurance that common methods bias is not a significant threat.
Limitations
Before discussing the results, four limitations of the study should be evaluated. First, the cross-sectional nature of our data did not allow us to test how real option value changes across different stages of a project. Future studies using longitudinal data can provide insights into the dynamics of evolution of real options. Second, the IT projects examined here are knowledge intensive and complex, thus generalizable to other types of comparable projects. However, it is unclear whether the findings generalize to other types of projects that do not share these characteristics. Third, our measures of NPV were based on self-reports from IT managers. These might exhibit a social desirability bias, leading to the quantifiable benefits being overstated. Future work should attempt to supplement such assessments with objective NPV data.

DISCUSSION
This study was motivated by the understudied phenomenon of whether managers systematically exhibit a bounded rationality bias in real options valuation. While real options thinking suggests that managers must take into consideration the value of real options in making judgments about the value of new capital investments, a different stream of research has shown that managers also are likely to exhibit cognitive biases because they are boundedly-rational. The results of this study connect these two independent but complementary streams of research. The central idea behind the study is that managers, in the presence of high parametric uncertainty, would associate real options created by a project with project value only when the project has low NPV. The overall pattern of results from our field data largely supports this idea, with some interesting exceptions.

Consistent with the hypothesized relationships, managers appear to associate growth, scaling, switching, and abandonment options with perceived project value in projects with low NPV (Hypotheses 1, 3, 4, 6). Somewhat surprisingly, they also associate the option to change scale with project value in projects with high NPV, suggesting that managers value the flexibility to change scale irrespective of project NPV. An interpretation for the value ascribed to this option in high NPV projects is that managers might view increasing scale as an attractive form of flexibility even in projects whose quantifiable benefits outweigh costs. Given that managers are already likely to be optimistic about a project with high NPV, exercising the scale option would potentially allow them to further enhance the payoff of a promising project.

A second surprising result is that managers did not associate the staging option with perceived project value in projects with low NPV. There are two possible interpretations for this result. First, when the NPV of the project is low, managers might be skeptical that they can realistically decompose a project into incremental stages in a manner that would allow them to realize identifiable positive benefits at the completion of the first stage. A second interpretation is that staging options often coexist in bundles with other real options such as scale, growth, and abandonment. These other options might appear more salient to managers and increase their perception of project value, thereby leading them to terminate their search for
additional information such as staging options. This satisficing behavior might lead them to neglect recognizing the value of a project’s staging options.

A related unexpected result was that the deferral option also did not have a significant relationship with perceived project value in low NPV projects. An interpretation for this is that uncertainty—especially technical uncertainty—cannot easily be resolved without gaining direct experience with the technology, making deferral options difficult to exercise. Such experiential knowledge also facilitates better governance of technology development projects (Tiwana & Keil, forthcoming). Since the respondents in our study were IT managers, they are more likely to be attuned to this subtlety about being unable to reduce a key dimension of parametric uncertainty without actually proceeding with a project. In other words, they might not associate the deferral option with project value.

Besides the test of the hypotheses, the significant beta weights also reveal insights into the relative importance that managers ascribe to various types of real options. Managers appear to most heavily weigh the switching real option ($\beta = .78$), followed by almost equal weightings on growth ($\beta = .63$) and scaling options ($\beta = .62$). They appear to weigh the abandonment option lowest ($\beta = .36$). This pattern of results is consistent with some recent field studies on managerial valuation of real options that did not examine the cognitive biases studied here (Fichman et al., 2005; Tiwana et al., 2006).

The overall pattern of results suggests that managers associate four of the six real options potentially created by a project with perceived project value in projects where the expected measurable payoff is low but only one of the six options with project value where the expected measurable payoff is high. This pattern of results supports our overarching idea that managerial valuation of options is systematically biased by bounded rationality.

**Contributions**

The primary contribution of this study to the managerial decision-making literature lies in empirically showing that managers exhibit systematic cognitive biases in real options valuation at the project level. Such biases are neither recognized nor directly examined in the theoretical or empirical real options literature (e.g., Tiwana et al., 2006). As one of the earliest field studies to empirically demonstrate systematic biases in managers’ valuation of real options, the study extends the burgeoning theoretical literature on real options and that on what Kahneman (2003) characterizes as severe and systematic errors that arise due to managers’ bounded rationality. This set of findings also contributes new insights to the real options literature by showing that observed managerial behavior is only partially consistent with what real options theory would predict. Although real options theory unequivocally suggests that uncertainty increases option value, managers appear to behave consistent with theory only when faced with negative information about a project. While our findings contradict some assumptions in the real options literature, it is not particularly surprising that managers pay closer attention to real options primarily when they encounter negative information about the projected payoffs of a project. Their behavior is rational. Our results apply only to the pre-initiation stages of project selection and evaluation, unlike prior work (e.g., Tiwana et al., 2006).
that has examined options thinking in post-initiation stages of projects. The second contribution of the study is the development of a new set of project-level measures for all six types of real options. We hope that these empirical measures will facilitate further field studies in the fertile domain of managerial decision-making involving real options.

Implications for Practice

Our research shows that managers intuitively value real options in project investment decisions but are highly vulnerable to being completely oblivious to them under certain conditions. Managers must be conscious of such biases, especially when they are trained to use NPV analyses to evaluate projects. When the NPV of a project is positive, they are likely not to account for the associated real options in their project evaluations. Managers should remain vigilant of embedded real options, even when a project exhibits positive returns and passes conventional DCF metrics such as NPV. This can be accomplished by encouraging an options checklist for any project proposal, irrespective of its NPV. Our results suggest that managers can recognize themselves as being adopters of real options thinking if they look for sources of project value beyond NPV estimates. Such managers are best prepared to be formally introduced to options thinking. Self awareness of the tendency to neglect options in positive NPV projects can also allow managers to better judge the merits of two projects with comparable NPV levels that appear equivalent in value and might have dramatically different option-adjusted values.

In practice, managers can use the questionnaire items in this study’s Appendix as an informal mechanism to estimate quickly the approximate option value for a given project. Although that approach is not a substitute for formal quantification, it allows multiple project stakeholders to pool their evaluations and arrive at a reasonable consensus on the relative option richness of multiple prospective projects. Finally, while our results suggest that managers are most likely to consider real options in low NPV projects, they must be formally exposed to real options thinking for this to become an organizational decision making norm. Failing this, managers run the risk of erroneously rejecting projects that are rich in future opportunities but do not pass the conventional NPV litmus test.

CONCLUSIONS

The objective of this article was to develop the idea that managers exhibit a bounded rationality bias in how they cognitively ascribe value to various real options in their project-level judgments. We collected project-level data in the field from 88 IT managers in 88 organizations to test this set of ideas. Overall, the results largely support our basic contention that managers—reverting to their boundedly-rational behavior—will associate real options with perceived project value only in projects with low NPV. We also developed a reliable set of measures for the six key types of real options. Although real options continue to provide a fertile arena for developing more sophisticated models for managerial decision making, we believe that this early field study scratches only the surface of a vast and promising area for future field research. [Received: May 2006. Accepted: January 2007.]
REFERENCES


**APPENDIX: CONSTRUCT MEASURES**

The respondents were asked to name an IT project that their organization was presently considering or had recently considered. They were then asked to respond to the survey specifically keeping that project in mind.

**Growth real option**a (3-item Likert scale; α = 0.80): For our organization, this project is: (a) necessary for unlocking future IT project opportunities, (b) a necessary foundation for developing future IT capabilities, (c) first in a chain of interrelated follow-on projects in the future.

**Stage investments real option**a (4-item Likert scale; α = 0.87): This project could easily be: (a) be funded incrementally in stages, (b) be completed in incremental stages, (c) be completed as a series of smaller projects, (d) be decomposed into smaller independent sub-projects.
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Scale real option\textsuperscript{a} (3-item Likert scale; $\alpha = 0.74$): It would be very easy to expand or contract the following resources initially allocated to this project (a) budget, (b) personnel, (c) other resources such as hardware and software.

Switch use real option\textsuperscript{a} (3-item Likert scale; $\alpha = 0.92$): This project could easily (a) be redeployed for another purpose, (b) serve another function, (c) serve a different function from the one for which it was created.

Defer real option\textsuperscript{a} (3-item Likert scale; $\alpha = 0.84$): If this project were postponed by two years (a) many technical uncertainties would be resolved, (b) project uncertainty would be reduced, (c) project requirements would be clearer.

Abandonment real option\textsuperscript{a} (3-item Likert scale; $\alpha = 0.83$): To what extent could the following resources be put to other uses if this project were abandoned prior to completion (a) allocated budget, (b) personnel, (c) other resources such as hardware and software.

Net Present Value (NPV) of Project (9-point semantic differential scale): Relative to other projects that your company has previously completed, how would you characterize the measurable benefits of this project?

1 = Costs greatly exceed benefits
3 = Costs somewhat exceed benefits
5 = Costs equal benefits
7 = Benefits somewhat exceed costs
9 = Benefits greatly exceed costs

Perceived project value (9-item semantic differential scale; $\alpha = 0.96$ in the first phase; 0.94 in the second phase): How would you assess the value of this project to your organization, if it were pursued?

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<th>5</th>
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<th>7</th>
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<td>Highly Useful</td>
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<td>Easy To Justify</td>
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<td>Of Great Benefit</td>
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Parametric uncertainty\textsuperscript{a} was measured as a cross product of technical uncertainty and business uncertainty.

Technical uncertainty\textsuperscript{a} (4-item Likert scale; $\alpha = 0.85$): How likely will unexpected or novel problems arise from the use of the following, during this project? (a) Hardware platform used for the system, (b) The system software platform, (c) Programming language used for coding the software, (d) Database technology used.
**Business uncertainty** (3-item Likert scale; $\alpha = 0.86$): Business requirements for this project are likely to fluctuate quite a bit (a) in the earlier phases, (b) during development, (c) in the later phases.

**Strategic importance of the project:** Which of the following best describes the primary purpose of this project? (a) Strategic, i.e., to provide a competitive advantage (dummy-coded as 1), (b) Transactional, i.e., to capture and process data related to routine organizational transactions (coded as 0), (c) Informational, i.e., to provide information for planning and decision-making (coded as 0).

**Relative project complexity:** Compared to other IT projects in your organization, how would you describe this project?

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<th>Much less complex</th>
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<th>3</th>
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<th>6</th>
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<th>Much more complex</th>
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**Project duration:** Approximately how many months do you expect this project to take to complete?

**Project team size:** Approximately how many individuals do you expect this project team to involve?

**Personal responsibility:** Do you have any direct personal responsibility in initiating this project? □ Yes □ No

**IT experience:** How many years of IT project experience do you have? ______

*Scale anchors were: 1 = Strongly Disagree; 2 = Disagree; 3 = Somewhat Disagree; 4 = Neither Agree nor Disagree; 5 = Somewhat Agree; 6 = Agree; 7 = Strongly Agree.*

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