

**Managers' Incorporation of the Value of Real Options into
Their Long-Term Investment Decisions: An Experimental Investigation ***

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Abstract

While academic and practitioner literature has advocated the use of real options in firms' long-term investment appraisal processes, few studies have examined the extent to which real options are incorporated into decisions when they *are* available for decision-making. Using two experiments, we examine supervising managers' reliance on real options values in their decisions about funding for subordinates' long-term investment project proposals. We predict and find with Experiment 1 that when making funding decisions, supervising managers rely less on the value of real options than on the value of a project's planned implementation path. We predict and find with Experiment 2 that, holding information constant, a simple accounting change influences supervisors' reliance on real options values in their funding decisions: they rely more on the real options components of project value when the amount is aggregated with (rather than displayed separately from) the value of the projects' planned implementation paths in a financial summary of subordinates' proposals. We provide evidence of the process underlying how the financial summary affects funding decisions – specifically, it does so by influencing perceptions of the relative accuracy of the planned path and real options components of value. Results for both experiments hold after controlling for participants' knowledge of discounted cash flow and real options valuation and perceptions of risk in subordinates' projects.

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1. Introduction

The most popular, widespread methods of evaluating long-term investment decisions are internal rate of return and net present value analysis (Graham and Harvey 2001). However, these methods only consider the value of a project if it unfolds as initially planned, and do not consider the value inherent in the choices available to management as the project progresses and new information becomes available, such as the option to expand or contract the scope of a project, or to abandon it altogether. For decades, academic literature and the business press have advised managers to incorporate the value of these choices, or *real options*, into the analysis of whether to fund long-term investment projects, claiming that doing so results in decisions superior to those made based on the value of the project's planned implementation path alone (Copeland and Antikarov 2001; Coy 1999; Myers 1977; Ross 1995; Teach 2003; Trigeorgis 1996, 7–9; see Denison 2009 for one empirical test of this claim). However, most firms in practice do not explicitly incorporate real options into their evaluations of long-term projects, even though the complexity of calculating real options values has declined (Busby and Pitts 1997; Fichman, Keil, and Tiwana 2005; Graham and Harvey 2001; Ryan and Ryan 2002; Teach 2003).

Although prior literature has recommended incorporating the value of real options into long-term investment analyses, it has not empirically examined how the value of real options affects judgments of project value. Prior literature on real options mostly focuses on the ability to implicitly recognize the value of real options when that value is not quantified (Benaroch, Lichtenstein, and Robinson 2006; Busby and Pitts 19997; Howell and Jagle 1997; Lankton and Luft 2008; Miller and Shapira 2004; Tiwana, Keil, and Fichman 2006; Tiwana et al. 2007; Yavas and Sirmans 2005), or on how calculating the value of real options can affect judgments

(Denison 2009). This literature has largely ignored the fact that the inclusion of explicitly quantified real options in long-term investment analyses is only effective if supervising managers are able to incorporate the values into funding decisions for those investments. We address this oversight in academic research by examining *supervising managers' reactions* to real options values when they *are* explicitly quantified and available for decision-making. In our setting, supervising managers examine proposals for long-term investments developed by subordinates that include the value of the investments' real options, and decide how to allocate firm funds across the projects (for descriptions of investment appraisal processes see Haka 2007, 705–708; Mintzberg 1994, 122–126).

This study addresses whether those supervising managers will rely as heavily on the real options component of project value as on the planned path component of project value in making those decisions. We predict that supervising managers will rely less on the real options component of project value than the planned path component, despite the fact that the value of the real options component is economically comparable, dollar for dollar, to the value of the planned path. We make this prediction for two reasons: we expect that managers will have greater knowledge of planned path valuation than real options valuation, and that managers will perceive planned path values to be more accurate than real options values.

To address this research question, we conducted an experiment in which participants playing the role of supervisors evaluated whether to fund long-term investment projects using project proposals prepared by subordinates. The subordinates' project proposals included discounted cash flow (DCF) values for the planned path and real options components of value, the total DCF value, and two non-cash flow measures. We find, as predicted, that participants place less weight on the real options component of value than on the planned path component. We also find that

they weight the components differently, at least in part, because they perceive real options values to be less accurate than planned path values.

Guided by findings in our initial experiment, we next consider whether the display of long-term investment proposals can influence supervisors' reliance on real options values. In practice, firms can choose a display that either aggregates or disaggregates planned path and real options values in subordinate reports to supervisors (see, e.g., formats in Amram, Li, and Perkins 2006, Jeffery 2006 versus Arnold and Shockley 2001, Bowman and Moskowitz 2001). We predict that when the two components of project value are displayed in an aggregated fashion, supervisors will perceive them as similar in nature, and as a result will weight the two components more similarly than when they are displayed in a disaggregated fashion.

To address this second research question, we conducted an experiment in which participants, again playing the role of supervisors, decided how much of a firm's total long-term investment budget to allocate to each of two subordinate-proposed projects. The projects had identical total DCF values, but real options comprised a greater proportion of the total value of one division's project than of the other. The planned path and real options components of value were readily available to all participants in the projects' descriptions, but we manipulated whether a tabular summary shown below the descriptions displayed only the total DCF value of the projects (aggregated) or displayed both the real options and planned path components of the projects (disaggregated). Consistent with our prediction, we find that participants who viewed the aggregated financial summary weight the real options and planned path components of value more similarly than do those who viewed the disaggregated summary, although the tendency to rely less on real options than planned path values persists. We also find evidence that the aggregation of project value affects participants' perception of the relative accuracy of the real

options component versus the planned path component of value.

Our study contributes to the real options literature, the accounting literature, and management practice. Prior literature on real options has argued for including the value of real options when analyzing long-term investments, but has focused on the role of subordinates implicitly or explicitly deriving the value of real options while preparing their proposals (Benaroch et al. 2006; Busby and Pitts 1997; Denison 2009; Howell and Jagle 1997; Lankton and Luft 2008; Miller and Shapira 2004; Tiwana et al. 2006, 2007; Yavas and Sirmans 2005). The literature has not examined the effect of real options values on *supervisors'* judgments and decisions whether to accept or fund projects. We provide the first evidence of the extent to which supervisors incorporate real options values into their decisions about funding for subordinates' projects when the real options values are *explicitly* provided.

Our study also extends prior accounting literature on aggregating information. First, we provide evidence on the *process* through which aggregating accounting information affects perceptions of the properties of that information. Second, most prior literature on information aggregation considers settings in which there are natural information differences across aggregated and disaggregated reports (e.g., Abdel-Khalik 1973; Arya, Glover, and Liang 2004; Benbasat and Dexter 1979; Berger and Hann 2003; Chervany and Dickson 1974; Datar and Gupta 1994; Gigler and Hemmer 2002; Hayes and Lundholm 1996; Hirst, Koonce, and Venkataraman 2007; Schwartz et al. 2009; Swink and Speier 1999)¹. In contrast, in our setting, information is held constant across our aggregated and disaggregated conditions, which allows us to unambiguously examine how aggregation affects perceptions of the characteristics of accounting information itself.

¹ An exception is Barefield (1972), but in that study knowledge of variances and extensive computations are needed to arrive at disaggregated information from the aggregated report.

Our study also has implications for management practice by providing useful insights to firms that use or are considering adopting real options valuation techniques. Our finding that supervising managers tend to place less weight on the real options component than the planned path component of value will help such firms better understand whether and how real options affect managerial judgments and decisions. Although the tendency to rely less on real options than planned path value is quite robust, we also demonstrate that a simple, low-cost reporting change in the investment appraisal process can influence this reliance.

The remainder of this paper is organized as follows. Section 2 provides background on investment appraisal processes and real options valuation, and develops our first hypothesis. We discuss our research design and results for Experiment 1 in Sections 3 and 4. Section 5 develops our second hypothesis, and we discuss our research design and results for Experiment 2 in Sections 6 and 7. We summarize and conclude in Section 8.

2. Background and hypothesis development for the first research question

Investment appraisal processes

In many decentralized firms, principals delegate decision rights regarding the identification of long-term investment opportunities to agents, since agents typically have more knowledge of local capabilities and opportunities. This delegation creates a need for a firm-wide investment appraisal process that motivates agents to search for, propose, and implement long-term investment projects that will be consistent with the principals' goals (Haka 2007, 699). Early research documented the stages of such an appraisal process (see Haka 2007, 705-708). In this study, we focus on what has been called the "evaluation" or "approval" stage.²

² Project evaluation and approval could be considered one or two stages of the overall appraisal process. On the one hand, one could consider project evaluation as the stage in which a supervising manager assesses project proposals submitted by subordinates, and approval as the stage in which the manager makes the decision as to which of those projects will be funded and to what extent. On the other hand, one could consider evaluation and approval as two

In our setting, the long-term investment project initial stage is complete – subordinates (for example, division heads in a decentralized organization) have identified potential long-term investment projects their divisions could undertake, analyzed the costs and benefits of each using real options valuation, and, for those projects deemed appropriate to pursue, prepared summary-level project proposals and submitted those proposals to a supervising manager for approval (for example, a corporate executive responsible for the firm-wide allocation of long-term investment capital). In practice, such project proposals are often prepared using a pre-specified format to enhance comparability across projects submitted by multiple subordinates, and include, amongst other information, financial projections for the investment projects. The supervising manager then undertakes the project approval stage of the appraisal process, reviewing and evaluating the subordinates' proposals and deciding how to allocate firm-level funds for project implementation across the projects under consideration (see, e.g., Ding, Yeaton and Eades 2008 and Luehrman 2009 for the capital expenditure processes and standardized forms used at Target Corporation and Stryker Corporation, respectively; also, personal communications: D. Henn, Gannett Co., Inc., April 8, 2008; D. LaPaul, Waste Management, Inc., July 1, 2008). We focus on the supervising manager's project funding decisions.

Real options in long-term investment projects

Real options exist in a long-term investment project whenever management has the choice to change how the project will proceed once it is underway. When real options (such as the option to expand, change, or abandon the project) can be identified before the project is undertaken, their values can be quantified and incorporated into the overall value of the project in the initiation stage of the appraisal process. In such cases, the overall value of the project can be

steps, both of which are conducted by the supervising manager, that comprise one stage of the appraisal process. We take the latter perspective: we focus on both project evaluation (which may or may not be observable) and approval (which is observable), and call both steps the project approval stage.

separated into two DCF components: the value of the project's planned implementation path, and the value of the real options (Barnett 2005; Copeland 2001; Trigeorgis 1993, 1996, 124; Van Putten and MacMillan 2004). The value of the planned path component is essentially the expected net present value of the project if events unfold as initially planned, while the value of the real options component is the expected net present value of management's ability to change the planned path as the project progresses (Trigeorgis 1993). Because management will only exercise a real option if its expected outcome is higher than the planned path outcome, real options always *add* value to a project. Therefore, the value of a project including its real options will always be higher than its value considering the planned path alone (Barnett 2005; Copeland 2001; Trigeorgis 1996, 124; Van Putten and MacMillan 2004).

Since the concept of real options was introduced, researchers have advocated that their value should be recognized in subordinates' long-term investment proposals at the initiation stage, and that supervising managers incorporate their value into their decisions at the project approval stage (Dixit and Pindyck 1994; Myers 1977; Trigeorgis 1993). Proponents of real options claim that considering real options value can result in superior investment decisions (Copeland and Antikarov 2001; Coy 1999; Ross 1995; Teach 2003). However, survey research indicates that only nine percent of firms explicitly incorporate real options into the long-term investment appraisal process, and about 65 percent of firms do not consider real options at all (Graham and Harvey 2001; Ryan and Ryan 2002).

One possible reason why real options analysis is not more widely used is that it is more complex than traditional DCF methods, involving more subjective estimates and more complex mathematics than are needed to calculate the value of the planned path alone (Brealey, Myers, and Allen 2008; Busby and Pitts 1997; Fink 2001; Lander and Pinches 1998). A variety of

techniques exist for computing real options values, including Black-Scholes valuation (e.g., Luehman 1998) and dynamic programming (Copeland and Tufano 2004; Haenlein, Kaplan, and Schoder 2006); see Lander and Pinches (1998) for a summary. Some firms may view the complexity of some of these methods as a barrier to adopting real options analysis (Teach 2003). In addition, many managers simply are not familiar with real options analysis, as it is relatively new, not widely used, and not widely taught (Stout et al. 2008).

Many managers who do consider real options in long-term investment projects do so only intuitively. A number of studies have addressed whether and how well managers intuitively perceive the value of real options and incorporate them into their decisions. In surveys of actual managers, Benaroch, Lichtenstein, and Robinson (2006) and Busby and Pitts (1997) found that managers' intuition is generally consistent with real options logic, although these studies did not compare perceived and calculated real options values. Yavas and Sirmans (2005) find in an experimental auction setting that individual investors do not behave as though they recognize the value of real options, although competition can correct this tendency. A number of studies have conducted experiments in which participants' perceptions of real options value are compared to calculated real options values (Howell and Jagle 1997; Lankton and Luft 2008; Miller and Shapira 2004; Tiwana et al. 2006, 2007). These studies find, in general, that judgments about real options value are often systematically biased in ways that are consistent with behavioral decision theory, and that the amount and direction of real options misvaluation depends on the type and size of the real options under consideration.

As these studies demonstrate, the subjective value ascribed to real options often departs from their economic value. Thus, some researchers suggest that investment appraisal decisions could be improved if those who *initiate* long-term investment proposals *explicitly* quantify the value of

real options (Benaroch et al. 2006). However, the efficacy of this suggestion will depend on the way in which quantified real options values are perceived and used in practice. To date, we are not aware of any studies that have examined how supervisors, whose job it is to *approve and fund* projects, perceive and use the value of real options when they are *explicitly* included in subordinates' long-term investment proposals.

Incorporating real options into project approval decisions

We argue that when supervising managers are provided with explicitly quantified real options values, they will rely less on the real options component of project value than on the planned path component.³ There are at least two reasons this may be the case. First, managers may have more knowledge of traditional DCF methods than real options methods, and thus may rely more on amounts computed using the tool with which they are more familiar (Coy 1999; Lander and Pinches 1998; Luehrman 1998; Ross 1995; Teach 2003; Triantis 2005). Second, because real options valuation is more complex and involves more subjective estimates than planned path valuation, *supervising* managers may recognize the additional difficulties *subordinates* face when computing real options value, and perceive it to be less accurate than the planned path value. This perception could lead them to rely less on the real options component of project value than on the planned path component.

Importantly, prior empirical work has not established the extent to which supervising managers rely on real options values in their project funding decisions when the values are explicitly incorporated into the investment appraisal process. We examine this reliance in our first hypothesis.

HYPOTHESIS 1. *When deciding whether to fund long-term investment proposals submitted by subordinates, supervisors will rely more on the planned path component of project value*

³ We focus on a supervisor's propensity to rely on real option values in making capital investment decisions. Determining the optimal reliance on real options is beyond the scope of this paper.

than on the real options component of project value.

3. Experiment 1: Research design

Participants

We conducted an experiment to test Hypothesis 1. Forty undergraduate students and 30 MBA and Masters of Finance or Accounting students participated. Undergraduate participants received extra credit in the course from which they were recruited, and graduate participants received \$20 cash for their participation.

Our participant pool is representative of the population of interest (see Table 1 for descriptive information). The experimental task required a basic understanding of long-term investments in a business setting. On average, participants had taken 2.6 accounting, 1.9 finance, 2.9 economics, and 1.7 statistics courses at the university level. Twenty-six percent of participants had a mean of 22.5 months of full-time work experience.

[Insert Table 1 about here]

We recruited both undergraduate and graduate participants who were likely to differ in their expertise in investment valuation techniques so the participant pool would be representative of managers, who come from various backgrounds and who likewise have differing levels of expertise in long-term investment evaluation (Triantis 2005). Managers also generally have greater knowledge of traditional discounted cash flow than real options valuation techniques (Coy 1999; Lander and Pinches 1998; Luehrman 1998; Ross 1995; Teach 2003; Triantis 2005). Similarly, of our participants, 100% (14%) had studied traditional DCF (real options) valuation in their coursework, and 61% (0%) of those with work experience had used DCF (real options) valuation in their jobs.

Independent and dependent variables

Experiment 1 is a 20 x 2 mixed-design experiment. Within-subjects, participants reviewed information about 20 hypothetical proposed investment projects submitted by division heads within their firm. Each proposal included the division name, a description of the project, the value of the project computed using real options valuation, and two non-financial measures: a Consumer Reports rating of the product prototype and an HHI rating of the level of competition in the product's market.⁴ The value of each project was broken down into planned path and real options components, which were reported along with total project value. See Exhibit 1 for a sample project proposal.

[Insert Exhibit 1 about here]

Participants indicated how much funding they wished to provide to each of the 20 projects using a scale of 1 to 100, where higher values indicate greater funding. We used these ratings as our dependent variable. We asked participants to rate the projects rather than allocate funding dollars across them to simplify both the task and our analysis.

Between-subjects, we varied the proportion of total project value comprised of real options (*High/LowROProp*) at two levels: *Low* (real options is less than one-third of project value for all proposals) and *High* (real options is more than two-thirds of project value for all proposals). Proposals in both conditions were identical, except that the values of the real options and planned path components were reversed. For example, the total value of one project was \$13,700,000. In the *Low* condition, the planned path component value was \$10,700,000 and the real options value was \$3,000,000. In the *High* condition, the planned path component was \$3,000,000 and the real options value was \$10,700,000. This manipulation was intended to control for the possibility that reliance on real options may differ based on their economic significance.

⁴ In practice, firms' long-term investment project proposals can include not only DCF values, but also non-financial measures such as the project's effect on customer satisfaction, product quality, or safety (Anthony and Govindarajan 2004; personal communications: D. Henn, Gannett Co., Inc., April 8, 2008).

Procedure and background materials

Participants were randomly assigned to conditions. The task was administered using paper-and-pencil materials in a series of envelopes. A proctor ensured that participants worked through the materials sequentially and did not return to previously completed parts of the task.

Participants took an average of 35 minutes to complete the task.

Participants were asked to assume the role of a corporate manager in an electronics firm. They were told that their job was to review proposals for investments in long-term new product development projects submitted by division heads in their firm, and to make decisions about corporate funding for those projects. Participants were then told that their firm required that division heads use real options valuation for long-term investment proposals, and were given a detailed overview of what real options represent, how their value can be calculated using decision trees, and how real options analysis differs from net present value analysis. This extensive overview, in essence, provided training on real options valuation, relating it to traditional DCF techniques with which participants were already knowledgeable, and biases against finding less reliance on real options than planned path values.

Participants were told to assume they had already completed a portion of their reviews and concluded that across the projects, there were no significant differences that would affect their decisions in terms of technology, division resources, the amount of the initial investment on which cash flow estimates were based, or the relationship between changes in that investment and changes in cash flows. Participants were also told to assume that division heads had reasonably estimated amounts used in their analyses and had properly prepared their proposals. Interspersed throughout these sections of the materials, participants answered four comprehension check questions about real options valuation and the task.

Next, participants made their funding decisions as previously described. Finally, participants answered follow-up questions about their decision processes and the task itself, and provided demographic information.

3. Experiment 1: Results

Comprehension checks and post-task questions

At least 87 percent of participants answered the four comprehension checks about real options valuation and the experimental task correctly, and there were no differences in the proportion of correct responses across experimental conditions for any question (all $\chi^2 < 3.13$, $p > 0.08$). If we include only participants who answered all four comprehension check questions correctly, results of hypothesis tests are the same as those reported. Self-reports of effort and task clarity, difficulty, and familiarity are reasonable and are included in Table 1.

Test of Hypothesis 1

Recall that Hypothesis 1 predicts that when making decisions about subordinates' long-term investment proposals, supervisors will rely more on the planned path component than on the real options component of long-term investment project value. Hypothesis 1 is supported if, across participants' rating decisions, the implicit weight placed on the planned path component of projects' values is higher than the implicit weight placed on the real options component.

To examine relative reliance on the planned path and real options components of value, we use a regression equation that estimates the weights participants assign to each component of value in their proposal ratings. The equation includes control variables for participants' status as undergraduate or graduate students and their perceptions of project riskiness.⁵

⁵ The control variable *GradStatus* was coded 0 (1) for undergraduate (graduate) participants. The control variable *Risk* is measured by the sum of each participant's responses to three questions on a scale from 0 (*Extremely unaffected*) to 10 (*Extremely affected*): "Indicate how your ratings of the group of 20 projects were affected by (i) observing very low possible outcomes of the projects; (ii) observing very high possible outcomes of the projects;

$$\begin{aligned}
\text{Rating}_{ij} = & \beta_1 + \beta_2 \text{PPValue}_{ij} + \beta_3 \text{ROValue}_{ij} + \beta_4 \text{CRRating}_j + \\
& \beta_5 \text{HHIRating}_j + \beta_6 \text{High / LowROP}_i + \beta_7 \text{High / LowROP}_i * \text{PPValue}_{ij} + \\
& \beta_8 \text{High / LowROP}_i * \text{ROValue}_{ij} + \beta_9 \text{GradStatus}_i + \beta_{10} \text{Risk}_i + \varepsilon.
\end{aligned}
\tag{1}$$

Where the primary variables of interest are defined as:

Rating_{ij} = participant *i*'s rating of Division_{*j*}'s proposal;

PPValue_{ij} = planned path value observed by participant *i* for Division_{*j*}'s project;

ROValue_{ij} = real options value observed by participant *i* for Division_{*j*}'s project;

CRRating_j = Consumer Reports rating for Division_{*j*}'s project;

HHIRating_j = HHI rating for Division_{*j*}'s project;

High / LowROProp_i = dummy variable, whether participant *i* observes proposals in which the proportion of total project value from real options is *Low* (0) or *High* (1).

[Insert Table 2 about here]

Results of the regression are in Table 2. The standardized coefficients for both the planned path (0.29) and real options (0.21) components of value are significant (both $p < 0.10$), and the standardized coefficient of *PPValue* (0.29) is greater than the coefficient of *ROValue* (0.21). Further, the interactions between *High / LowROProp* and *PPValue* and *ROValue* are not significant (both $p > 0.60$). Thus, participants rely more on the planned path component of value than the real options component regardless of whether the proportion of project value from real options is low or high.

Additional analyses: Why managers rely less on real options values

We conduct additional analyses to investigate our contention that managers may rely less on real options values relative to planned path values because they may have less knowledge about real options values or they may perceive real options values to be less accurate than planned path values. We asked participants to assess their pre-task knowledge of traditional DCF and real options valuation using a scale from 0 (*Not at all knowledgeable*) to 10 (*Extremely*

and (iii) observing high variances in possible future net cash flows from the projects.” Results are inferentially the same when the model also includes dummy variables for each participant (not reported) to control for non-independence of observations instead of control variables for participant characteristics.

knowledgeable). We also asked participants to judge the relative accuracy of real options and planned path values on a scale from 0 (*Only estimates for the planned implementation path were accurate*) to 10 (*Only estimates for the real options were accurate*). We then re-estimate (1) but expand the model to include *KnowDiff* (the self-reported knowledge of DCF valuation less knowledge of real options valuation), *RelAccuracy* (the value of their relative accuracy judgments), and the interactions of *KnowDiff* and *RelAccuracy* with *PPValue* and *ROValue*. The expanded regression is shown below.

$$\begin{aligned}
Rating_{ij} = & \beta_1 + \beta_2 PPValue_{ij} + \beta_3 ROValue_{ij} + \beta_4 CRRating_j + \\
& \beta_5 HHIRating_j + \beta_6 High / LowROP_i + \beta_7 High / LowROP_i * PPValue_{ij} + \\
& \beta_8 High / LowROP_i * ROValue_{ij} + \beta_9 GradStatus_i + \beta_{10} Risk_i + \beta_{11} KnowDiff_i + \\
& \beta_{12} RelAccuracy_i + \beta_{13} KnowDiff_i * PPValue_{ij} + \beta_{14} KnowDiff_i * ROValue_{ij} + \\
& \beta_{15} RelAccuracy_i * PPValue_{ij} + \beta_{16} RelAccuracy_i * ROValue_{ij} + \varepsilon.
\end{aligned} \tag{2}$$

Results of the expanded regression are shown in Table 3. We focus our analysis on β_{13} through β_{16} , the interactions of knowledge differences (*KnowDiff*) and relative accuracy judgments (*RelAccuracy*) with the weight assigned to planned path and real options values. The *KnowDiff x PPValue* interaction ($\beta_{13} = 0.18$; $p = 0.05$) and the *KnowDiff x ROValue* interaction ($\beta_{14} = 0.13$; $p = 0.11$) suggest that knowledge differences do affect the weight assigned to the two values. However, our contention regarding knowledge differences is supported if smaller knowledge differences are associated with greater weight assigned to real options value (i.e., if β_{14} is negative), which is not the case.

Our contention regarding accuracy perceptions is supported if larger values of *RelAccuracy* are associated with greater weight assigned to real options value (i.e., if β_{16} is positive). The regression results indicate that participants' perceptions of the relative accuracy of real options does interact with the weight assigned to real options value ($\beta_{16} = 0.27$; $p = 0.07$), so our contention is supported.

[Insert Table 3 about here]

5. Background and hypothesis development for the second research question

Can the display of accounting reports affect reliance on real options?

The additional analyses reported above imply that accounting reports can affect managers' reliance on real options values if the display of those reports influences managers' perceptions of the accuracy of real options values relative to planned path values. For organizations that include the value of real options in subordinates' standardized long-term investment proposals, flexibility exists in how the planned path component and the real options component of project value can be displayed. For example, Anheuser-Busch and Merck combine the planned path and real options components of value in their analyses of investment projects (Arnold and Shockley 2001; Bowman and Moskowitz 2001), while Kimberly-Clark and "Global Airlines"⁶ use reports that display the planned path and real options components of value separately (Amram et al. 2006; Jeffery 2006).

From an economic perspective, the manner in which the value of real options is displayed in subordinates' proposals should have no impact on the extent to which supervising managers rely on them in project funding decisions. However, we argue that when the amount of information available is held constant, whether the real options component is aggregated with or disaggregated from the planned path component of project value can influence supervisors' judgments. Specifically, we predict that supervisors' tendency to rely less on the real options component than on the planned path component of value in long-term investment funding decisions is mitigated when the two components of value are aggregated in a summary of subordinates' proposals. We predict that this effect will occur because supervisors will view the accuracy of the two components more similarly when the components are aggregated into one

⁶ The name of the major U.S. firm has been disguised in the Jeffery (2006) case.

total project value than when they are disaggregated.

Judgmental effects of aggregation in accounting

Accounting as a discipline is concerned to a large extent with aggregating and categorizing information (Arya, Fellingham and Schroeder 2000; Ijiri 1975, 109). This is true for all specialties in accounting, such as when financial accounting aggregates individual transactions and categorizes them into accounts, or management accounting aggregates costs and categorizes them into pools. When information is aggregated, the accountant *adds* information about the similarity of the underlying pieces of information (Sunder 1997, 89).

Past research suggests that users of accounting information perceive those similarities and use them in their judgments. Hopkins (1996) found that analysts treated hybrid financial instruments as if they have characteristics similar to equity when they are aggregated with equity securities, and as if they have characteristics similar to debt when they are aggregated with debt securities. Similarly, users perceive components of comprehensive income differently when it is aggregated with equity than when it is disaggregated in a separate statement (Hirst and Hopkins 1998; Maines and McDaniel 2000), and perceive financial instruments as more or less risky depending on how they are categorized (Koonce, Lipe, and McAnally 2005).

These studies demonstrate that when financial accounting information is aggregated and categorized in a particular way, investors and analysts respond as if the aggregated information is similar in nature. That is, users appear to infer that pieces of information that have been combined have similar properties, and this inference affects their judgments. Similarly, we argue that when a subordinate's information about a long-term investment is aggregated into total project value using management accounting methods, supervisors may infer that the pieces of information that have been combined have similar properties which may likewise affect

supervisors' judgments.

Aggregated versus disaggregated project summary

We contend that even when planned path and real options values are provided separately in a subordinate's project summary, aggregating the values together in a tabular financial summary of all subordinates' proposals will cause the supervising managers to associate the two pieces of information with each other and perceive their characteristics – specifically accuracy – to be more similar. Therefore, we predict that when the planned path and real options components of project value are aggregated so that the total value of the long-term investment is displayed as a single number, supervising managers will rely more on real options than if the planned path and real options components are displayed separately.

HYPOTHESIS 2. In decisions about funding long-term investment proposals submitted by subordinates, supervisors will place more similar weight on the real options and planned path components of project value when, in a financial summary of proposals, the components are aggregated together than when the components are disaggregated from each other.

6. Experiment 2: Research design

Participants

We conducted a second experiment to test Hypothesis 2. An additional 83 undergraduate and 62 MBA and Masters of Finance or Accounting students participated in Experiment 2, and were compensated in the same manner as were participants in Experiment 1. As seen in the descriptive statistics in Table 1, there are no significant differences in participant demographics across Experiments 1 and 2 (all $p > 0.05$, two-tailed).

Independent and dependent variables

Experiment 2 is a between-subjects experiment in which the manipulated independent variable, *Aggregation*, captured whether the planned path and real options components of project

value were aggregated (*Agg*), or disaggregated (*Disagg*) in a tabular financial summary of the DCF information about two long-term investment proposals. In both conditions, the DCF value of the planned path component and the total DCF value of each project were *explicitly* included in written project descriptions that appeared on the same page just above the financial summary (see Exhibit 2), so participants could easily ascertain the real options component of value (i.e., the total DCF value less the DCF value of the planned path).

[Insert Exhibit 2 about here]

Each participant evaluated project proposals that had been (hypothetically) submitted by the heads of Divisions A1 and B2, and allocated \$10,000,000 in corporate funds between the two projects in whatever proportion they wished, contingent on a minimum of \$1,000,000 allocated to each. The total (i.e., planned path plus real options) estimated DCF values were identical for both projects (\$12,000,000), but the planned path component of Division A1's project was a higher proportion of total value (91.7 percent, or \$11,000,000, for a real options component value of \$1,000,000) than was the planned path component of Division B2's project (66.7 percent, or \$8,000,000, for a real options component of value of \$4,000,000). Because the total DCF values of the two projects were identical, if participants relied on the planned path and real options components equally, they would on average allocate the available \$10,000,000 evenly across the projects (i.e., \$5,000,000 to each). Therefore, we consider participants' funding decisions to be influenced more by the planned path component of value than the real options component when they allocate more than half of the available funds to Division A1's project. We used the amount allocated to Division A1's project as our dependent variable (*DivA1Alloc*).

Procedure

Experiment 2 was administered following the same procedures as used in Experiment 1. In

addition, participants received information about their role, their task, real options analysis, and assumptions they were to make about their pre-decision reviews as in Experiment 1, and answered four comprehension check questions as in Experiment 1. However, unlike in Experiment 1, participants were told to assume that historically, division heads had always chosen to follow the planned implementation paths of their projects. This design choice simulates the existence of organizational or behavioral constraints that discourage the exercise of real options which frequently exist in the natural environment (see Adner and Levinthal 2004; Busby and Pitts 1997; Fink 2001; Jensen 1993; McGrath 1999; Staw 1997; Triantis 2005) and increases the likelihood of replicating the findings of Experiment 1 in a more limited experimental setting. Importantly, this design choice does not bias either for or against finding results for Hypothesis 2.⁷

Participants were then given descriptive information about the projects proposed by Division A1 and Division B2: either a new MP3 player or a new digital video recorder (DVR) (see Exhibit 2).⁸ As noted previously, the descriptions explicitly stated the planned path and total project values, so based on the descriptions alone, participants could easily compute the value of the real options. Directly below the descriptions of the projects and on the same page, participants viewed a financial summary of the two projects (the *Aggregation* manipulation). Half of the participants viewed a financial summary that aggregated the planned path and real options components of value, displaying only the \$12,000,000 total value of each project; the

⁷ In a different experiment (not reported) that shares characteristics of Experiment 2, participants were told that division heads had sometimes followed and sometimes deviated from the planned implementation path. Results showed that participants relied more on planned path than real options values in their decisions. Thus, the finding that supervisors rely less on real options values relative to planned path values may be robust to providing variants about subordinates' historical real options exercise choices or no historical information whatsoever (as in Experiment 1).

⁸ The division that proposed each project was counterbalanced within each condition. In other words, within a given experimental condition, half the participants were told that Division A1's product was the MP3 player and Division B2's project was the DVR, and the other half were told that Division A1's product was the DVR and Division B2's product was the MP3 player.

remaining half viewed a financial summary that reported the planned path and real options components of value separately (see Exhibit 2). Participants then made their allocation decision and answered post-task questions.

7. Experiment 2: Results

Comprehension checks and post-task questions

At least 92 percent of participants answered the four comprehension check questions correctly, and there were no differences in the proportion of correct responses across experimental conditions for any question (all $\chi^2 < 2.03$, $p > 0.15$). If we include only participants who answered all four comprehension check questions correctly, results of hypothesis tests are the same as those reported.

Replication of Hypothesis 1

As a precondition for testing whether display mitigates the tendency of supervisors to rely less on the real options component than the planned path component of project value, we must first determine whether that tendency (predicted by Hypothesis 1) exists in Experiment 2. Hypothesis 1 is supported in Experiment 2 if participants allocated more than half the available funds to Division A1's project. Descriptive statistics show that across conditions, participants allocated an average of \$5,944, 759 to Division A1's project (Table 4, panel A). Results of a one-sample t -test (Table 4, panel B) using a test value of \$5,000,000 indicates that participants, on average, allocated more than half of the funds to Division A1's project ($t = 5.78$, $p < 0.01$, one-tailed). Thus, our findings supporting Hypothesis 1 are replicated in Experiment 2.⁹

⁹ We perform four robustness checks for this result. First, *Div1Alloc* does not differ across undergraduate and graduate students ($t = 0.70$, $p > 0.48$, two-tailed), and results of the Hypothesis 1 replication are the same for undergraduate and graduate students. Second, when *GradStatus* is used as a between-subjects factor in an ANOVA with controls for *Risk* and *KnowDiff*, *Div1Alloc* is not associated with these measures (all $F < 1.17$, all $p > 0.33$, two-tailed). Third, to insure results are the same if participants did not allocate the \$10,000,000 to both projects, we use the allocation to Division A1 divided by the total allocated to both divisions as the dependent variable; results are the same (one-sample t -test with a test value of 0.50, $t = 6.61$, $p < 0.01$, one-tailed). Fourth, since participants were

[Insert Table 4 about here]

Test of Hypothesis 2

Hypothesis 2 predicts that supervising managers' greater reliance on the planned path than the real options component of value will be mitigated when a financial summary of subordinates' project proposals presents aggregated values for the two components of value compared to when it presents disaggregated values. Hypothesis 2 is supported if participants allocate less to Division A1's project when the values are aggregated (*Agg*) than when they are disaggregated (*Disagg*).

Descriptive statistics show that participants in the *Agg* condition allocated a mean of \$5,716,301 to Division A1's project, compared to a mean allocation to Division A1's project of \$6,176,389 by participants in the *Disagg* condition (Table 4, panel A). An ANOVA that includes control variables for degree status (*GradStatus*), differential knowledge of valuation techniques (*KnowDiff*), and risk perceptions (*Risk*)¹⁰ confirms that the amount allocated to Division A1's project is significantly lower when the planned path and real options components of value are aggregated than when they are disaggregated ($F = 2.84, p = 0.05$, one-tailed; Table 4, panel C). Thus, Hypothesis 2 is supported. Note that for participants who received an aggregated financial summary, the \$5,716,301 allocated to Division A1's project is still significantly greater than

provided with information about subordinates' past real options exercise and the probabilities of the perfection of new technologies in Experiment 2 but not Experiment 1, we examine whether these design changes affected participants' reliance on real options in Experiment 2. In a post-task question, participants reported their perceptions of the chance that division heads would exercise real options using a Likert scale from 0 (*Division heads were extremely likely to choose to follow the planned implementation path*) to 10 (*Division heads were extremely likely to choose to deviate from the planned implementation path*). In addition, participants allocated 100 points across factors that influenced their allocation decisions, of which two factors were information about division heads' prior real options exercise and chances that new technologies would be perfected. When the Likert scale response and the two point allocations are included in the ANOVA previously described, *DivA1Alloc* is not associated with any of these measures or the controls (all $F < 1.50$, all $p > 0.16$), providing evidence that participants do not rely less on the real options component of value simply because they believe exercise is a low-probability event.

¹⁰ *Risk* is the sum of participant responses to the following two questions on a scale from 0 (*A1 Division's proposed project is riskier*) to 10 (*B2 Division's proposed project is riskier*): "Indicate which project you believe is riskier, where risk is defined as (i) having a high variance in possible future net cash flows from the project; and (ii) having a loss as a possible outcome of the project."

\$5,000,000, or half the available funds (one-sample t -test, $t = 2.62$, $p < 0.01$, two-tailed, not tabulated); thus, greater reliance on planned path than real options values persists.

Evidence of the process underlying reliance on real options

Exhibit 3 illustrates the judgment process we have proposed: that aggregation affects the perceived relative accuracy of real options, which in turn affects the weight assigned to real options in long-term investment allocation decisions, which is reflected in funding decisions.

[Insert Exhibit 3 about here]

In Experiment 2 we collected the following additional data to support this process. First, as in Experiment 1, participants judged the relative accuracy of the planned path and real options components of value (*RelAccuracy*). Second, participants allocated 100 points across several factors to indicate the degree to which each influenced their funding decisions.¹¹ One factor was described as “*Differences [across projects] in the discounted value for the planned implementation paths*”, while another was described as “*Differences [across projects] in discounted values for the real options*”. For each participant, we subtracted the points allocated to the real options factor from the points allocated to the planned path factor to derive *WeightDiff*, the extent to which participants consciously assigned greater weight to the planned path component than the real options component of value. Larger (smaller) values of *WeightDiff* indicate lesser (greater) relative reliance on real options values.

We use the above measures to conduct analyses of the relationships illustrated in Exhibit 3. First, we examine whether participants assigned greater weight to the real options component of value relative to the planned path component as the perceived relative accuracy of the real

¹¹ The factors used were as follows: differences in the planned path values, differences in the real options values, differences in the percentage of the total values from real options, differences in the total values, information about what paths funded projects have followed in the past, differences in the type of product, differences in the divisions, differences in the risk/uncertainty in the projects, differences in the chance new technologies would be perfected, and other (with space provided for a description).

options component increased. This is the case if *WeightDiff* is negatively associated with *RelAccuracy*. For our analysis, we estimate the following regression equation (which includes the same control variables used in previous analyses):

$$WeightDiff = \beta_1 + \beta_2 RelAccuracy + \beta_3 GradStatus + \beta_4 KnowDiff + \beta_5 Risk + \varepsilon \quad (3)$$

As expected, results (Table 5, panel A) show a negative association between *RelAccuracy* and *WeightDiff* (standardized $\beta_2 = -0.20$, $t = 2.40$, $p = 0.02$).

[Insert Table 5 about here]

Second, we examine whether the weight participants assigned to the real options component of value relative to the planned path component (measured by *WeightDiff*) is associated with their funding judgments. Our reasoning is supported if *DivA1Alloc* is positively associated with *WeightDiff*. Here, we estimate the following regression equation:

$$DivA1Alloc = \beta_1 + \beta_2 WeightDiff + \beta_3 GradStatus + \beta_4 KnowDiff + \beta_5 Risk + \varepsilon \quad (4)$$

As expected, results (Table 5, panel B) show a positive association between *DivA1Alloc* and *WeightDiff* (standardized $\beta_2 = 0.19$, $t = 2.34$, $p = 0.02$).

The combined results are consistent with our findings from Experiment 1, and with the relationships depicted in Exhibit 3. As the difference between the perceived accuracy of the planned path and real options components of value decreases (measured by higher values of *RelAccuracy*), differences in the weight managers assign to the planned path versus the real options component of project value decreases (measured by lower values of *WeightDiff*). This in turn increases the amount allocated to projects with a higher proportion of total value from real options (measured by lower values of *DivA1Alloc*).

Third, to extend our investigation to Hypothesis 2, we consider whether aggregating or disaggregating the planned path and real options components of value in a financial summary

affects participants' judgments of the relative accuracy of these components of value. We reason that supervising managers will judge the accuracy of the real options component to be more similar to the accuracy of the planned path component when the two values are aggregated than when they are disaggregated. Our reasoning is supported if *RelAccuracy* is greater when the financial summary presents aggregated values than when it presents disaggregated values. Marginal mean values for *RelAccuracy* are 4.92 and 4.38 for the aggregated and disaggregated conditions, respectively (Table 6, panel A). The results of an ANOVA with *GradStatus* and *KnowDiff* included as control variables (Table 6, panel B) show that *Aggregation* significantly affects *RelAccuracy* ($F = 3.89, p = 0.03$, one-tailed).^{12,13} Thus, our reasoning regarding the process underlying our results extends to Hypothesis 2.

[Insert Table 6 about here]

In summary, we find evidence of the relationships illustrated in Exhibit 3: (1) participants' perceptions of the accuracy of real options values relative to planned path values differ across the two formats of the financial summary; (2) participants' perceptions of relative accuracy are associated with the weight they assign to the real options component relative to the planned path component of project value; and (3) the relative weight participants assign to the real options component of project value is associated with their funding decisions.

A note on salience

One could argue that providing disaggregated planned path and real options values increases the salience of real options values compared to providing aggregated planned path and real

¹² For completeness, we also estimated the relationships using path analysis. Results are inferentially the same, with path coefficient estimates nearly identical to the reported coefficients and acceptable statistics of model fit. Overall goodness of fit is 102 percent using the Tucker-Lewis index, which measures the proportion of improvement in the fit of our model relative to a null model (indices close to 100 percent represent a good fit). Similarly, our model yielded an acceptable Incremental Fit Index of 101 percent.

¹³ We do not include *Risk* as a control since there is no reason to expect that perceptions of risk in projects should affect perceptions of the relative accuracy of real options.

options values, which would provide an alternative explanation for our results. However, our materials and tasks make real options values highly salient across all conditions. Prior to beginning the experimental task, all participants received detailed instruction regarding the use and calculation of real options values, and answered a comprehension question about real options values. Thus, participants were primed to look for real options as part of their resource allocation decisions. More importantly, our finding that participants' perception of the relative *accuracy* of real options values differs by aggregation condition cannot be explained by differences in the salience of real options values, but is consistent with our theory.

8. Discussion and conclusion

This study investigates the extent to which supervising managers' long-term investment funding decisions are influenced by the real options component of project value when that value is explicitly available for decision-making. In Experiment 1, we find evidence that supervising managers rely more on the planned path component than on the real options component of project value, and find evidence that this could be due to their perception that the planned path component of value is more accurate than the real options component of value. This finding leads us to conduct Experiment 2, in which we confirm the findings of Experiment 1 and also find that the extent to which supervising managers rely on the real options component of value in their funding decisions can be influenced by aggregating or disaggregating the components of project value in a financial summary of subordinates' long-term investment proposals, as the report format influences perceptions of the relative accuracy of the planned path and real options components of project value. This section discusses these results and their implications, acknowledges some limitations of the study and suggests future research, and concludes.

Discussion and implications of results

Findings related to real options

Although practitioners and academics have long advocated the explicit inclusion of real options in the long-term investment appraisal process, very little research has examined their impact on judgment. Of the few previous studies that directly examine the use of real options in the long-term investment appraisal process at the decision-maker level (Benaroch et al. 2006; Busby and Pitts 1997; Denison 2009; Howell and Jagle 1997; Lankton and Luft 2008; Miller and Shapira 2004; Tiwana et al. 2006, 2007; Yavas and Sirmans 2005), only one examines a setting in which real options values are *explicitly* available and separable from planned path values (Denison 2009), and in that study, participants were required to calculate the real options values themselves. To our knowledge, our study is the first that examines the impact of real options values on the judgments of *supervisors*, who use the values in making funding decisions but do not calculate the values themselves. Our finding that supervisors rely less on the real options component of value than on the planned path component of value should provide insight to the literature advocating the calculation and inclusion of real options value in the long-term investment appraisal process. Although our study makes no claims regarding the optimal level of reliance on real options value, the existing literature assumes that real options value is comparable, dollar for dollar, to planned path value. Our study suggests that users may not perceive this to be the case.

Findings related to information aggregation

Our finding that the display of information as either aggregated or disaggregated affects the way supervisors perceive and weight real options values in their judgments contributes to the accounting literature on aggregation. Prior literature has shown that categorizing information can affect user perceptions of the riskiness of the underlying asset (Koonce et al. 2005). Our

study expands upon these findings by demonstrating that aggregating information can affect perceptions about the information itself, as well as the object of that information; namely, we show that aggregation can affect user perceptions of the accuracy of the information provided.

In addition, our study isolates the effect of aggregation from the effect of providing different information, as we hold the amount of information constant across aggregated and disaggregated conditions. In our setting, all participants have the same information about the project under consideration; the aggregation manipulation occurs as part of a summary of information already provided in full. This contrasts with prior literature on information aggregation in which there are natural information differences across aggregated and disaggregated reports (e.g., Abdel-Khalik 1973; Arya, Glover, and Liang 2004; Benbasat and Dexter 1979; Berger and Hann 2003; Chervany and Dickson 1974; Datar and Gupta 1994; Gigler and Hemmer 2002; Hayes and Lundholm 1996; Hirst, Koonce, and Venkataraman 2007; Schwartz et al. 2009; Swink and Speier 1999). Our setting allows us to isolate the effect of aggregation on user perceptions of the characteristics of the information provided.

Implications for managerial practice

The results of our study offer insights into a simple, low-cost accounting mechanism – aggregating or disaggregating the planned path and real options components of project value – that firms could use to influence supervising managers’ incorporation of real options into their long-term investment funding decisions. Our finding that supervising managers place more weight on the real options component of project value when that value is aggregated with the planned path component of value in a financial summary of the project could be useful to firms that use real options, regardless of whether they wish to encourage or discourage reliance on the real options component of value.

Limitations and future research opportunities

Our work has several limitations that provide opportunities for further research. First, although we selected a setting that is consistent with evaluation settings commonly observed in the natural environment, our findings may not apply to all settings. Indeed, there may be other reasons why managers rely more or less on the planned path component of value than on the real options component of project value (e.g., implicit or explicit contracts, a culture that views abandonment as failure). Future research can shed more light on additional factors that affect managers' reliance on the real options component of project value and the interactions between those factors, and on other mechanisms that could encourage managers to incorporate real options into their decisions. For example, we note that perceptions of the riskiness of real options impacts resource allocation decisions, but we do not examine this deeply. Further work could examine the extent to which risk perceptions impede economically beneficial decision making in this setting, and what, if any, mechanisms firms could use to address this issue. Second, we made particular design choices to maintain tight experimental control, but our setting is necessarily simplified. Further work could investigate the extent to which our results hold, and why, in other settings. Third, we do not claim to know the "optimal" weight that should be placed on the real options component of project value in long-term investment decisions, and thus we cannot conclude whether higher or lower reliance on the real options component relative to the planned path component leads to higher or lower quality decisions. As such, it is left to future work to identify conditions under which aggregating or disaggregating the planned path and real options components of value is more appropriate.

Conclusion

This study conducts two experiments examining how the real options component of

project value, when it is explicitly calculated and provided, affects supervising managers' judgments about funding long-term investment projects. We find that supervising managers rely more on the planned path component than on the real options component of project value, at least in part because they perceive the planned path component of value as more accurate than the real options component of value. Furthermore, we find that supervising managers' reliance on the real options component of value in their funding decisions can be influenced by aggregating or disaggregating the components of project value in a financial summary of subordinates' long-term investment proposals.

References

- Abdel-Khalik, A. 1973. The effect of aggregating accounting reports on the quality of the lending decision: An empirical investigation. *Journal of Accounting Research* 11(3): 104–138.
- Adner, R. and D. Levinthal. 2004. What is not a real option: Considering boundaries to the application of real options to business strategy. *Academy of Management Review* 29(1): 74–85.
- Amram, M., F. Li, and C.A. Perkins. 2006. How Kimberly-Clark uses real options. *Journal of Applied Corporate Finance* 18(2): 40–47.
- Anthony, R.N. and V. Govindarajan. 2004. *Management Control Systems*. New York, NY. McGraw-Hill/Irwin.
- Arnold, T. and R. Shockley. 2001. Value creation at Anheuser-Busch: A real options example. *Journal of Applied Corporate Finance* 14(2): 52–61.
- Arya, A., J. Fellingham and D. Schroeder. 2000. Accounting information, aggregation, and discriminant analysis. *Management Science* 46(6): 790–806.
- Arya, A., J. Glover and P. Liang. 2004. Intertemporal aggregation and incentives. *European Accounting Review* 13(4): 643–657.
- Barefield, R. 1972. The effect of aggregation on decision-making success: A laboratory study. *Journal of Accounting Research* 10(2): 229–242
- Barnett, M. 2005. Paying attention to real options. *R&D Management* 35(1): 61–72.
- Benaroch, M., Y. Lichtenstein, and K. Robinson. 2006. Real options in information technology risk management: An empirical validation of risk-option relationships. *MIS Quarterly* 30(December): 827–864.
- Benbasat, I and A. Dexter. 1979. Value and events approaches to accounting: An experimental evaluation. *The Accounting Review* 54(4): 735–749.
- Berger, P.G. and R. Hann. 2003. The impact of SFAS No. 131 on information and monitoring. *Journal of Accounting Research* 41(2): 163–223.
- Bowman, E. and G. Moskowitz. 2001. Real options analysis and strategic decision-making. *Organization Science* 12(6): 772–777.
- Brealey, R., S. Myers and F. Allen. 2008. Brealey, Myers and Allen on Real Options. *Journal of Applied Corporate Finance* 20(4): 58–71.

- Busby, J. and C. Pitts. 1997. Real options in practice: An exploratory survey of how finance officers deal with flexibility in capital appraisal. *Management Accounting Research* 8(2): 169–187.
- Chervany, N. and G. Dickson. 1974. An experimental evaluation of information overload in a production environment. *Management Science* 20(10): 1335–1344.
- Copeland, T. 2001. The real options approach to capital allocation. *Strategic Finance* 83(4): 33–37.
- Copeland, T. and V. Antikarov. 2001. *Real Options: A Practitioner's Guide*. New York, NY: W.W. Norton and Company.
- Copeland, T. and P. Tufano. 2004. A real-world way to manage real options. *Harvard Business Review* 82(3): 90–99.
- Coy, P. 1999. Exploiting uncertainty: The “real-options” revolution in decision-making. *Business Week Online*, June 7. Available at http://www.businessweek.com/1999/99_23/b3632141.htm.
- Datar, S. and M. Gupta. 1994. Aggregation, specification and measurement errors in product costing. *The Accounting Review* 69(4): 567–591.
- Denison, C. 2009. Real options and escalation of commitment: A behavioral analysis of capital investment decisions. *The Accounting Review* 84(1): 133–155.
- Ding, D., S. Yeaton, and K. Eades. 2008. *Target Corporation*. Charlottesville, VA: University of Virginia Darden School Foundation.
- Dixit, A. and R. Pindyck. 1994. *Investment Under Uncertainty*. Princeton, NJ: Princeton University Press.
- Fichman, R., M. Keil and A. Tiwana. 2005. Beyond valuation: “Options thinking” in IT project management. *California Management Review* 47(2): 74–96.
- Fink, R. 2001. Reality check. *CFO Magazine* 17(11): 85–86.
- Gigler, F. and T. Hemmer. 2002. Information costs and benefits of creating separately identifiable operating segments. *Journal of Accounting and Economics* 33(1): 69–90.
- Graham, J. and C. Harvey. 2001. The theory and practice of corporate finance: Evidence from the field. *Journal of Financial Economics* 60(May): 187–243.
- Haenlein, M., A. Kaplan, and D. Schoder. 2006. Valuing the real option of abandoning unprofitable customers when calculating customer lifetime value. *Journal of Marketing* 70(3): 5–20.

- Haka, S. 2007. A review of the literature on capital budgeting and investment appraisal. In C. Chapman, A. Hopwood, and M. Shields (eds.), *Handbook of Management Accounting Research, Volume 2*, (pp. 697–728). Oxford, UK: Elsevier.
- Hayes, R.M., and R. Lundholm. 1996. Segment reporting to the capital market in the presence of a competitor. *Journal of Accounting Research* 34(2): 261–279.
- Hirst, D. and P. Hopkins. 1998. Comprehensive income reporting and analysts' valuation judgments. *Journal of Accounting Research* 36 (Supplement): 47-75.
- Hirst, D., L. Koonce, and S. Venkataraman. 2007. How disaggregation enhances the credibility of management earnings forecasts. *Journal of Accounting Research* 45(4): 811–837.
- Hopkins, P. 1996. The effect of financial statement classification of hybrid financial instruments on financial analysts' stock price judgments. *Journal of Accounting Research* (Supplement): 33–50.
- Howell, S. and A. Jagle. 1997. Laboratory evidence on how managers intuitively value real growth options. *Journal of Business Finance and Accounting* 24(September): 915–935.
- Ijiri, Y. 1975. *Theory of Accounting Measurement*. AAA: Sarasota, Fl.
- Jeffery, M. 2006. *Teaching note: The value of flexibility at Global Airlines*. Evanston, IL: Kellogg School of Management at Northwestern University.
- Jensen, M. 1993. The modern industrial revolution, exit, and the failure of internal control systems. *The Journal of Finance* 48(3): 831–880.
- Koonce, L., M.G. Lipe, and M.L. McAnally. 2005. Judging the risk of financial instruments: Problems and potential remedies. *The Accounting Review* 80(3): 871–895.
- Lander, D. and G. Pinches. 1998. Challenges to the practical implementation of modeling and valuing real options. *The Quarterly Review of Economics and Finance* 38(3, Part 2): 537–567.
- Lankton, N. and J. Luft. 2008. Uncertainty and industry structure effects on managerial intuition about information technology real options. *Journal of Management Information Systems* 25(2): 203–240.
- Luehrman, T. 1998. Investment opportunities as real options: Getting started on the numbers. *Harvard Business Review* 76(4): 51.
- Luehrman, T. 2009. *Stryker Corporation: Capital Budgeting*. Boston, MA: Harvard Business School Publishing.
- Maines, L.A. and L.S. McDaniel. 2000. Effects of comprehensive-income characteristics on

- nonprofessional investors' judgments: The role of financial-statement presentation format. *The Accounting Review* 75(2): 179–207.
- McGrath, R. 1999. Falling forward: Real options reasoning and entrepreneurial failure. *Academy of Management Review* 24(1): 13–30.
- Miller, K. and Z. Shapira. 2004. An empirical test of heuristics and biases affecting real options valuation. *Strategic Management Journal* 25(3): 269–284.
- Mintzberg, H. 1994. *The Rise and Fall of Strategic Planning: Reconceiving Roles for Planning, Plans and Planners*. New York, NY: Macmillan Inc.
- Myers, S. 1977. Determinants of corporate borrowing. *Journal of Financial Economics* 5(2): 147–175.
- Ross, S. 1995. Uses, abuses, and alternatives to the net-present-value rule. *Financial Management* 24(3): 96–102.
- Ryan, P. and G. Ryan. 2002. Capital budgeting practices of the Fortune 1000: How have things changed? *Journal of Business and Management* 8(4).
- Schwartz, S., E. Spires, D. Wallin and R. Young. 2009. The behavioral implications of aggregation and delay on budget approval decisions. Working paper: Binghamton University and Ohio State University.
- Staw, B. 1997. The escalation of commitment: An update and appraisal. In Z. Shapira (ed.), *Organizational Decision Making* (pp. 191–215). Cambridge, UK: Cambridge University Press.
- Stout, D.E., H. Qi, Y. Xie, and S. Liu. 2008. Incorporating real-options analysis into the accounting curriculum. *Journal of Accounting Education* 26 (4): 213–230.
- Sunder, S. 1997. *Theory of Accounting and Control*. International Thomson Publishing: Cincinnati, OH.
- Swink, M. and C. Speier. 1999. Presenting geographic information: Effects of data aggregation, dispersion, and users' spatial orientation. *Decision Sciences* 30(1): 169–195.
- Teach, E. 2003. Will real options take root? Why companies have been slow to adopt the valuation technique. *CFO Magazine*, July 1. Available at <http://www.cfo.com/printable/article.cfm/3009782?f=options#>.
- Tiwana, A., M. Keil, and R. Fichman. 2006. Information systems project continuation in escalation situations: A real options model. *Decision Sciences* 37(3): 357–391.
- Tiwana, A., J. Wang., M. Keil, and P. Ahluwalia. 2007. The bounded rationality bias in

managerial valuation of real options: Theory and evidence from IT projects. *Decision Sciences* 38(1): 157–181.

Triantis, A. 2005. Realizing the potential of real options: Does theory meet practice? *Journal of Applied Corporate Finance* 17(2): 8–16.

Trigeorgis, L. 1993. Real options and interactions with financial flexibility. *Financial Management* 22(3): 202–224.

Trigeorgis, L. 1996. *Real Options: Managerial Flexibility and Strategy in Resource Allocation*. Cambridge, MA: The MIT Press.

Van Putten, A. and I. MacMillan. 2004. Making real options really work. *Harvard Business Review* 82(12): 134–141.

Yavas, A. and C. Sirmans. 2005. Real options: Experimental evidence. *The Journal of Real Estate Finance and Economics* 31(1): 27–52.

Table 1
Descriptive statistics for experiment participants *

	Experiment 1			Experiment 2			Both Experiments		
	Undergraduate (N=40)	Graduate (N=30)	All (N=70)	Undergraduate (N=83)	Graduate (N=62)	All (N=145)	Undergraduate (N=123)	Graduate (N=92)	All (N=215)
mean number of accounting courses	2.5	2.8	2.6	2.5	2.2	2.4	2.5	2.4	2.4
mean number of finance courses	1.4	2.6	1.9	1.3	2.4	1.8	1.3	2.4	1.8
mean number of economics courses	3.3	2.4	2.9	3.8	2.8	3.4	3.6	2.7	3.2
mean number of statistics courses	1.7	1.8	1.7	1.8	2.0	1.9	1.8	1.9	1.8
percent who studied DCF	100%	100%	100%	98%	97%	97%	98%	98%	98%
percent who studied real options	10%	20%	14%	14%	21%	17%	13%	21%	16%
mean prior knowledge of DCF (where 0 = not at all knowledgeable, 10 = extremely knowledgeable)	6.7	7.8	7.1	6.6	7.5	7.0	6.6	7.6	7.0
mean prior knowledge of real options (where 0 = not at all knowledgeable, 10 = extremely knowledgeable)	2.3	3.3	3.0	2.5	3.4	2.8	2.6	3.3	2.9
percent with full-time work experience	12%	43%	26%	16%	40%	26%	15%	41%	26%
mean months full-time work experience (for those with experience > 0)	6.0	28.8	22.5	7.2	23.9	18.2	6.8	25.6	19.6
percent who used DCF at work (for those with experience > 0)	40%	69%	61%	38%	44%	42%	39%	53%	48%
percent who used real options at work (for those with experience > 0)	0%	0%	0%	8%	20%	16%	6%	13%	11%
mean task clarity (where 0 = extremely unclear, 10 = extremely clear)	7.0	7.4	7.1	7.3	7.5	7.4	7.2	7.5	7.3
mean difficulty of decision(s) (where 0 = extremely easy, 10 = extremely difficult)	5.6	5.5	5.6	5.2	4.7	5.0	5.4	5.0	5.2
mean familiarity with decision(s) (where 0 = extremely unfamiliar, 10 = extremely familiar)	3.8	4.8	4.2	5.2	5.1	5.2	4.8	5.0	4.9
mean effort (where 0 = extremely low, 10 = extremely high)	5.5	6.1	5.8	5.3	6.1	5.6	5.4	6.1	5.7

Notes:

* Across all participants in Experiments 1 and 2, there are no differences in reported characteristics (all $p > 0.05$, two-tailed) except that participants in Experiment 1 reported less familiarity with the decisions in their task than did participants in Experiment 2 ($p < 0.05$, two-tailed).

Table 2
Experiment 1 – Test of Hypothesis 1

Results from estimating the following regression:^{*}

$$\begin{aligned} Rating_{ij} = & \beta_1 + \beta_2 PPValue_{ij} + \beta_3 ROValue_{ij} + \beta_4 CRRating_j + \\ & \beta_5 HHIRating_j + \beta_6 High/LowROProp_i + \beta_7 High/LowROProp_i * PPValue_{ij} + \\ & \beta_8 High/LowROProp_i * ROValue_{ij} + \beta_9 GradStatus_i + \beta_{10} Risk_i + \varepsilon. \end{aligned}$$

Independent Variable	Standardized Coefficient	Standard Error	<i>t</i>	<i>p</i> [†]
β_2 , <i>PPValue</i>	0.29	0.00	5.14	0.00
β_3 , <i>ROValue</i>	0.21	0.00	1.46	0.08
β_4 , <i>CRRating</i>	0.32	0.07	12.02	0.00
β_5 , <i>HHIRating</i>	0.31	0.00	12.44	0.00
β_6 , <i>High/LowROProp</i>	0.00	4.69	(0.02)	0.99
β_7 , <i>High/LowROProp x PPValue</i>	(0.03)	0.00	(0.53)	0.60
β_8 , <i>High/LowROProp x ROValue</i>	0.07	0.00	0.35	0.73
β_9 , <i>GradStatus</i>	(0.07)	1.05	(2.91)	0.00
β_{10} , <i>Risk</i>	0.13	0.10	5.54	0.00

Notes:

* The model regressed all participants' funding ratings of all projects on the projects' planned path values (*PPValue*); real options values (*ROValue*); Consumer Reports ratings of the product prototypes (*CRRating*); HHI ratings of the level of competition in the products' markets (*HHIRating*); a dummy variable (*High/LowROProp*) for whether the proportion of total project value from real options was low (0) or high (1); interactions between *High/LowROProp* and *PPValue*, *ROValue*, *CRRating*, and *HHIRating*; *GradStatus*, coded 0 or 1 for undergraduate or graduate participants, respectively; and *Risk*, the sum of each participant's responses to three questions about risk.

† Because, a priori, we expected the coefficient to be positive for *PPValue* and *ROValue*, the *p*-values for these two variables are one-tailed. All other *p*-values are two-tailed.

Table 3**Knowledge differences, relative accuracy perceptions, and managers' real options reliance**Results from estimating the following regression:^{*}

$$\begin{aligned}
Rating_{ij} = & \beta_1 + \beta_2 PPValue_{ij} + \beta_3 ROValue_{ij} + \beta_4 CRRating_j + \\
& \beta_5 HHIRating_j + \beta_6 High/LowROProp_i + \beta_7 High/LowROProp_i * PPValue_{ij} + \\
& \beta_8 High/LowROProp_i * ROValue_{ij} + \beta_9 GradStatus_i + \beta_{10} Risk_i + \beta_{11} KnowDiff_i + \\
& \beta_{12} RelAccuracy_i + \beta_{13} KnowDiff_i * PPValue_{ij} + \beta_{14} KnowDiff_i * ROValue_{ij} + \\
& \beta_{15} RelAccuracy_i * PPValue_{ij} + \beta_{16} RelAccuracy_i * ROValue_{ij} + \varepsilon.
\end{aligned}$$

Independent Variable	Standardized Coefficient	Standard Error	<i>t</i>	<i>p</i> (two-tailed)
β_2 , <i>PPValue</i>	0.18	0.00	1.20	0.23
β_3 , <i>ROValue</i>	(0.09)	0.00	(0.44)	0.66
β_4 , <i>CRRating</i>	0.32	0.07	12.10	0.00
β_5 , <i>HHIRating</i>	0.31	0.00	12.52	0.00
β_6 , <i>High/LowROProp</i>	(0.01)	4.71	(0.06)	0.96
β_7 , <i>High/LowROProp x PPValue</i>	(0.03)	0.00	(0.49)	0.62
β_8 , <i>High/LowROProp x ROValue</i>	0.05	0.00	0.27	0.79
β_9 , <i>GradStatus</i>	(0.08)	1.10	(3.29)	0.00
β_{10} , <i>Risk</i>	0.12	0.10	4.97	0.00
β_{11} , <i>KnowDiff</i>	(0.18)	0.75	(1.68)	0.09
β_{12} , <i>RelAccuracy</i>	(0.03)	1.47	(0.25)	0.80
β_{13} , <i>KnowDiff x PPValue</i>	0.18	0.00	2.00	0.05
β_{14} , <i>KnowDiff x ROValue</i>	0.13	0.00	1.58	0.11
β_{15} , <i>RelAccuracy x PPValue</i>	0.01	0.00	0.07	0.94
β_{16} , <i>RelAccuracy x ROValue</i>	0.27	0.00	1.80	0.07

Notes:

- * See descriptions for *PPValue*, *ROValue*, *CRRating*, *HHIRating*, *High/LowROProp*, *GradStatus*, and *Risk* in Table 2. *KnowDiff* represents participants' differential knowledge of DCF and real options valuation, and is measured using self-reported knowledge of DCF valuation less self-reported knowledge of real options valuation (with responses on an 11-point Likert scale anchored by 0 = *Not at all knowledgeable* and 10 = *Extremely knowledgeable*). *RelAccuracy* represents participants' assessments of the relative accuracy of planned path and real options DCF values using an 11-point scale anchored by 0 = *Only estimates for the planned implementation path were accurate* and 10 = *Only the estimates for the real options were accurate*.

Table 4
Experiment 2 – Descriptive statistics and tests for Hypothesis 1 replication and Hypothesis 2

Panel A: Descriptive statistics for amount allocated to Division A1 project *

Financial Summary Condition	Mean	[Std. Deviation]	<i>N</i>
Aggregated (<i>Agg</i>)	\$5,716,301	[\$2,337,195]	73
Disaggregated (<i>Disagg</i>)	\$6,176,389	[\$1,486,796]	72
Column Mean	\$5,944,759	[\$1,968,363]	145

Panel B: Hypothesis 1 replication one-sample *t*-test

	<i>df</i>	Difference	<i>t</i>	<i>p</i> [†]
Is mean amount allocated to Division A1 (\$5,944,759) greater than even split across divisions (i.e., \$5,000,000)?	144	+ \$944,759	5.78	< 0.01

Panel C: Hypothesis 2 ANOVA with Division A1 allocation as the dependent variable

Source	<i>df</i>	Mean Square	<i>F</i>	<i>p</i> [†]
<i>Aggregation</i>	1	1.02 E13	2.84	0.05
<i>GradStatus</i> [‡]	1	3.89 E9	0.00	0.97
<i>KnowDiff</i> [§]	12	3.11 E12	0.86	0.58
<i>Risk</i> [#]	19	4.76 E12	1.32	0.18

Table 4 (continued)

Notes:

- * Participants observed background information and estimates of the discounted cash flows for two long-term investment projects proposed by two separate divisions, Division A1 and Division B2. Division A1's project had higher (lower) planned path (real options) DCF values than Division B2's project, but the total DCF values were the same. Participants observed the planned path and real options values either aggregated together (*Agg*) or disaggregated from each other (*Disagg*) in the proposal. Participants then judged what amounts to allocate across the two projects from \$10 million in available funds. Our analysis is based on the amounts participants allocated to Division A1's project (*DivA1Alloc*).
- † The *p*-values in Panel B and for *Aggregation* in Panel C are one-tailed; other *p*-values are two-tailed.
- ‡ *GradStatus* controls for any effects of participants' degree status on the funding decision, and is coded 0 or 1 for undergraduate or graduate participants, respectively.
- § *KnowDiff* controls for participants' differential knowledge of DCF and real options valuation, and is measured using self-reported knowledge of DCF valuation less self-reported knowledge of real options valuation (with responses on an 11-point Likert scale anchored by 0 = *Not at all knowledgeable* and 10 = *Extremely knowledgeable*).
- # *Risk* controls for perceptions of the relative risk in the divisions' projects, and is measured by the sum of participant responses to the following two questions: "Indicate which project you believe is riskier, where risk is defined as (i) having a high variance in possible future net cash flows from the project; and (ii) having a loss as a possible outcome of the project" (with responses on an 11-point Likert scale anchored by 0 = *A1 Division's proposed project is riskier* and 10 = *B2 Division's proposed project is riskier*).

Table 5
Experiment 2 – Evidence of the process underlying
the effect of accuracy perceptions on funding decisions *

Panel A: Relationship between the relative weight assigned to real options values and the relative accuracy of real options values (with controls for degree status, differences in knowledge of DCF and real options valuation, and risk perceptions), estimated with the equation:

$$WeightDiff^{\dagger} = \beta_1 + \beta_2 RelAccuracy + \beta_3 GradStatus + \beta_4 KnowDiff + \beta_5 Risk + \varepsilon$$

Source	Standardized Beta	<i>t</i>	<i>p</i> [‡]
<i>RelAccuracy</i> [§]	-0.20	2.40	0.02
<i>GradStatus</i> [#]	0.10	1.27	0.21
<i>KnowDiff</i> ^{**}	-0.02	0.26	0.80
<i>Risk</i> ^{††}	0.22	2.55	0.01

Panel B: Relationship between the amount of funds allocated to Division A1 and the relative weight assigned to real options values (with controls for degree status, differences in knowledge of DCF and real options valuation, and risk perceptions), estimated with the equation:

$$DivA1Alloc^{\ddagger\ddagger} = \beta_1 + \beta_2 WeightDiff + \beta_3 GradStatus + \beta_4 KnowDiff + \beta_5 Risk + \varepsilon$$

Source	Standardized Beta	<i>t</i>	<i>p</i> [‡]
<i>WeightDiff</i> [†]	0.19	2.34	0.02
<i>GradStatus</i> [#]	-0.08	1.03	0.30
<i>KnowDiff</i> ^{**}	-0.01	0.06	0.95
<i>Risk</i> ^{††}	0.26	3.14	0.01

Table 5 (continued)

Notes:

- * This table provides evidence of the process by which participants rely on real options values in their funding decisions: (1) participants' perceptions of the relative accuracy of real options compared to planned path values is associated with the relative weight they assign to real options (Panel A), and (2) the relative weight participants assign to real options is associated with their funding decisions (Panel B). See Figure 3 for a diagram of the process.
- † Participants assigned 100 points among several factors to represent their importance to their funding decisions. *WeightDiff* is the points assigned to the factor for planned path values less the points assigned to the factor for real options values.
- ‡ *p*-values are two-tailed.
- § Participants assessed the relative accuracy of planned path and real options DCF values using an 11-point scale anchored by 0=*Only estimates for the planned implementation path were accurate* and 10=*Only the estimates for the real options were accurate*.
- # *GradStatus* controls for any effects of participants' degree status on the funding decision, and is coded 0 or 1 for undergraduate or graduate participants, respectively.
- ** *KnowDiff* controls for participants' differential knowledge of DCF and real options valuation, and is measured using self-reported knowledge of DCF valuation less self-reported knowledge of real options valuation (with responses on an 11-point Likert scale anchored by 0=*Not at all knowledgeable* and 10=*Extremely knowledgeable*).
- †† *Risk* controls for perceptions of the relative risk in the divisions' projects, and is measured by the sum of participant responses to the following two questions: "Indicate which project you believe is riskier, where risk is defined as (i) having a high variance in possible future net cash flows from the project; and (ii) having a loss as a possible outcome of the project." (with responses on an 11-point Likert scale anchored by 0=*A1 Division's proposed project is riskier* and 10=*B2 Division's proposed project is riskier*).
- ‡‡ Participants observed background information and estimates of the discounted cash flows for two long-term investment projects proposed by two separate divisions, Division A1 and Division B2. Division A1's project had higher (lower) planned path (real options) DCF values than Division B2's project, but the total DCF values were the same. Participants then judged what amounts to allocate across the two projects from \$10 million in available funds. Our analysis is based on the amounts participants allocated to Division A1's project (*DivA1Alloc*).

Table 6
Experiment 2 – Evidence of process underlying Hypothesis 2 *

Panel A: Descriptive statistics for relative accuracy judgments †

Financial Summary Condition	Marginal Mean	Std. Deviation	<i>N</i>
Aggregated (<i>Agg</i>) ‡	4.92	1.40	73
Disaggregated (<i>Disagg</i>) ‡	4.38	1.75	72

Panel B: ANOVA for the effect of aggregation on the relative accuracy of real options values

Source	<i>df</i>	Mean Square	<i>F</i>	<i>p</i> §
<i>Aggregation</i> ‡	1	9.32	3.89	0.03
<i>GradStatus</i> #	1	3.12	1.30	0.26
<i>KnowDiff</i> **	12	3.43	1.43	0.16

Notes:

- * Table 5 documents support for lower reliance on real options due to differences in the perception of accuracy, consistent with Experiment 1. To expand our evidence to include the reasoning underlying H2, we examine whether *Aggregation* affects participants' perceived relative accuracy of real options values. We expect that judgments of the relative accuracy of real options are associated with whether planned path and real options values are aggregated or disaggregated in a financial summary of subordinates' projects. See Figure 3 for a diagram of this process.
- † Participants assessed the relative accuracy of planned path and real options DCF values using an 11-point scale anchored by 0=*Only estimates for the planned implementation path were accurate* and 10=*Only the estimates for the real options were accurate*.
- ‡ Participants observed background information and estimates of the discounted cash flows for two long-term investment projects proposed by two separate divisions, Division A1 and Division B2. Division A1's project had higher (lower) planned path (real options) values than Division B2's project, but the total values were the same. Participants observed the planned path and real options values either aggregated together or disaggregated from each other in the proposal.
- § The *p*-value for *Aggregation* is one-tailed; other *p*-values are two-tailed.
- # *GradStatus* controls for any effects of participants' degree status on the funding decision, and is coded 0 or 1 for undergraduate or graduate participants, respectively.
- ** *KnowDiff* controls for participants' differential knowledge of DCF and real options valuation, and is measured using self-reported knowledge of DCF valuation less self-reported knowledge of real options valuation (with responses on an 11-point Likert scale anchored by 0=*Not at all knowledgeable* and 10=*Extremely knowledgeable*).

Exhibit 1
Experiment 1 – Sample investment proposal report provided to participants *

Division Name: A01 Division

Project Description: Tablet personal computer (PC)

Discounted value for planned implementation path ¹	\$ 10,700,000
Discounted value for real options ¹	<u>\$ 3,000,000</u>
Total discounted value for project ¹	<u>\$ 13,700,000</u>

Consumer Reports rating of product prototype ²	76
HHI rating of competition in product’s market ³	1091

Your rating of the amount of funding that should be provided
 (use a scale of 0 to 100, where higher values indicate greater funding) _____

NOTES:

- ¹ Computed using ROV analysis.
- ² *Consumer Reports* provided an independent rating of a product prototype, using a scale which can range from 0 to 100 (where higher values represent a better product).
- ³ The Herfindahl-Hirschman (HHI) rating of the level of competition in the product’s market, which can range from 0 to 10,000. *Lower* values of the HHI indicate that there are *more* firms selling similar products, while *higher* values of the HHI indicate that there are *fewer* firms selling similar products. The U.S. Department of Justice considers a market with an HHI of less than 1,000 to be competitive (i.e., many firms selling similar products); with an HHI of 1,000 to 1,800 to be moderately concentrated (i.e., a moderate number of firms selling similar products); and with an HHI of 1,800 or greater to be highly concentrated (i.e., a monopoly over the product market).

Notes:

* We counterbalanced the proportion of total value from real options. Half the participants received projects for which the proportion of total value from real options was less than one-third (as in this exhibit); the other half received projects for which the proportion was more than two-thirds (not shown). As such, discounted values for the planned path and the real options were switched for each of the 20 projects across these counterbalanced conditions, but all other information, including Consumer Reports and HHI ratings, were the same.

Exhibit 2
Experiment 2 – Information about proposed projects provided to participants and aggregation manipulation*

Project Proposals from A1 Division and B2 Division

The head of A1 Division proposes to begin development on a new *digital video recorder (DVR)*. This product is similar to a product already manufactured by A1 Division, except that it is smaller and has a larger memory capacity. The discounted value of this project if all goes as planned is \$11,000,000. In addition, the R&D department is currently perfecting technology that would allow *users to record more channels simultaneously*. If the technology is perfected before development begins, management could choose to add the feature if market conditions warrant the addition. The head of A1 Division believes there is a 10% chance this could happen. The overall discounted value of this project including real options is \$12,000,000.

The head of B2 Division proposes to begin development on a new *MP3 player*. This product is similar to a product already manufactured by B2 Division, except that it is smaller and has a larger memory capacity. The discounted value of this project if all goes as planned is \$8,000,000. In addition, the R&D department is currently perfecting technology that would allow *wireless downloads of music from a music service directly to the MP3 player*. If the technology is perfected before development begins, management could choose to add the feature if market conditions warrant the addition. The head of B2 Division believes there is a 10% chance this could happen. The overall discounted value of this project including real options is \$12,000,000.

Summary Financial Information for Proposals

The division heads have provided the following summary financial information for your review.†

Aggregated condition:

	A1 Division	B2 Division
Discounted value for planned implementation path + real options	\$ 12,000,000	\$ 12,000,000

Disaggregated condition:

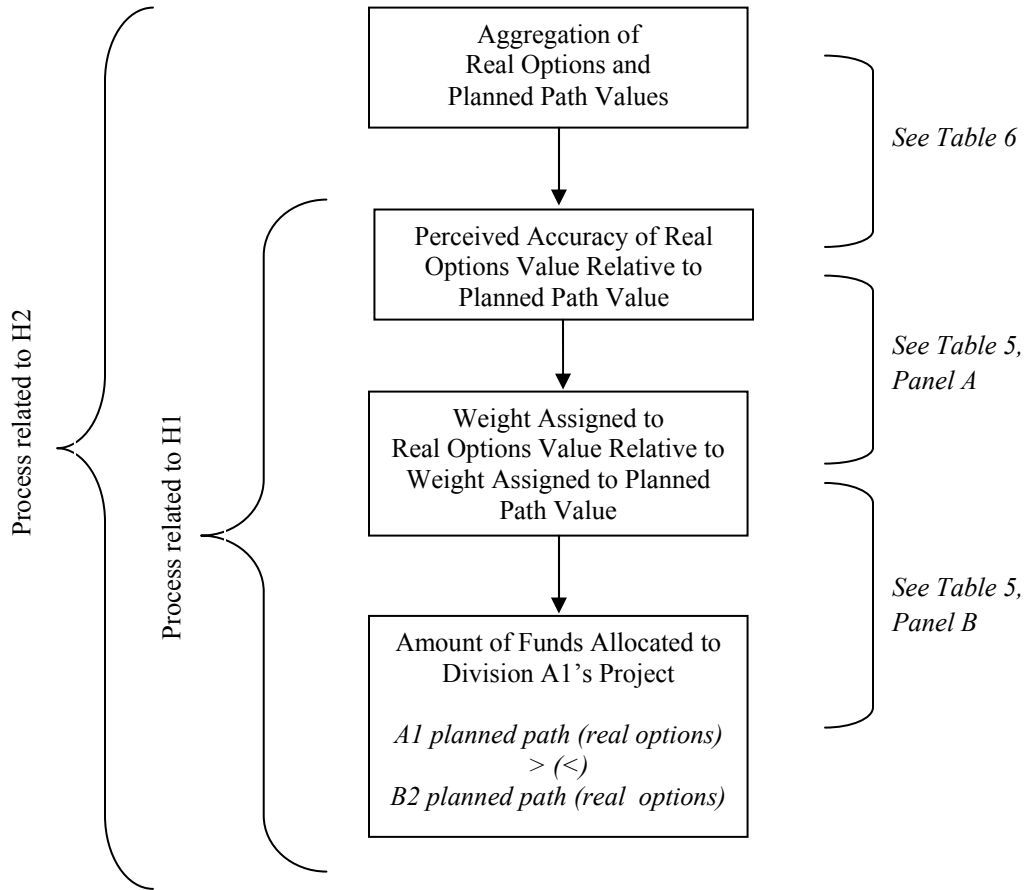
	A1 Division	B2 Division
Discounted value for planned implementation path	\$ 11,000,000	\$ 8,000,000
Discounted value for real options	\$ 1,000,000	\$ 4,000,000

Exhibit 2 (continued)

Notes:

- * In the project descriptions, the information in italics was counterbalanced within each experimental condition (i.e., within a given experimental condition, half the participants were informed that Division A1's product was the MP3 player and Division B2's product was the DVR, and the other half were informed that Division A1's product was the DVR and Division B2's product was the MP3 player).
- † Participants received only one of these two financial summaries just as shown in this exhibit – directly below the descriptive information and on the same page – except that the condition information in italics was not included.

Exhibit 3
Experiment 2 – Process underlying participants’ funding judgments *



Notes:

* This exhibit illustrates the process by which supervising managers’ accuracy perceptions affect their reliance on planned path and real options values and thus their decisions about funding for subordinates’ proposed long-term investment projects.