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Real options in the laboratory: An experimental study of sequential investment decisions

Ryan O. Murphy [a], Sandra Andraszewicz [b,*], Simon D. Knaus [c]

[a] University of Zürich, Blümlisalpstrasse 10, 8006 Zürich, Switzerland
[b] ETH Zürich, Scheuchzerstrasse 7, 8092 Zürich, Switzerland
[c] University of St. Gallen, Bodanstrasse 6, 9000 St. Gallen, Switzerland

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ABSTRACT

Many real-life risky decisions in finance and management are dynamic and decision policies can be adapted as uncertainty is reduced by the arrival of new information. In this type of situation, called a *real options* problem, a decision maker must choose how much of his finite resources to invest in a dynamic risky environment. In two laboratory experiments, we test a well-defined decision problem with the central characteristics of a real options framework and do so in such a way that it is amendable to formal modeling. We find that people choose differently than the expected value maximizing policy, consistent with risk aversion and non-linear probability weighting. We conclude that although real options analysis is useful as a normative valuation method, its recommendations are sometimes contrary to people's innate tendencies when making risky choices and this counterintuitiveness should be considered when implementing real options analysis in training and practice.

1. Introduction

Decision makers must sometimes choose whether to invest valuable resources in an ongoing and evolving prospect or abandon the prospect given the arrival of new information. Take as one prototypical example a firm that has the option to invest money in a nascent start-up company. This start-up has an uncertain future and thus an uncertain chance of paying off as an investment. The potential return for the venture capital (VC) firm is proportional to the amount of money it cumulatively invests in the start-up. If the expected return is sufficiently high for the start-up, the VC firm should invest money; conversely if the expected return is low for the start-up, the VC firm should refrain from investing its resources. One constraint that makes this type of problem nontrivial is that the VC firm is limited in that it must make these investment decisions sequentially over discrete periods, and moreover it is restricted in how much money it can invest at any one time. Dynamic risky decision situations (Edwards, 1962) like this are referred to as *real options* problems, a term first coined by Myers (1977). In these contexts, a decision agent must repeatedly choose, over multiple distinct periods, if it is sensible to invest in ongoing and evolving prospects, and if so, how much to invest. Conversely, a decision agent can choose to abandon the prospect and not invest resources. Real option problems are characterized by sequential dynamic decisions, where information about the success of these decisions is revealed over time, past decisions are irreversible, and future decision strategies can be adapted depending on newly available information. In this paper, we develop a real options decision task, derive the optimal normative policy, experimentally examine people's risky choices, compare the observed behavior to the normative policy, and comparatively evaluate several descriptive models of the observed behavioral patterns emerging from the choices.

1.1. Literature review

Real options contexts are widely encountered in real world settings including entrepreneurial decision making (McGrath, 1997, 1999), labor economics (Jacobs, 2007; Hogan and Walker, 2007), mineral and oil exploration (Babajide, 2007), research and development (Rogers et al., 2002; Schwartz, 2004; Sereno, 2010), environmental technology investments (Cortazar et al., 1998), and venture capital investing (Hsu, 2008). As such, the topic has been addressed by several disciplines and from a variety of different angles. At the macro level, these situations are often related to

* Corresponding author.
E-mail addresses: ryan.murphy@econ.uzh.ch (R.O. Murphy), sandraszewicz@ethz.ch (S. Andraszewicz), sknaus@gmx.ch (S.D. Knaus).

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strategy and corporate finance. Bowman and Hurry (1993) points out that real options are essential components of a firm's overall strategic capacity, an assertion that multiple other studies echo (e.g., McGrath, 1997, 1999; Sirmon et al., 2007; Dess et al., 2003). Klingebiel and Adner (2015) conducted qualitative research in which 28 practitioners from eleven firms in diverse industries were interviewed to evaluate the performance advantage in product innovation when firms applied a real options approach. They found that sequential investments, consistent with real options analysis, resulted in better firm performance. This supports the notion that in a dynamic choice environment a firm can capitalize on flexibility and this yields added value. Although real options may confer a strategic advantage to firms, it is not always observed in industry and markets. For example, Quigg (1993) featured a real options pricing model that considered the value of waiting different time intervals to invest in real estate. Results showed the existence of persistent market inefficiencies in that observed prices systematically exceeded the model-implied values. Howell and Jägle (1997) found similar results when they investigated the valuation of options by managers in nine major British companies and report a general overvaluation of options relative to the normative (i.e., expected value maximizing) pricing policy. These studies provide evidence of the strategic importance of real options problems for firms, but they do not address the micro foundations of individual decision making, namely individuals' abilities and propensities to follow the dictates of an optimal decision policy in a dynamic setting.

Other studies highlight the relationship between a real options context and individual risky decision making. In a micro setting Miller and Shapira (2004) asked decision makers to specify the price for selling or buying a call or a put option for simple binary lotteries. In that task, individual participants generally undervalued options (with regard to the expected payoffs), but overestimated expected losses for selling a put. Further, Yavas and Sirmans (2005) reported that in a real options problem individuals generally invested too early and thus failed to realize the full value of the flexibility granted by their options. In another study (Wang et al., 2009), participants had to trade commodities produced by their "factory", depending on the commodities' price changes that developed over time. The results indicated that participants did not follow an optimal policy but rather exhibited two distinct kinds of decision biases: first, not incorporating the expected price, and second, exhibiting a general insensitivity to the termination date. Oprea et al. (2009) presented somewhat contrasting results from a laboratory experiment where participants had to decide when to invest in a risky option. In this setting, participants eventually learned to wait and enact their decision when uncertainty was sufficiently resolved. However, this near optimal behavior was not observed at the beginning of the study, but only in the last block of the experiment.

Overall, these results indicate that, although the real options valuation approach is widely applicable and does bestow value, it may be difficult for people to implement properly. Previous work suggests innate behavioral tendencies that are contrary to the normative dictates of real options analysis and expected value maximization in dynamic contexts. However, the distribution, persistence, and structure of these biases is not clear. Additionally, previous approaches to real options research do not allow for formal modeling, which can be a useful tool for discerning the actual decision policies of decision makers.

To better understand the behavioral propensities and the cognitive biases operating as people make these kinds of dynamic risky choices, we develop a general real options problem that is amenable to both formal modeling and laboratory experimentation. It has a clear and simple structure that can be easily implemented in an incentive compatible experimental setting. This dynamic decision problem retains the central conflict that is at the core of the real options vignette presented previously and in many other problems found in the wild. In these settings a decision maker faces, over multiple discrete stages, the option of trading a certain alternative of real value, for a risky option with potentially greater value, all within the context of a dynamic environment with updating information about the probability of gain.

1.2. Motivation for the current paper

The major research questions for this paper are twofold: First, we wish to compare individuals' sequential investment decisions in a set of real option decision problems to the normative (e.g., a risk neutral expected value maximizing) decision policy. Do individuals make decisions (generally) consistent with this normative solution, and thus maximize their expected earnings? Alternatively, do individuals' decisions deviate significantly from what is optimal to these ends, thus diminishing potential earnings. And if there are significant deviations, what, if any, decision patterns do individuals exhibit in these real option problems?

Second, assuming we find some systematic non-expected value maximizing behavioral results,[1] can the emergent choice patterns be sensibly modeled? Would simple utility theory account for the stylized facts? Or would non-expected utility theory involving both risk aversion and probability weighting (considered concurrently) be necessary to describe the results? Or would a different characterization invoking different heuristic models better capture the pattern of empirical findings? In order to adequately address this second set of questions, a host of different choice models will be competitively compared for goodness-of-fit and out-of-sample predictive power in accounting for the observed decisions. The data used to address these empirical questions result from two laboratory experiments using a tractable multistage real options decision problem explained below.

Lastly, we are motivated to promote more attention to the study of dynamic risky decision making in general. Many interesting and important decision problems from the real world have a sequential structure, where the decision maker is called upon to make a series of choices with updated information and where her later options depend on her previous choices. This class of problems has a long history (e.g., Edwards, 1962) but unfortunately remains understudied given its potential richness. To be sure, simple static gambles, which currently prevail in the research landscape, are useful building blocks—but there is a great deal more to understanding risky decision making in people than can possibly be uncovered using only one-shot gambles.

In the following sections in the paper, we formally define and solve a well structured real options problem, identifying the expected value maximizing decision policy. Then, we analyze and report the behavior resulting from the experiments, using the normative solution as a benchmark. Thereafter, we develop, contrast, and explore different behavioral choice models and evaluate how well they correspond to the pattern of empirical results. This includes testing whether expected utility maximization is sufficient to describe the results. Lastly, we conclude with a discussion about some persistent biases we find and offer suggestions for countering these tendencies when considering real options analysis.

[1] The descriptive inadequacy of expected value maximization is well known (see for example Camerer, 1995, Wakker, 2010, Barberis, 2013, and Fox et al., 2015 for general overviews).