AN ANALYSIS OF THE EFFECTS OF RISK BIASES
ON REAL OPTIONS PRICING

by

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for the degree of Doctor of Business Administration

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(Signed) ___________________________

Nathan Brady
DEDICATION

To my wife Tobey for her unwavering support of my academic pursuits over the years, and to my daughter Kora for reminding me that sometimes playtime comes first.
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ABSTRACT

Over the past two decades, a significant amount of academic knowledge has been created on how to apply real options analysis to business investments. Despite the many apparent advantages of using real options to value projects, the approach has not found favor with managers in practice. Some critics claim that the method is untrustworthy and might encourage too much risk taking. This dissertation provides an exploration of risk biases, viewed through the lens of prospect theory, as a potential cause for the mistrust toward real options. Using evidence from a survey of 67 business school students, the results showed that participants generally evaluated options with prospect theory’s S-shaped utility function rather than with the straight, risk-neutral function that is often assumed by normative pricing models. Pricing differences were found to be dependent on the framing of the scenario as either a gain or a loss and whether or not there were small probabilities involved. These findings bring into question the appropriateness of models based on the risk-neutral assumption.

Keywords: Real options, prospect theory, expected utility, risk neutrality, options pricing
CHAPTER 1: INTRODUCTION

According to an old adage, wise people keep their options open. This advice may be as applicable to business investments as it is to everyday life (Luehrman, 1998b). This research was designed to explore how managers valued certain flexible business investments, such as those with options to expand or abandon the investment at various stages and to uncover evidence of a gap between theory and practice in the pricing of these investments.

In general, flexibility within an investment project leads to a higher valuation than the project would have without flexibility. Consider, for example, two competing proposals to construct a new office building that is expected to be needed in a few years. Further, assume both proposals are identical in every way, including price, except that Bidder A requires the entire fee up front and offers no process for changing the specification once construction begins. Bidder B, on the other hand, has offered to complete the construction and submit invoices in phases. Assuming that there is at least some probability that the construction may need to be changed or even canceled, Bidder B’s proposal is intuitively more favorable. The question remains, however: How much more favorable? Would the flexibility in Bidder B’s contract be worth an additional 1%, 5%, or 10%? How might one go about evaluating such a price?

These are some of the questions addressed by an area of finance theory called real options analysis (ROA). Because such flexibility often represents an exclusive right, not an obligation, to take some course of action in the future, real options analysis works by modeling business projects similarly to how financial options are modeled (Copeland & Antikarov, 2003; Trigeorgis, 1991). For example, a right to expand or invest, or to sell or abandon the project in later stages can be modeled as call and put options, respectively.
Despite available and mature theory for modeling these scenarios, ROA is not popular in practice. In fact, prior research has shown that managers tend to rely on more traditional techniques such as discounted cash flows (DCF), internal rate of return (IRR), and the payback period, despite a well-documented tendency for these methods to undervalue flexible business projects (Dixit & Pindyck, 1994; Ryan & Ryan, 2002). Additionally, a general lack of trust in real options models has been found to be a primary reason for managers’ preference for traditional models over ROA (Luehrman, 1998a; Teach, 2003). This research represents an attempt to explain the lack of trust and scant adoption of ROA by showing how cognitive risk biases cause managers to price options at a discount relative to the normative value calculated by ROA.

1.1 Purpose

The primary purpose of this research was to understand how psychological biases may affect the valuation of business investments containing one or more embedded real options. Researchers have suggested that managers may price real options according to prospect theory utility rather than according to the often-assumed risk-neutral expected value (Miller & Shapira, 2004). Unlike the straight line generally implied by expected value, prospect theory presents an s-shaped utility curve that is concave for gains and convex and steeper for losses. Further, unlike expected value, prospect theory includes the idea that people are prone to overweighting small probabilities (Kahneman & Tversky, 1979). This research extends the literature through an exploration of the effects that certain features of prospect theory—a steeper function for losses/disutility and overweighting of small probabilities, for example—may have on the options pricing behavior of managers (Kahneman & Tversky, 1979, 1992).

A survey of 67 business school students at the University of Newcastle, Australia, was conducted in the fall of 2013. The survey consisted of six hypothetical
options scenarios with uncertain financial outcomes. In each scenario, the respondents were asked to report how much they would be willing to pay for the option to participate in (a call) or exclude themselves from (a put) the situation. The results showed that participants generally evaluated options consistently with prospect theory’s S-shaped utility function rather than with the straight, risk-neutral function that is often assumed by normative pricing models. These findings brought into question the appropriateness of the risk-neutral assumption, as the resulting differences in valuation could be significant.

Many definitions were required for this study. In order to provide consistency and clarity throughout this paper, definitions for many key terms are available in Appendix A.

1.2 Significance

A variety of flexible or multistage projects, such as investments in natural resources, research and development, and information technology, for example, can be more accurately modeled as options rather than as fixed-income assets. These projects are usually modeled using mainstream methods such as discounted cash flows (DCF) and internal rate of return (IRR). Managers have tended to prefer these conventional methods to real options, however, which may have led to an underinvestment in flexible or staged projects because these cannot account for valuable features such as an ability to defer all or a portion of a project, the possibility of increasing or decreasing the amount of investment based on information learned in later stages of the project, or the opportunity to abandon a failing project before being fully invested (Benaroch, Lichtenstein, & Robinson, 2006; Brennan & Schwartz, 1985; Hartmann & Hassan, 2006; Panayi & Trigeorgis, 1998).
Until the mistrust in real options analysis is more fully understood, it will be
difficult to influence managerial behavior, and the underinvestment already noted by
researchers is likely to continue. The findings of this research provide insight into why
managers are reluctant to adopt ROA. The findings from this study could lead to
insights and improvements in real options modeling, ultimately effecting change in
managerial practice.

1.3 Research Objective

Since human decision-making regarding financial matters is based on utility
rather than on an accumulation of money, a mismatch between the assumed utility
curves and those actually present in the minds of managers could be a major contributor
to their mistrust in ROA (Friedman & Savage, 1948, 1952; Kahneman, 2003;
Kahneman & Tversky, 1979, 1992). The specific objective of this research was to
explore the risk-neutral utility assumption that is common to ROA models as a potential
cause for mistrust in the method.

1.4 Research Questions

In accordance with these research objectives, the following research questions
provided the basis for this study:

- **RQ1**: What role does the utility function play in options pricing?
- **RQ2**: Is risk-neutrality a valid or useful assumption for modeling real
  options?
1.5 Research Model

The simplified research model shown in Figure 1 illustrates the hypothetical effects that a prospect theory utility curve could have on option prices. For clarity of presentation, a call option is shown in this simplified version but both call and put options are included in the full model shown in Figure 5.

First, the model shows how decreasing marginal utility for gains in prospect theory leads to lower expected utility than the straight line, risk-neutral utility curve. Second, because option premiums must be paid regardless of the outcome they are perceived as a loss and so are evaluated against prospect theory’s steeper disutility.

Figure 1. Simplified research model
curve for losses. Third, the option price under prospect theory is shown to be lower
than it would be under the risk neutral assumption. The general effects shown in this
simplified model were used to generate the new hypotheses that will be covered in
greater detail in next chapter.

1.6 Dissertation Structure

This dissertation adheres the five chapter format for theses recommend for
D.B.A. dissertations at The University of Newcastle, Australia. A brief outline of the
dissertation structure follows.

Chapter 1 provides a high-level background of real options analysis and outlines
the prospective usefulness in business project valuation. In addition, the chapter
highlights a lack of adoption in mainstream management practice. The chapter also
provides a deeper explanation of the purpose and significance of this research, detailing
the hypotheses, research methodology, and the central research questions that motivated
the study.

Chapter 2 provides an overview and literature review of two relevant bodies of
knowledge: options pricing and utility theories. A detailed discussion of prior research
on the effect of utility on option pricing models is also provided. The basis for the
hypotheses, research model, and study methodology are developed late in the chapter.

Chapter 3 involves the general research method, including sample identification,
survey design, data collection and preparation procedures, and hypotheses tests. The
methods developed include extensions of those employed by previous researchers as
well as enhancements and additions that are unique to this study.

Chapter 4 provides the results of the hypothesis testing using statistical methods
and visual plots. An analysis of the results is presented, including a description of the
observed relationship between prospect theory and option prices.
Chapter 5 summarizes the findings and provides a discussion of the implications of the findings for theory as well for practice. The chapter also addresses the limitations of this research and indicates opportunities for future research on this topic.
CHAPTER 2: LITERATURE REVIEW

This chapter provides a literature review of prior works that form the basis for this research. The literature review begins with a summary of the relevant bodies of knowledge for both options pricing and utility theories. The gap into which this new research fits is identified. Finally, five new hypotheses are introduced, along with their respective justifications and mathematical explanations.

2.1 Options Theory

A real option can be casually described as an exclusive right, but not an obligation, to make a business investment in the future (Myers, 1977). Put another way, real options represent flexibility in business projects. Flexibility encompasses such options as the ability to expand, contract, abandon, or otherwise change the project to adapt to new information and circumstances. For example, most research and development investments do not directly yield cash flows (Hartmann & Hassan, 2006). Rather, these investments give their owners exclusive rights to continue research, launch a new product, or sell intellectual property. There is also the possibility that the research and development (R&D) project will show early signs of failure, leading to abandonment of the project before all the invested cash is spent. The existence of these outcomes and the probability of each can have a significant effect on the expected value of the R&D investment (Copeland & Antikarov, 2003; Luehrman, 1998b). Real options analysis (ROA) provides a unique method to model such projects with complex distributions of possible outcomes.

Real options analysis can be used to model a wide variety of corporate projects more accurately than can more traditional valuation techniques such as discounted cash flows (DCF), internal rate of return (IRR), or the payback period (Luehrman, 1998b; Myers, 1977; van Putten & MacMillan, 2004). Where traditional methods tend to
model a fixed set of periodical cash flows that are discounted by a single discount rate, ROA models outcomes using a stochastic process and can accommodate multiple discount rates to reflect different levels of risk at each period (Dixit & Pindyck, 1994; Trigeorgis, 1993). The following sections provide a history of the origins of ROA and its taxonomy, a selection of use cases commonly found in the literature, and a summary of mature analysis techniques available to practitioners.

2.1.1 Financial Options

Much of real options theory is based on the deeper literature for financial options. For example, nearly all of the real options taxonomy and many of the formulae either come directly from or have their roots in financial options theory. Considering this, a review of financial options literature is of some value before moving onto the real options literature. This subsection provides a summary and background of options theory, terminology, and pricing.

2.1.1.1 Definitions

Common knowledge in the financial world includes knowledge about two types of options: calls and puts. Both of these option types represent a temporary contract between two parties, in which one party seeks to limit exposure to risk associated with some asset, while the other party seeks exposure to the risk in exchange for a premium. The transfer of risk usually occurs by way of an agreement to buy or sell an asset at a specified price at or by some point in the future. The party who seeks to limit risk exposure by having the right to buy or sell the asset is the option holder (the long position). The party who is obligated to buy or sell is the option seller (the short position). The premium is generally paid up front and is kept by the seller regardless of whether the option is ever exercised by the holder.
Where a “call” option confers the right to buy an asset on the long party and creates an obligation to buy for the short party, a “put” option represents the right to sell for the long party and an obligation to buy for the short. In major financial markets, calls and puts are frequently written on a tradable security such as a stock and can come in the form of European options or American options. European options can be exercised only on the expiration date of the contract, not before. American options, which are far more common, can be exercised at any time before the contract expires. For the purposes of this paper, all options modeled, both financial and real, are assumed to be of the American style. The following is a list of the common criteria specified in an options contract:

- Option type: Call or put
- Underlying asset: A financial security such as a stock, bond, or fund
- Strike price: The price at which the underlying asset is to be bought or sold
- Expiration date: The date after which the option can no longer be exercised

2.1.1.2 History

The trading of option contracts dates back to at least 332 B.C., when Aristotle described the buying and selling of options contracts on olive presses (Aristotle & Lord, 1984). He described how owners of the presses were subjected to volatility in seasonal olive yield and hedged this risk by selling the right to use the presses before the size of the harvest was known, locking in certain profits. The buyers of the option paid the premium regardless of whether they would actually have occasion to use the press, an outcome that depended on their olive yields. In a good harvest, owning the option would be profitable because the option owner would avoid having to pay high a market
price in an environment where many olive growers were looking to rent the presses. However, in a poor harvest, the presses might not be needed; thus, the option to use them would expire unused and worthless.

The modern conception of a standardized option contract dates back to 1973 ("CBOE History," 2014). Option contracts are now traded nearly around the clock on a variety of electronic markets. Options contracts can be purchased on everything from physical commodities such as corn, wheat, or gold to financial instruments such as stocks, bonds, and exchange-traded funds.

2.1.1.3 Call Options

A call option represents a right, but not an obligation, to buy a security at a preset “strike” price from a counterparty. The seller of a call exchanges uncertain gain over and above the strike price for an up-front premium, while the buyer exchanges the nonrefundable premium for uncertain gains. If the market price of the security rises above the strike price, the option is said to be “in the money,” otherwise it is considered “out of the money.”

The buyer of a call option locks in the right to gains in the price of the underlying asset over the strike price. Consider the following hypothetical option:

- Option type: Call
- Underlying asset: 1,000 shares of symbol “FAKE”
- Strike price: $10.00
- Expiration date: 90 days in the future

If the current price of FAKE is $8.00, the buyer of this call option would need the price to rise to this price before the option had any value, that is, exercising the option at a price lower than the strike price would mean the buyer would be paying more for the shares than he or she could buy them for on the open market.
Suppose that the buyer and seller agree on a premium of $1.00 per share. The buyer must make this payment regardless of the eventual outcome. For there to be a net gain for the buyer, the market price of the underlying asset must rise to the strike price plus the premium, as shown in Figure 2.

![Call Option Payoffs](image)

**Figure 2.** Call option payoffs

### 2.1.1.4 Put Options

A put option represents a right, but not an obligation, to sell a security at a preset “strike” price to a counterparty. The seller of a put exchanges uncertain losses that occur below the strike price for an up-front premium, while the buyer exchanges the premium for the ability to limit his or her potential losses. If the market price of the security falls below the strike price, the option is said to be “in the money,” otherwise it is considered “out of the money.”

The buyer of a put option locks in the right to limit losses in the underlying asset under the strike price. Consider the following hypothetical option:

- Option type: Put
- Underlying asset: 1,000 shares of symbol “FAKE”
- Strike price: $10.00
- Expiration date: 90 days in the future

If the current price of FAKE is $12.00, the buyer of this put option would need the price to fall at least $2.00 before the option had any value, that is, exercising the option at a higher than the strike price would mean the option owner would sell the shares for a lower price than he or she could get on the open market.

Suppose that the buyer and seller agree on a price of $1.00 per share. The buyer must pay this premium regardless of the eventual outcome, so for the option to pay off (a limited loss), the market price of the underlying asset must fall to the strike price minus the premium as shown in Figure 3.

![Put Option Payoffs](image)

*Figure 3. Put option payoffs*

2.1.1.5 Valuation

In comparison to other financial instruments, options are complicated to value. Both DPV and IRR fall short of valuing options accurately due to differences in cash
flow structure, probability, and timing. Valuation models such as DPV and IRR are based on the assumption that investments have cash flows similar to a bond, with fixed payments at one or more known intervals. Options models, on the other hand, account for a potentially infinite number of outcomes, each with its own probability of occurring. Moreover, as new information is known, these probabilities may change with time, which can shift the value of the option; thus, an options value is dependent on the value of the underlying asset at or before the time of expiry, which can make them notoriously difficult to value (Black & Scholes, 1973).

Black and Scholes (1973) overcame these modeling issues in their seminal paper on options pricing. The researchers devised a differential equation that incorporated a bell-shaped curve of potential outcomes and included the volatility of the investment through time. Their model greatly simplified the process for pricing options, eventually earning Black and Scholes the Nobel Prize in Economics in 1997. Even today, the Black-Scholes model provides a popular basis for options valuation models, both in theory and in practice (Read, 2012).

2.1.2 Real Options

After discovering that the structure of many corporate projects bears a closer resemblance to a financial option than to a bond, Stewart Myers of MIT coined the term “real options” to describe these investments (1977). Real options are similar to financial options in that they represent an exclusive right, but not an obligation, to invest, sell, or abandon all or part of a business project at some point future. Borrowing from the financial options taxonomy, a right to invest is commonly modeled as a call, while a right to sell is modeled as a put. The right to abandon a project emphasizes the fact that business managers often have no obligation to continue injecting capital into a failing project (Dixit & Pindyck, 1994; Lander & Pinches, 1998; Trigeorgis, 1993).
2.1.2.1 **Calls**

When a project includes a discretionary ability to continue investment or spawn new projects, it can be modeled as a real call option, that is, managers have an ability, but not an obligation, to continue to invest in the project should future outcomes be favorable. Examples of real calls are bountiful in phased R&D projects where investment rarely leads directly to cash flows but more likely results in a gain of property or knowledge that when employed in a downstream project might lead to cash flows (Hartmann & Hassan, 2006; Huchzermeier & Loch, 2001; Schwartz, 2004).

2.1.2.2 **Puts**

A real put option exists when managers have an ability to stop investing or otherwise cut losses if and when conditions are unfavorable or the project is otherwise floundering. Real put options commonly involve the ability to halt production or cash flows into the project or to abandon the project altogether. For example, when the price of a commodity drops below levels needed for profitability, production can be paused or abandoned to limit losses (Brennan & Schwartz, 1985).

2.1.3 **Use Cases**

Lander and Pinches (1998) provided a summary of the major areas where real options theory had been used to solve problems. These areas included natural resource investment, competition and corporate strategies, manufacturing, real estate, international finance and business, research and development, regulated sectors, mergers and acquisitions, general finance (interest rates), inventory management, labor force strategy, venture capital, advertising, law, and environmental conservation. While the use cases in the literature are too numerous to review each in detail, it is helpful to review a sample in order to illustrate how real options can be useful in practice. Following is a brief review of four areas of the literature—natural resources investment,
competitive strategy, patent litigation, and research and development—that demonstrate a wide range of uses for real options.

2.1.3.1 Natural Resources

Slade (2001) and Brennan and Schwartz (1985) described how real options could be used to model mining investments, as the value of a mine is dependent on the uncertain value of the minerals being extracted. Mines are only profitable when the owners can extract minerals at prices below the clearing price of the market. Because market prices fluctuate, so does the value of mining production. If prices drop below a certain threshold, minerals would be extracted at a net loss. Where other methods, such as DCF, would build in these negative cash flows into the mine’s net present value, ROA can model the stopping and restarting of the mine, avoiding some of the losses in such scenarios.

Slade (2001) argued that because real options theory can account for this flexibility, the method is a superior valuation method for mining investments, compared to the mainstay DCF method. In other words, DCF generally models a project as a single set of irreversible investments and expected cash flows, with all uncertainty summed up in the discount rate, while the real options approach makes any uncertainties more explicit and models the project with multiple stages, each with its own discount rate.

2.1.3.2 Competitive Strategy

Smit and Ankum (1993) and Trigeorgis (1991) described how real options analysis can be used to model strategic competition and preemption games. In a competitive marketplace, the option to invest in a new product or technology might not be exclusive to a single firm. In these cases, uncertainties include more than just price and cost: There could be advantages or disadvantages that affect only the first mover
(the firm that exercises the option first). Modeling these scenarios as options allows managers to understand more clearly the extent to which value is dependent upon a competitor’s action or inaction.

2.1.3.3 **Patents**

Real options can be used to model and estimate the value of holding a patent. A holder of a patent can gain cash flows from it in three ways: (a) obtain uncertain profits from products or services that use the technology described in the patent, (b) sell the patent to another firm for a known amount, and (c) pursue uncertain court judgments against others using the patented technology (Marco, 2005). Traditional capital budgeting techniques, such as the prevalent DCF method, are unable to evaluate these cash flows because the cash flows are exclusive of each other, and each has a different level of risk. For instance, a patent holder could choose to forgo the risky profit streams from using the patent by selling it for a certain amount. Estimating the value of a patent using real options can account not only for the flexibility of a patent asset, but also for the multiple levels of risk associated with each possible cash flow.

2.1.3.4 **Research and Development**

Mechlin and Berg (1980) described how ROI calculations performed using mainstream techniques such as DCF and IRR could be troublesome when applied to very uncertain and long-term projects such as those commonly found in research and development. A central point made by the authors was that relying on these quantitatively focused but often inaccurate tools for R&D decision making can lead to costly underinvestment.

Faulkner (1996) observed that valuations of R&D projects using real options were often much higher than those found through other methods. This was especially true under three conditions: when the initial R&D investment was small, compared to
the commercialization effort; when the size or frequency of resulting earnings was uncertain; or when the value of the project was highly dependent on information that would be gained at some point in the future. Faulkner (1996) provided recommendations for considering option value in such situations, including:

- creating optimistic and pessimistic scenarios for the uncertainties
- continuously monitoring uncertainties with a critical effect on project value
- identifying decisions that could be deferred until more information becomes available
- framing projects as phases of a longer-term, more strategic objective
- applying “options thinking” in general when managing R&D projects.

2.1.4 Valuation Models

A literature search yielded many use-case models specifically used for valuing real options. The bulk of those models can be summarized as belonging to one of three main strategies: differential equations, binomial lattices, and simulation (Collan, 2011; Copeland & Antikarov, 2003; Dixit & Pindyck, 1994; Lander & Pinches, 1998; Luehrman, 1998a, 1998b; Trigeorgis, 1993).

2.1.4.1 Stochastic Differential Equations

The original and perhaps most common category of real option models is the stochastic differential equation. These models use familiar equations such as Black-Scholes to simulate stochastic processes and to calculate the option value based on expected value of the entire distribution of outcomes that could occur on the option’s expiration date.

The value of a financial option can be described as a function of the underlying security’s price, trend, and volatility, along with the risk-free rate and expiration date of the option (Black & Scholes, 1973). Black and Scholes (1973) provided a partial
differential equation that calculates the risk-neutral value of an option, based on these variables. Although Black-Scholes was originally designed to value financial options, finance pioneers such as Myers (1977), Trigeorgis (1993), and Dixit and Pindyck (1994) recognized that the model could be adapted for many real options scenarios in which the primary source of uncertainty is known and the distribution of outcomes forms a bell-shaped, normal distribution.

The primary advantage of using differential equations to model real options is that the process is relatively simple to implement when modeling a single, normally distributed source of variability. As of this writing, off-the-shelf computer software such as Microsoft Excel can be used to build real options models with relatively little understanding of the differential equation itself. However, the task becomes more complicated if the distribution of outcomes is not normal or when there are multiple sources of risks, as these types of scenarios require more specialized knowledge to model (Copeland & Antikarov, 2003; Perlitz, Peske, & Schrank, 1999; Schwartz, 2004).

2.1.4.2 Binomial Lattices

Another common technique for evaluating real options in the literature is the binomial or trinomial lattice (Copeland & Antikarov, 2003; Herath & Park, 2002; Lander & Pinches, 1998). With this method, each decision (to invest, defer, grow, etc.) is shown visually along with the possible outcomes and respective probabilities and discount rates. The value of the option is calculated by discounting the probabilistic cash flows at each node back through the lattice.

A significant advantage to the lattice approach is that it provides a more intuitive process than differential equations: It allows decision makers to visually inspect each decision. Further, the mathematics involved are far less challenging. Lattices also allow for the inclusion of compound options with relative ease, as the outcome of one option
can be “fed into” another (Lander & Pinches, 1998). The major disadvantage to this method is that lattices can quickly become too large to navigate or manage effectively without specialized computer software and training.

2.1.4.3 Simulation

For modeling real options with multiple stochastic variables, a Monte Carlo simulation can often be the most practical choice. In these simulations, the sources of variability (normally distributed or not) are programmed into the model, and possible outcomes are repeatedly calculated, usually through thousands of iterations, in order to create a sample large enough for statistical analysis. Once the simulation is complete, managers can examine the distribution of means and perform further analysis to determine the sensitivity of the model to individual variables. In addition, it is possible to examine outlying cases to discern the course of simulated events that led to their occurrences.

A primary advantage of using a Monte Carlo simulation is that it has no practical limit to the number of stochastic variables (regardless of the distribution shape), the number of relationships, or the amount of options nesting that can be built into the model. While simple models can be created using common software such as Microsoft Excel, more intricate, complex models may require the use of specialized software such as @RISK, plus the associated training. The specialized knowledge required to build the complicated models is a major disadvantage of both the Monte Carlo method, as well as of real options analysis in general (Borison, 2005; Copeland & Antikarov, 2003).

2.1.5 State of Adoption

Despite the many advantages and use cases that real options analysis provides over other methods of valuing flexible projects, real options analysis does not have a
strong following with managers in practice. The limited amount of empirical research on the use of real options in practice indicates that real options is not a popular approach for valuing business projects (Block, 2007; Busby & Pitts, 1997; Hartmann & Hassan, 2006; Ryan & Ryan, 2002). Busby and Pitts (1997) found that, as of 1996, 80% of large firms in the UK did not have procedures in place to evaluate the flexibility of what could be considered a deferment option. In addition, the authors found that 86% of large UK firms provided no procedures for accounting for an ability to abandon a project; 57% had no procedures to value rescaling options; and 75% had no way to consider the effect of growth options. A decade later, Block (2007) found that about 86% of firms appearing on the Fortune 1,000 still did not make use of real options. The main reason ROA was not used in these firms was a “lack of top management support.” Nearly half of the survey respondents cited this cause.

Block (2007) finding a lack of top-management support for real options raises some further questions regarding the root cause. For instance, why are managers so reluctant to accept real options analysis in practice despite the plethora of theoretical evidence that the method is superior for many common types of projects? Could managers hold some bias that causes them to reject real options at a more fundamental level? What elements of the real world are so different from the theoretical?

Tiwana, Wang, Keil, and Ahluwalia (2007) found a potential explanation in “bounded rationality” and judgment heuristics subconsciously employed by managers. For example, if the valuation of a project is intuitively consistent, a manager’s tendency to adopt a bounded-rationality approach will lead him or her to stop searching for more information. Thus, managers are only likely to explore real options when a valuation performed using one of the conventional methods is perceived as being lower than the manager expected. The findings of Tiwana et al. (2007) imply that managers’
subjective assessments of a project may ultimately have an impact on the valuation because the managers control the search for the information that will be used.

Many researchers including Friedman and Savage (1948, 1952) and Kahneman and Tversky (1979, 1992) have found that people generally approach risky situations with the goal of maximizing utility, as opposed to maximizing wealth. Utility refers to the subjective feeling of satisfaction that results from the accumulation of wealth rather than from the amount of wealth itself. The price a person is willing to pay for a risky asset, such as an option, is a reflection of the utility the option is expected to provide from the addition of wealth and not from the wealth itself (Friedman & Savage, 1948, 1952; Kahneman & Tversky, 1979, 1992). Being human, it stands to reason that managers’ perceptions involving utility payoff would affect their subjective valuations, which in turn would affect their search for information, which in turn would affect the “objective” value (Kahneman, 2003; Tiwana et al., 2007). Therefore, an understanding of how utility is evaluated and converted into a price is needed in order to explain how utility might affect option prices. A literature review and summary on relevant utility theories follows in the next section.

2.2 Utility Theory

The concept of utility is a familiar topic in economics. Essentially, utility represents the subjective value that an individual assigns to an item, whether that item is an object, an experience, or even money, relative to all other alternatives. In the case of business investment, managers must often decide between simple, low-risk, and low-return projects or complex, high-risk, and high-return projects. There are two dominant theories in the literature that explain how people go about making these risky choice decisions: Friedman and Savage’s (1948, 1952) expected utility theory and Kahneman
2.2.1 Expected Utility Theory

Expected utility theory, pioneered by Friedman and Savage (1948, 1952) is based on the position that when evaluating situations involving risk, such as gambling, buying insurance, or making a business investment, individuals tend to make decisions based on the utility they expect to gain or lose from the possible outcomes rather than on the outcomes themselves. Prior research has shown that nearly everything, including goods, services, and money, has diminishing marginal utility such that each additional item, experience, and dollar yields less satisfaction than the one before it. In the case of money, this means that the dollars one already has in one’s pocket carry more utility per dollar than the dollars one has yet to gain.

Expected utility theory has been successfully used to explain some seemingly irrational behavior. From a purely rational, expected-value point of view, it rarely makes sense to purchase insurance when the premiums for the insurance exceed the amount of the expected loss from an adverse event. However, when expected utility is substituted for expected value, the choice makes much more sense: Insurance premiums are usually paid with money one does not already have, which carries less utility than the money or possessions one already has. Thus, even though the expected value of a loss might be lower than the insurance premium, the utility associated with the insured possessions might still be greater than the utility associated with the premium (Friedman & Savage, 1948, 1952).

An often-cited problem with expected utility theory is that it does not explain many types of human economic behavior. For instance, if the money a person already has always carries more utility than each additional dollar yet to be gained, then why...
would a person ever choose to gamble when a loss is the expected outcome? Even in a fair, 50/50 game of chance, people ought never to play, because the utility of the possible gains would always be less than what could be lost; yet it is common to see people gambling, even at much less favorable odds (Barberis, 2012; Marshall, 1910).

2.2.2 Prospect Theory

Kahneman and Tversky (1979, 1992) built on Friedman and Savage (1948, 1952) research by explaining that decisions involving risk take into account not only a comparison of the expected change in utility relative to a reference point, but also whether the situation is framed as a gain or a loss. In multiple surveys of students and faculty at various universities, the researchers found that people are risk-averse when choices are framed in terms of gains; however, they are risk-seeking when choices are framed in terms of losses. For example, in one survey, 84% of people exhibited risk aversion by preferring a certain gain of $500 to a 50/50 chance of winning $1000 or $0. However, 69% of the same respondents displayed risk-seeking behavior by preferring a 50/50 chance of losing $1,000 to a certain loss of $500. Although the expected gain or loss was the same in both scenarios ($500), the respondents were consistently risk-averse when the situation was framed as a gain and risk-seeking when the situation was framed as a loss (Kahneman & Tversky, 1979). Along a similar line of thought, researchers found that for any pair of equally sized gains and losses, the loss was always associated with more disutility than the gain was associated with utility, that is, losses hurt more than gains felt good. For example, if a person were to find a sum of money and later lose it, that person would be less happy (have less utility) than he or she would have been before the money was found (Thaler, 1999). The resulting s-shaped utility function appears with gains stemming from the reference point (usually a person’s
current state of affairs), resembling the concave shape of Friedman and Savage (1948, 1952) model and reflecting risk aversion, as shown in Figure 4.

![Prospect theory utility curve](image)

*Figure 4. Prospect theory utility curve adapted from Kahneman & Tversky (1979)*

In addition to finding a difference between human perceptions of gains and losses, Kahneman and Tversky (1979, 1992) found that people tend to overweight small probabilities, that is, people tend to act as if improbable outcomes are more likely to occur than they really are. For example, a person would be willing to pay a proportionately (premium to expected value) higher premium for an event that had a 1% chance of occurring than they would pay for an event with a 10% chance of occurring. The same pricing phenomenon would also be true for a lottery ticket.

2.3 **Questioning the Risk-Neutral Assumption**

Nearly all financial valuation techniques commonly used by businesses that were found during a search of the literature, whether it was one of the mainstays such as
discounted cash flows or internal rate of return or an options pricing model such as Black-Scholes, employed the assumption of a risk-neutral investor. Risk-neutrality means that a person is neither risk-seeking nor risk-averse. In other words, his or her decisions are not biased by the amount of uncertainty or by whether a gain or loss is at stake; only the probabilistic outcome (expected value) matters. A risk-neutral person would be indifferent between a $500 gain versus a 50/50 chance at winning $1,000 (a $500 expected value). If such a person found a sum of money and then later lost it, that person would have the same level of happiness (utility) as he or she started with. Moreover, a risk-neutral individual would be willing to pay only up to the expected value of a loss or gain no matter how likely or improbable the outcome might be.

Empirical studies performed by researchers such as Friedman and Savage (1948, 1952) and Kahneman and Tversky (1979, 1992) provided strong evidence that humans are far from risk-neutral. Given the questionable nature of the risk-neutral assumption, it is prudent to ask: What if the assumption is wrong? How far off might risk-neutral, value-maximizing prices be from those that a utility-maximizing person expects?

A search of the literature using keywords such as “real options” and “options pricing,” combined with other terms such as “risk-neutrality,” “expected utility,” and “prospect theory” produced only a few studies; however, these few important works influenced this dissertation and are discussed in the following section.

2.4 Influential Works

Some prospect theory studies have been criticized for using mostly hypothetical scenarios presented to subjects who were mostly college students rather than business professionals accustomed to dealing with risk. Additionally, the situations presented to respondents by (Kahneman & Tversky, 1979, 1992) were purely hypothetical, so respondents had nothing to truly gain or lose. Aiming to overcome such a critique, Fox,
Rogers, and Tversky (1996) added credibility to prospect theory by taking a sample from options traders, who are exposed to and have experience with risky situations on a daily basis. In addition, the research introduced a chance to win real money.

To accomplish this study, the researchers asked the options traders to determine a price at which they were willing to sell what was effectively a simple option contract. These prices were used to calculate decision weights, which are a measure of the strength of the risk bias. These weights were compared and contrasted with the decision weights found in the studies that involved students. The results indicated that options traders were indeed risk-neutral for simple scenarios where there was no room for subjective assessment. However, when probability was allowed to be subjective (as it is in the real world), the traders exhibited the same risk-averse behavior as other populations tested in prior studies.

Although Fox et al. (1996) were not directly concerned with understanding the effect of prospect theory on option prices, a side effect of their study showed that prospect theory may have an effect on option prices when there is room for subjective managerial assessment of prices, either directly or indirectly, by way of controlling the search for information. Miller and Shapira (2004) observed that these findings “ought to alert us to the potential for biases in the more complex contexts of real option identification, valuation, and exercise decisions” (p. 270).

Miller and Shapira (2004) extended this line of research by explicitly testing for evidence of prospect theory in options pricing. They hypothesized that a prospect theory utility curve ought to cause both buyers and sellers of options to price options at discounts relative to the values predicted by the risk-neutral models that were commonly seen in the literature. The researchers hypothesized that call option buyers, operating within the prospect theory domain of gains, would exhibit risk aversion by
being willing to pay a maximum price below that of the risk-neutral expected value of the option. Similarly, call option sellers were expected to show risk aversion by being willing to accept a price less than the expected value. In other words, the expectation was for call sellers (to some extent) to prefer a smaller but certain gain to a larger but uncertain one.

Miller and Shapira (2004) anticipated both buyers and sellers of call options to work within the framework of gains and risk aversion; thus, they predicted that buyers and sellers of put options would work in the framework of losses and show risk-seeking tendencies in their pricing. The researchers reasoned that put option buyers, aiming to exchange an uncertain loss for a certain one, would display risk-seeking behavior by being willing to pay only an amount less than the expected value of the loss, that is, they would prefer to keep the gamble than pay the expected value of the loss. At the same time, a put option buyer, seeking risk exposure they did not have before would show risk-seeking behavior by being willing to accept a price that was lower than the expected value of the loss they were covering.

Miller and Shapira’s (2004) research included a survey in which subjects were asked how much they would be willing to pay for various hypothetical call or put options with a 50/50 chance of paying off. The researchers then compared the prices given by the respondents with the risk-neutral expected value calculated by the normative models. The results were consistent with the hypotheses: Both buyers and sellers of both calls and puts showed a clear trend toward discounting valuations, suggesting not only that subjects had an s-shaped utility curve consistent with prospect theory, but that this utility curve was affecting the subjects’ option valuations.
2.5 Research Gap

The previous studies by Fox et al. (1996) and Miller and Shapira (2004) formed a well-defined basis for future research. However, they also left some unanswered questions. First, Fox et al. (1996) were primarily concerned with whether people with extensive experience in valuing risky prospects (options traders) exhibited the same general behavior as the rest of the population. As a result, the researchers selected only the long-call scenario, leaving the short-call, long-put, and short-put scenarios untested. Although Fox et al. (1996) provided an excellent theoretical foundation to study prospect theory effects on options pricing, they did not report their findings in terms of price nor did they provide any discussion regarding price or discount. This gap provides an opportunity for more-developed theoretical models and empirical research.

Second, Miller and Shapira (2004) directly addressed the issue of prospect theory interacting with options pricing by forming hypotheses about the options pricing, relative to normative models, for every combination of calls and puts, short and long. They reasoned, for example, that because a call option buyer perceived the final disposition as a probabilistic gain, the buyer would be risk-averse and willing to pay only a price that was less than the option’s expected value. Miller and Shapira (2004) confirmed each of their hypotheses through survey research. However, the research involved only scenarios with 50/50 odds and did not include a test to determine if the hypotheses would hold at other probabilities. Further, an important unexamined element of prospect theory was the overweighting of small probabilities. Miller and Shapira (2004) acknowledged this limitation and encouraged further investigation:

‘Future research could vary these probabilities and determine the implications for perceived option values. Of particular interest would be the differences in
willingness to pay for options with certain outcomes vs. near-certainty outcomes, and impossible outcomes vs. nearly impossible outcomes.' (p. 282)

Third, Miller and Shapira (2004) assumed that the utility function was symmetric and invertible about the origin, which, in effect, made a gain or loss of equal magnitude yield the same amount of utility or disutility. While the assumption was made for the purpose of simplifying their hypotheses and proofs, this approach ignored an important feature of prospect theory that distinguishes it from utility theories such as Friedman and Savage (1948, 1952): that losses provide more disutility than gains provide utility. As a result, Miller and Shapira (2004) could not necessarily rule out other decreasing marginal utility models, such as the Friedman-Savage model, as the cause for the discounting they observed.

This study was intended to overcome these gaps in the literature through an investigation of the effects of prospect theory on options pricing in ways previously unexplored. First, this research included both call and put options in its questionnaire to capture the duality of gains and losses in prospect theory. Second, a variety of payoff probabilities ranging from low to high were presented to research subjects in order to test for overweighting of small probabilities. Third, this research did not assume a symmetric utility function for gains and losses; thus, effects of prospect theory’s steeper disutility curve on options pricing could be examined.

2.5.1 Low Adoption Rate

There is ample evidence that despite being a mature and theoretically superior approach for valuing flexible business projects, the real options technique is not common in practice and lags far behind the almost universally accepted discounted cash flows method (Block, 2007; Busby and Pitts 1997). Tiwana et al. (2007) found that managers were unlikely to turn to real options analysis for valuing a project except
where its present value fell short of subjective valuations. This finding indicates that despite their best attempts to perform objective valuations, managers may still depend on intuition and subjectivity in valuing projects and to some extent use techniques such as discounted cash flow to quantitatively justify what they already know to be true. Put another way, subjective valuations may be the benchmark by which objective valuations are evaluated and trust is gauged. It follows then that if subjective valuations differ significantly from truly objective (risk-neutral) prices, that the subjectivity itself may be a cause for the lack of adoption of the real options technique; managers just may not believe the numbers.

Miller and Shapira (2004) confirmed that cognitive biases tend to cause managers to price options at a consistent discount relative to their risk-neutral values, at least when considering options with a 50/50 chance of paying off. Still unexplored is the question of how the discounting may be magnified, diminished, or reversed at other probabilities as prospect theory would indicate (Kahneman and Tversky (1979, 1992). The research gap identified here formed the basis for the research proposed and conducted in this dissertation.

2.6 Proposed Research Model

In order to help build new hypotheses and design this research project, a research model (Figure 5) was developed to show the expected relationship between the risk biases in prospect theory and options pricing. Because this research focused on the valuation of projects with managerial flexibility, the research model was constructed from the buyer’s point of view, although evidence indicates that it could be similar for option sellers (Copeland & Antikarov, 2003; Dixit & Pindyck, 1994; Miller & Shapira, 2004).
The research model relates the s-shaped utility curve to pricing expectations using a two-axis grid. The X-axis shows the change (gain or loss) in wealth, while the Y-axis represents the resulting utility gain or loss. The relationship between changes in wealth and changes in utility is illustrated by a prospect theory curve drawn over the matrix showing diminishing marginal utility for gains and diminishing marginal disutility for losses. Losses show a steeper slope than do gains. The curve is described by the equation $Y = U(X)$ where $Y$ is utility, $X$ is the change in wealth, and $U$ is the utility function.

An uncertain gain scenario with a value of $X_1$, and with a probability $P_1$ of occurring is shown and mapped to the utility associated with the gain $U(X_1)$, and the probability-adjusted expected value of the gain $U(P_1X_1)$. Expected utility holds that
humans will evaluate the utility of the gain first and then adjust for probability, meaning that for risk-averse individuals, the expected utility associated with the uncertain gain at $P_1U(X_1)$ will be less than the utility of gain equal to the expected value at $U(PX_1)$ (Friedman & Savage, 1948, 1952; Kahneman & Tversky, 1979).

Miller and Shapira (2004) assumed the utility curve was symmetric and invertible, so their model predicted that individuals were willing to pay an amount that equated to the utility associated with the expected utility of the uncertain gain $Y_{1A}$ (via the inverse function). As Miller and Shapira (2004) pointed out, the assumption was not critical to their hypotheses because they were looking only for discounting behavior and were not attempting to compare any behavior they found. However, this means Miller and Shapira (2004) did not necessarily show prospect theory in action; a symmetric and invertible utility curve is also consistent with other diminishing marginal utility models (Friedman & Savage, 1948).

A hallmark feature of prospect theory is that losses have a steeper utility function than gains—losses hurt more than gains feel good. This aspect of prospect theory is reflected in the research model by emphasizing the distinction between $Y_{1A}$, as hypothesized by Miller and Shapira (2004), and $Y_{1B}$, which comes as a result of measuring the disutility of the premium against prospect theory’s steeper disutility curve. The result is that larger discounts are expected for call option prices than were predicted by Miller and Shapira (2004).

Based on the research model, put options are expected to show similar price discounting behavior, with the expected utility from the loss at $P_2U(-X_2)$ linked to the hypothetical put option price at $Y_2$. The major difference for put options is that their purchase serves to limit losses. Thus, both the loss potentially avoided by the put and the put option premium are evaluated on the steeper disutility portion of prospect theory’s utility
curve. The result of this evaluation is that for any pair of call and put options with similar expected values, the call option ($Y_1A$) will be perceived to have a lower value than will the put option ($Y_2$).

### 2.7 List of Hypotheses

The following hypotheses were formed from the full research model shown in Figure 5.

#### 2.7.1 Hypothesis 1

Call option buyers will price options below their risk-neutral expected values.

Given a call option with probability $P$ of paying off an amount $X_1$ with premium of $Y_1$ or $Y_2$:

1. A risk-averse call buyer will be willing to pay an option premium that provides less disutility than the expected utility from the payoff, assuming a symmetric and invertible utility curve for gains and losses, as in Miller and Shapira (2004).

   $$-U(-Y_{1A|B}) < P_1 U(X_1)$$

2. The concavity of the utility function for gains means that expected utility of the payoff will always be less than the utility of the expected payoff, that is, utility for the payoff is evaluated first and then adjusted for probability, as opposed to evaluating the expected value first and then converting to utility (Miller & Shapira, 2004). The difference can be visualized by comparing the two values forming the inequality on the research model, as shown:

   $$P_1 U(X_1) < U(P_1 X_1)$$

3. Thus, the value associated with the expected utility from the payoff is less than the value associated with the expected value of the payoff:

   $$Y_{1A} := U^{-1}(P_1 U(X_1)) < P_1 X_1$$
4. Still assuming that the utility is symmetric and invertible, buyers will value calls at a discount (Miller & Shapira, 2004):

\[ \frac{Y_{1A}}{P_1X_1} < 1 \]

5. Expanding on Miller and Shapira’s (2004) reasoning, there will be more disutility associated with a given loss than with an equally sized gain, since the slope of utility is steeper for losses than it is for gains in prospect theory:

\[-U(-X_1) > U(X_1)\]

6. Thus, the value associated with a given amount of disutility will be less than is associated with an equal amount of utility, that is, a smaller value is placed on disutility because utility for losses is steeper than it is for gains.

\[ Y_{1B} < Y_{1A} \quad | -Y_{1B} | < Y_{1A} \]

2.7.2 **Hypothesis 2**

Put option buyers will price options below their risk-neutral expected values.

Given a put option with probability \( P \) of losing an amount \( X_1 \) with premium of \( Y_2 \):

1. A risk-averse put buyer will be willing to pay an option premium where the disutility associated with the put option premium is less than the expected disutility from the adverse outcome (Miller & Shapira, 2004).

\[ U(-Y_2) > P_2U(X_2) \]

2. The convexity of the utility function for losses means that expected disutility of the loss will always be less than the disutility of the expected loss. To put it another way, disutility for the loss is calculated first and then adjusted for probability (Miller & Shapira, 2004).

\[ -P_2U(X_2) < -U(p_2X_2) \]
2. Thus the value change associated with the expected disutility from the loss is less than the value change associated with the expected value of the loss:

\[ Y_2 := U^{-1}(P_2 U(-X_2)) < U^{-1}(-X_2) \]

This results in a discount from normative (risk-neutral) valuations:

\[ \frac{-Y_2}{P_2 X_2} < 1 \]

4. Since the value associated with the disutility of the option premium is less than the value associated with the expected utility of the gain, the option will be valued at an even greater discount than if the utility function was symmetrical for gains and losses.

\[ \frac{Y_{1A}}{P_1 X_1} < \frac{Y_{1B}}{P_1 X_1} < 1 \]

2.7.3 **Hypotheses 3**

Relative to risk-neutral expected values, call options will be priced at greater discounts than puts.

Given a pair of call and put options with equal payoffs \(X_1\) and \(X_2\), respectively, and probabilities \(P_1\) and \(P_2\), respectively:

1. The slope of the utility function is greater for gains than it is for losses.

   Thus, disutility \((-U)\) for a loss is always greater than utility \((U)\) for a gain of equal magnitude.

   \[ -U(-X_2) > U(X_1) \]

2. Given equal probabilities \((P_1 = P_2)\) and payoffs \((X_1 = X_2)\), expected disutility for a probabilistic loss will be greater than the utility for a probabilistic gain of equal magnitude:

   \[ -P_2 U(-X_2) > P_1 U(X_1) \]
3. Inverting the utility function means that a loss associated with a given amount of disutility will be smaller than the gain associated with an equal amount of utility. In general terms with \( Q \) representing a quantity of utility:

\[
-U^{-1}(-X_2) < U^{-1}(X_1)
\]

4. Put options, dealing with loss avoidance are expected to be evaluated in the domain of losses. While certain types of “naked” financial options allow an individual to gain from a put option by not being exposed to the underlying asset risk, this is not possible with real options. Within the scope of real options, a put buyer exchanges a probabilistic loss for a certain loss and seeks a premium with a disutility that is less than the expected disutility of the loss.

\[
-U(-Y_2) < -PU(X_2)
\]

5. The payoff for a call option is evaluated in the domain of gains as a quantity of expected utility while the option premium is evaluated in the domain of losses as quality of disutility. The call buyer seeks a price where expected utility exceeds the disutility:

\[
PU(X_1) > -U(-Y_1)
\]

6. The payoff from a call option is an uncertain gain. Thus, it results in less expected utility than an uncertain loss of similar magnitude. Because of this, the maximum price associated with a call option will be lower than a put option covering a loss of the expected value.

\[
-U^{-1}(-P_1 U(X_1)) < -U^{-1}(P_2 U(-X_2))
\]

7. Since the price a buyer will be willing to pay for a call is lower than that for a similar put, it can be said that calls will be priced at a greater discount relative to expected values:
2.7.4 Hypothesis 4

For testing purposes, Hypothesis 4 was split into two subhypotheses:

*Hypothesis 4A.* Call options with near-certain payoffs will be priced at larger discounts relative to calls with smaller probabilities.

*Hypothesis 4B.* Put options with near-certain payoffs will be priced at a larger discount relative to puts with smaller probabilities.

As the probability of an option’s payoff increases, so will its expected value. A risk-neutral individual would perceive a linear relationship between probability and expected utility, that is, doubling the probability of a payoff would also double expected utility. In prospect theory, however, small probabilities are overweighted (Kahneman & Tversky, 1979, 1992). This means that for a call option with a nearly certain payoff, the probability of not paying off will be perceived to be larger than it actually is. Likewise, in the case of a put option with a nearly-certain payoff, the probability of the adverse outcome not occurring is also perceived to be larger than it really is. The result in both extreme cases should be that the ratio of expected utility to expected value is lower for these options than for others with less certain payoffs (reflected as a higher discount).

2.7.5 Hypothesis 5

For testing purposes, Hypothesis 5 was split into two subhypotheses:

*Hypothesis 5A.* Call options with very low probabilities of paying off will be priced at smaller discounts relative to calls with larger probabilities.

*Hypothesis 5B.* Put options with very low probabilities of paying off will be priced at smaller discounts relative to puts with larger probabilities.

As the probability of an option’s payoff decreases, so does its expected value. A risk-neutral individual would perceive a linear relationship between probability and
expected utility. As a result, halving the probability of a payoff would also halve expected utility. Since small probabilities are overweighted in prospect theory, call options with a very low chance of paying off will be perceived to have a higher chance than they really do. Likewise, in the case of a put option with a very low chance of paying off, the probability of the adverse outcome actually occurring is also perceived to be larger than it really is (Kahneman & Tversky, 1979, 1992). The result in both extreme cases should be that the ratio of expected utility to expected value is higher for these options than for others with less certain payoffs (reflected as a higher discount or even a premium).
CHAPTER 3: RESEARCH DESIGN

This chapter begins with a description of the research method and details about the process for selecting it. Previous research in the field is explored in terms of research designs, followed by a discussion of how the current study adds to the existing body of knowledge. Next, the sample, sampling method, and research instrument are described. The chapter closes with proposals for testing the hypotheses described in Chapter 2 and a discussion of the limitations and ethical implications of this study.

3.1 Background

Miller and Shapira (2004) suggested that discounting behavior in subjective options valuations is consistent with prospect theory. However, as discussed in Chapter 2, some of their findings could also be consistent with the diminishing marginal utility curve. This research study is intended to first confirm and then to extend Miller and Shapira (2004) in two ways. First, the question of whether the steeper disutility curve associated with prospect theory manifests in pricing behavior will be examined. Second, testing for differences in behavior when the probability of an option payoff is remote will be conducted.

3.2 Research Method Selection and Design

3.2.1 Research Method

Abramson and Abramson (2008) described cross-sectional research as an assessment of the state of things at a particular point in time. Cross-sectional research, in contrast with longitudinal research, does not involve how the responses of a population or individual subjects within that population would change over time (Abramson & Abramson, 2008). This study used the cross-sectional approach primarily due to the general and non-temporal nature of utility and pricing theories, but even if
this had not been the case, constraints placed on this DBA dissertation would have made longitudinal research impractical.

### 3.2.2 Design Process

Tull and Hawkins (1993) provided a model for designing the research process, summarized as follows:

1. Define the research problem.
2. Identify relevant bodies of knowledge and form hypotheses.
3. Select a measurement instrument capable of providing the data necessary to test the hypotheses.
4. Identify and collect an appropriate sample.
5. Identify and select an appropriate analysis technique.
6. Ensure time and financial restraints are reasonable.

This project’s research problem and a summary of existing knowledge on how prospect theory affects real options valuation are provided in Chapter 2. This chapter focuses on the remaining research design steps recommended by Tull and Hawkins (1993).

### 3.2.3 Research Instrument

The dominant data collection instrument used in the related economics literature has been the questionnaire (Friedman & Savage, 1948, 1952; Kahneman & Tversky, 1979, 1992; Miller & Shapira, 2004). Experimental and exploratory research conducted with questionnaires is advantageous because it allows the formation of correlation and causal links backed by statistical significance. In essence, economics researchers can use survey and questionnaire research to make general conclusions about how people would act, given a change to their available choices or environment (Baker, 2002).
The primary advantage of survey research is that it provides the social researcher a way to collect standardized, quantitative data about subjects without having to rely on his or her own senses and perspective, which can often lead to biased or inaccurate results (Jick, 1979). Survey research is, however, subject to bias from the researcher in the way he or she interacts with the subject, in the wording of the questionnaire and/or instructions, and even in the topic itself. Podsakoff, MacKenzie, Lee, and Podsakoff (2003) discussed the five stages of questionnaire response along with the activities and biases that can occur at each stage (Table 1).
Table 1

**Biases by Response Stage**

<table>
<thead>
<tr>
<th>Stage of the response process</th>
<th>Activities involved in each stage</th>
<th>Potential method biases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehension</td>
<td>Attend to questions and instructions, represent logical form of question, identify information sought, and link key terms to relevant concepts</td>
<td>Item ambiguity</td>
</tr>
<tr>
<td>Retrieval</td>
<td>Generate retrieval strategy and cues, retrieve specific and generic memories, and fill in the missing details</td>
<td>Measurement context, question context, item embeddedness, item intermixing, scale size, priming effects, transient mood states, and item social desirability</td>
</tr>
<tr>
<td>Judgment</td>
<td>Assess completeness and accuracy of memories, draw inferences based on accessibility, inferences that fill in gaps of what is recalled, integrate material retrieved, and make estimate based on partial retrieval</td>
<td>Consistency motif (when it is an attempt to increase accuracy in the face of uncertainty), implicit theories, priming effects, item demand characteristics, and item context-induced mood states</td>
</tr>
<tr>
<td>Response selection</td>
<td>Map judgment onto response category</td>
<td>Common scale anchors and formats and item context-induced anchoring effects</td>
</tr>
<tr>
<td>Response reporting</td>
<td>Editing response for consistency, acceptability, or other criteria</td>
<td>Consistency motif (when it is an attempt to appear rational), leniency bias, acquiescence bias, demand characteristics, and social desirability</td>
</tr>
</tbody>
</table>

Note: Adapted from Podsakoff et al. (2003)

With the goal of extending the work pioneered by Miller and Shapira (2004) and others, a questionnaire format similar to those used by these researchers was chosen as the research instrument. While similar in presentation format, several changes were made to the way independent variable values were generated. Details on the sample and the design of the questionnaire follow.
3.2.4 Sample and Sampling

A questionnaire with six hypothetical options pricing scenarios was distributed to about 320 business school students enrolled at The University of Newcastle, Australia. The decision to collect a sample from students at The University of Newcastle was driven by time and financial constraints, as well as by a desire to be consistent with prior research, such as that of Kahneman and Tversky (1979, 1992) and Miller and Shapira (2004), who surveyed 95 and 67 students, respectively. Splitting the difference in sample size, the goal of this research was to collect responses from about 80 individuals, providing a total sample of 240 call valuations and 240 put valuations. This number of responses was anticipated to be enough to estimate the population means with 95% confidence with a ±7% margin of error.

Kaplowitz, Hadlock, and Levine (2004) estimated the response rates for various questionnaire distribution modes. Invitations via physical mail had the highest response rate (about 31%), while e-mail had the lowest response rate (about 21%). However, by these researchers’ estimates, e-mail was more than 8 times more cost effective, which makes it an attractive method provided that enough respondents are invited. Additionally, the response rate for all types of distributions was increased when an incentive was provided.

In order to strike a balance between cost and research effectiveness, questionnaires for this research were distributed by e-mail and in some cases promoted by professors and other staff who agreed to hand out a printed flyer. The e-mail and physical flyers were identical in content (see Appendix B). Recipients of the invitation, regardless of format, were asked to visit a customized Internet URL to access the electronic questionnaire. In order to maximize response rates, a random drawing was offered for an Apple iPad Mini valued at AU $349.
3.3 Questionnaire Design

To ensure that respondents comprehended the questions, a primer on options theory and vocabulary was provided prior to presenting any questions (see Appendix C). Additionally, questions were presented in a consistent format and were limited to options terminology covered in the instructions. As Podsakoff et al. (2003) explained, the retrieval and judgment stages of the questionnaire response process depend heavily on the context and clarity of the questions and identification of benchmarks. For this reason, both net worth and a time horizon were provided, which were intended to give context and scale to the risks and rewards associated with each option presented for pricing.

In order to avoid biases dealing with scale and consistency in the response selection and reporting stages, the questionnaire used in this research adhered to Miller and Shapira (2004) strategy. Respondents were asked to price the option rather than to provide a preference between two or more options, as was sometimes done in other prospect theory research (Fiegenbaum & Thomas, 1988; Kahneman & Tversky, 1979).

The research questionnaire was divided into two sections. The first section collected respondents’ demographic information, including age, gender, work experience, and status in school. The second section provided hypothetical options pricing scenarios, in which respondents were asked to value three call options and three put options. The three call options were presented in the following format:

\[
\text{Suppose that your net worth totals } W. \text{ You are presented with an opportunity to buy a call option that has a } P_1 \text{ percent chance to be worth } X_1, \text{ and a } P_{1B} \text{ percent chance to be worth } 0 \text{ by the end of the day. For this option, I would be willing to pay: } Y_1
\]

Three questions involving put options were presented as follows:
Suppose that you own an investment portfolio totaling $W, representing most of your net worth. By the end of the day, the portfolio has a $P_1$ percent chance to retain its current value and a $P_2$ percent chance to lose $X_2$. You are offered the chance to buy a put option on your portfolio which would limit your losses to zero. For the option to transfer the day’s outcome to someone else (insuring against any loss), I would be willing to pay: $Y_2$

In order to collect a sample with a wide variety of payoff (or loss) probabilities, the questionnaire was programmed to produce random values within certain bounds. A summary of the variables used in the research model, hypotheses, data collection, and analyses is shown in Table 2.
### Table 2

**Research Variables**

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Type and Bounds</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W$</td>
<td>Independent, Fixed $W = $100,000$</td>
<td>Net worth, intended to provide context and scale to the gains and losses presented.</td>
</tr>
<tr>
<td>$P_1$</td>
<td>Independent, Random $0.05 \leq P_1 \leq 0.95$ Stepping: 0.15</td>
<td>Probability of call option payoff. Varies randomly between 5% and 95% at 15% increments (5%, 20%, 35%).</td>
</tr>
<tr>
<td>$P_{1B}$</td>
<td>Independent, Random $P_{1B} = 1 - P_1$</td>
<td>Probability of call option not paying off. This was whatever quantity was needed to make total probability equal to 1.</td>
</tr>
<tr>
<td>$X_1$</td>
<td>Independent, Random $10,000 \leq X_1 \leq 100,000$ Stepping: 10,000</td>
<td>The sum that will be gained if the call option paid off. This varies randomly between $10,000 and $100,000 at $10,000 increments.</td>
</tr>
<tr>
<td>$Y_1$</td>
<td>Dependent, input $0 &lt; Y_1 &gt; X_1$ Whole number</td>
<td>The amount the respondent reports he or she is willing to pay for the call option. $Y_{1A}$ is compatible with Miller and Shapira (2004) symmetrical and invertible simplification whereas $Y_{1B}$ is consistent with prospect theory in Kahneman and Tversky (1979, 1992).</td>
</tr>
<tr>
<td>$P_2$</td>
<td>Random $0.05 \leq P_2 \leq 0.95$ Stepping: 0.15</td>
<td>Probability of loss occurring (put option payoff). Varies randomly between 5% and 95% at 15% increments (5%, 20%, 35%).</td>
</tr>
<tr>
<td>$P_{2B}$</td>
<td>Random $P_{2B} = 1 - P_2$</td>
<td>Probability of put option not paying off. This was whatever quantity was needed to make total probability equal to 1.</td>
</tr>
<tr>
<td>$X_2$</td>
<td>Random $10,000 \leq X_2 \leq 100,000$ Stepping: 10,000</td>
<td>The loss that will be avoided if the call option pays off. This varies randomly between $10,000 and $100,000 at $10,000 increments.</td>
</tr>
<tr>
<td>$Y_2$</td>
<td>Dependent, input $0 &lt; Y_2 &gt; X_2$ Whole number</td>
<td>The amount the respondent reports he or she is willing to pay for the put option.</td>
</tr>
</tbody>
</table>
As the respondents completed each question, the values for all variables generated, as well as the text displayed to the respondent and his or her response, were recorded in a database. In order to link responses from the same subject while maintaining privacy, a unique but non-identifying Internet session identifier (SID) was used as a grouping variable.

The variable requirements, logic, and overall design of the questionnaire were beyond the capabilities of commonly used affordable questionnaire tools. For instance, email addresses collected for the purpose of a prize draw could not be separated from the rest of the data which could cause privacy concerns that would have delayed or prevented the approval of this research by The University of Newcastle’s Human Research Ethics Committee (HREC). As a result, a custom web application was built using Microsoft Active Server Pages (ASP) and Microsoft Visual Studio Web Express. The visual portion of the survey are provided in Appendices C, D, E, and F while the source code and variable logic follows in Appendix G.

3.4 Analysis Techniques and Hypotheses Testing

The general goal of the analyses performed in this project was to discern patterns in the data in order to show an acceptable level of confidence that the hypotheses were true. All tests involved comparing the statistical means in one group to those of another group or to a known value. Differences were considered statistically significant in this project only when $p$ values for equality of means tests were less than the commonly used threshold of .05.

The following hypotheses tests were devised using the research model shown in Figure 5.
3.4.1 Hypothesis 1

Call option buyers will price options below their risk-neutral expected values. This hypothesis was confirmed if the lower bound of the 95% confidence interval for the mean discount on call options with nonextreme probabilities (.05 < P < .95) was greater than zero, that is, that there was less than a 5% chance for the true mean discount on call options to be zero or negative.

\[
\frac{Y_{1A}}{P_1X_1} < \frac{Y_{1B}}{P_1X_1} < 1
\]

3.4.2 Hypothesis 2

Put option buyers will price options below their risk-neutral expected values. The hypothesis was confirmed if the lower bound of the 95% confidence interval for the mean discount on put options with nonextreme probabilities (.05 < P < .95) was greater than zero, that is, that there was less than a 5% chance for the true mean discount on put options to be zero or negative.

\[
\frac{-Y_2}{P_2X_2} < 1
\]

3.4.3 Hypothesis 3

Relative to risk-neutral expected values, call options will be priced at greater discounts than puts. This hypothesis was tested by comparing the means discounts of call to puts. If the mean discount for calls was significantly (p < .05) larger than the mean discount for puts, then the hypothesis was confirmed.

\[
1 - \frac{-U^{-1}(P_1U(X_1))}{P_1X_1} > 1 - \frac{-U^{-1}(P_2U(-X_2))}{P_2X_2}
\]

3.4.4 Hypothesis 4

Options with a very high chance of payoffs will be priced with comparatively larger discounts relative to those with smaller probabilities.
Hypothesis 4A. Call options with near-certain payoffs will be priced with comparatively larger discounts relative to calls with smaller probabilities.

Hypothesis 4B. Put options with near-certain payoffs will be priced with comparatively larger discounts relative to puts with smaller probabilities.

All else being equal, as the probability of an option’s payoff increases, so does its expected value. A risk-neutral individual would perceive a linear relationship between probability and expected utility, that is, doubling the probability of a payoff would also double expected utility. However, in prospect theory, both large and small probabilities are overweighted (Kahneman & Tversky, 1979, 1992). This means that for a call option with a nearly certain payoff, the probability of not paying off is perceived to be larger than it actually is, as people fear the small chance that the options will not pay off.

Likewise, in the case of a put option with a near-certain payoff, the probability of the loss outcome not occurring is also perceived to be larger than it really is. The result in both extreme cases should be that the ratio of expected utility to expected value is lower for these options than for others with less certain payoffs (reflected as a higher discount).

For the purposes of creating groups for comparison, cut points were made in the data at 5% and 95% chance for payoff to distinguish between “small” and “nonsmall” probabilities respectively. Options in the 5% group were considered low probability, those in the 95% group were considered high probability, and those in between were considered to have nonsmall probabilities.

Call options in the high probability group were hypothesized to exhibit the certainty effect (Kahneman and Tversky, 1992) by being priced at a greater discount, as people attempted to compensate for the larger-than-actual chance of disappointment.
Put options in the high probability group were also hypothesized to exhibit the certainty effect through greater discounts as people perceived the small chance of a negative outcome not occurring to be greater than it really was and adjusted the price as a result.

Hypotheses 4A and 4B were confirmed by testing the data for a statically significant ($p < .05$) negative difference in discounting between the high-probability and nonsmall probability group for calls and puts, respectively.

### 3.4.5 Hypothesis 5

Options with very unlikely payoffs will be priced with comparatively smaller discounts (or even a premium) relative to those with smaller probabilities.

*Hypothesis 5A.* Call options with very low probabilities of paying off will be priced at a premium relative to calls with larger probabilities.

*Hypothesis 5B.* Put options with very low probabilities of paying off will be priced at a premium relative to puts with larger probabilities.

According to prospect theory, the chance of a low probability event occurring may be overweighted when an option is evaluated in terms of utility (Kahneman & Tversky, 1979, 1992). This means that call options with low probabilities of paying off will be perceived to have a larger chance to pay off than actually exists, which should cause subjects to price the option higher than they otherwise would have. Likewise, in the case of a put option with a low probability of a loss to avoid, the probability of the adverse outcome occurring is overweighted, so that the likelihood of the event occurring is larger in the mind of the subject than it really is. This causes the person to price the option higher than he or she would have otherwise.

In a similar fashion to that detailed in Hypotheses 4A and 4B, the data were grouped by probability, with small probabilities of 5% and 95% separated into low
probability and high probability groups, respectively, while the rest of the data were considered part of the nonsmall probability group.

To confirm Hypothesis 5, the data were tested for a statistically significant ($p < .05$) negative difference in discounting between the low-probability and nonsmall probability groups. If the options in the small-probability group were priced at premium (or smaller discount) relative to the options in the nonsmall probability group, then the hypothesis was confirmed.

3.5 Reliability

Reliable experimental measures are those that produce consistent results when repeated; it is only considered reliable if it produces similar results under similar conditions (Bryman & Bell, 2007). Although there is no direct way to measure reliability, it can be estimated using the following four general constructs adapted from Hair, Babin, Money, and Samouel (2003):

- Inter-rater/observer – The extent to which different respondents or observers provide consistent answers
- Test-retest – The ability of a measure to get consistent results from a single respondent or observer when retested later
- Parallel-forms – The ability for two or more test instruments to consistently measure the same construct
- Internal consistency – The consistency of results across multiple items in a test that are designed to measure the same construct

A primary goal of this research was to identify trends in human pricing of options values. As the same questions were presented to different subjects, any trend found has by definition high inter-rater/observer reliability. However, due to time and resource limitations, only one test instrument was conceived, and no retesting was performed.
Internal consistency can be measured using Cronbach’s alpha, which tests correlations between data sets that are expected to be related. A high alpha score ($\alpha > .7$) indicates high intra-item correlations and is indicative of high internal consistency and reliability (Hair, Anderson, Tatman, & Black, 1998). The internal consistency and reliability of this research was estimated by evaluating Cronbach’s alpha using respondents’ valuations and expected (normative model) values as inputs. Although discounting behavior was expected as part of the hypothesis, a general correlation between these two variables was expected, even if the relationship was not linear.

3.6 Validity

Validity involves the applicability of scientific research to the precise circumstances of a study, as well as to other situations to which the research might be applied. Validity can be categorized as internal or external. Internal validity refers to the extent to which conclusions reached as part of the research process were well reasoned and warranted. A common threat to the internal validity of human research is observation bias: Respondents may behave differently knowing they are being observed in a hypothetical situation, compared to how they would behave if the situation were real or if they were not being observed. Additionally, research design issues that might influence responses or cause subjects to become confused might lead to research instruments measuring something other than what was intended, which would also weaken validity (Bryman & Bell, 2007).

Similarly, external validity refers to the extent that conclusions are applicable outside of the specific circumstances of the research (Hair et al., 2003). Threats to external validity include biases and research design issues. In particular, a sampling bias can occur when differences exist between the sample and the population the sample is supposed to represent (Hair et al., 1998). For example, this dissertation research was
conducted using business school students from one particular university, presenting a risk that any relationships discovered may not exist in some or all of the general population of business decision makers. However, this risk was mitigated to the extent that the research findings were consistent with similar studies and with economic theory generated from outside of the University of Newcastle, such as Fox et al. (1996), Kahneman and Tversky (1979), and Miller and Shapira (2004). Threats to internal and external validity were considered thoroughly in the research design. For example, making the survey responses anonymous help to ensure that respondents would not need to worry that somebody might judge them by their choices. Further description of protections for internal and external validity described in the sampling and questionnaire design sections of this chapter.

3.7 Ethical Considerations

As required by The University of Newcastle HREC, the ethical implications of this research were considered throughout the design and execution of this research. Safeguards to ensure voluntary cooperation and privacy were implemented at every stage of interaction with participants. Safeguards for voluntary cooperation, privacy, data retention, and other regulatory requirements are described in the questionnaire design section of this chapter as well as in the presentation of the result in Chapter 4.

The researchers on this project certify that the research was executed in a manner consistent with that described in the HREC protocol number H-2013-0255 (see Appendix D).
CHAPTER 4: RESULTS

This chapter provides the results of the analyses of the data. The chapter begins with a general and demographical description of the sample and concludes with the results of the hypotheses tests.

4.1 Ethical and Regulatory Safeguards

Prior to being presented with the electronic questionnaire, each respondent was required to review and agree to a statement providing him or her with information on why the research was being conducted, explaining who it was being conducted by, and giving assurances that participation was voluntary (see Appendix E). Additionally, participants who elected to participate in the optional iPad Mini drawing were asked to agree to the terms of the drawing (see Appendix F) and provide a University of Newcastle e-mail address, which was used for the sole purpose of notifying the winner.

Care was taken during data collection to keep participation anonymous and to make it impossible to link responses back to individuals. No personal information, such as names, phone numbers, or identification numbers, were collected at any point during the survey. Although e-mail addresses were provided by some participants for prize-notification purposes, the data were stored in a separate data table without an index or timestamp, making it impossible to link e-mail addresses to responses.

The University of Newcastle, Australia, requires that data used for student assessment purposes be retained for a minimum of 12 months following the conclusion of the research project. With the exception of the e-mail address table, which was permanently deleted immediately after a winner for the drawing was confirmed, copies of the raw and final data sets were stored in an encrypted format on CD-ROM as well as archived to Amazon Web Services Glacier backup system for long-term storage. The procedures used in the research were consistent with the research proposal submitted to
and approved by the Human Research Ethics Committee (HREC) at The University of Newcastle, Australia (protocol number H-2013-0255).

4.2 Response to Survey

Approximately 320 business school students were contacted via various methods, including e-mail or in-classroom invitations, to participate in the electronic survey. In total, 67 individuals completed the survey, resulting in a response rate of about 21%, somewhat short of the target 25% response rate.

4.3 Preparation for Analysis

4.3.1 Amendments to the Data

Before performing any analysis, the data were checked for spurious responses that might indicate that the respondent did not understand what was expected or that he or she may have hurried through the survey in order to enter the contest for the iPad mini. Except where otherwise noted, each exclusion of a respondent corresponded to six valuations.

The data from four respondents were removed from the data because the answers provided were identical or very similar for very different scenarios. This indicated these individuals may not have understood the instructions or provided answers just to advance the survey.

One respondent was removed because the answers provided were very low yet very precise, given the scale of the numbers provided, which indicated the respondent might not have understood the question or may have entered answers on a different scale. For example, this respondent reported that she would pay only $1 and $12 for call options theoretically worth $3,500 and $26,000, respectively.

One respondent was removed for reporting that he was not part of the faculty or student body at any University of Newcastle campus. This person may have received a
shared link to the electronic survey from another person or found it through a search engine.

In addition to excluding some respondents from the date entirely, 21 individual valuations were removed because the price that the respondent reported that he or she was willing to pay exceeded the potential payoff or loss associated with the option. In these cases, it was assumed that the respondent simply made an error on an individual item; his or her responses to other items were left in the data set.

The amended data set contained a total of 344 responses from 61 subjects.

### 4.3.2 Formation of the Discount Variable

The most important dependent variable to this research was the discount (or premium) that respondent placed on options prices relative to risk-neutral expected values. Simple formulae were used to calculate two new variables, $D_{\text{CALL}}$ and $D_{\text{PUT}}$, to represent the discount (or premium) for call and put options, respectively:

$$D_{\text{CALL}} = \frac{Y_1}{P_1 \ast X_1}$$

$$D_{\text{PUT}} = \frac{Y_2}{P_2 \ast X_2}$$

The term *discount* refers to a result where subjective values are expected to fall below risk-neutral expected values. If a subjective value is above the expected value for the option, the discount will be negative, indicating a premium to the risk-neutral expected value.

In order to simplify coding and analysis procedures, the discount was entered into the SPSS database as a single calculated variable because call and put options could be arranged in a separate column with each entry labeled as either a call or a put.
4.4 Results of Reliability Testing

In order to provide reassurance that this study was reliably measuring the construct of option value, Cronbach’s alpha was calculated using intra-item correlation between the normative, expected values of the option and those provided by survey respondents. Although the hypotheses expected some deviation between the two variables, it was not expected to be so strong as to prevent a correlation from being detected. Cronbach’s alpha was calculated using SPSS statistics software, with a result of .762, which exceeded the .7 target set in the research design. Therefore, the data collection and results were as reliable as could be measured.

4.5 Results of Hypothesis Testing

Each of the hypotheses were tested using the methods specified in the original research plan using statistical software package SPSS with the raw output from all analyses available in Appendix H. Table 3 summarizes the general results of the hypotheses testing and a detailed description of the test and rationale for each result follows.

A key dependent variable in the hypothesis testing was the discount, which reflects the percentage difference between the risk-neutral, expected value of the option and the price survey respondents reported that they were willing to pay. Positive discounts, which are reported without a sign, indicate a price lower than the option’s expected value, while a negative discounts are reported using the minus (-) symbol, reflect a price higher than the option’s expected value. Where hypotheses involved testing the difference between two mean discounts, such as that between calls and puts, results are always reported with a sign; the plus (+) symbol to indicates a positive difference the first and second variable (VAR₁ - VAR₂ > 0) and the minus (-) symbol
indicates a negative difference between the first and second variable \((\text{VAR}_2 - \text{VAR}_1 < 0)\).

Table 3

_Hypotheses Testing Summary_

<table>
<thead>
<tr>
<th>Hypothesis Number</th>
<th>Summary</th>
<th>Mean Discount or Difference</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>Discounting of call options with non-extreme probabilities</td>
<td>62.65%*</td>
<td>Confirmed</td>
</tr>
<tr>
<td>H2</td>
<td>Discounting of put options with non-extreme probabilities</td>
<td>25.82%*</td>
<td>Confirmed</td>
</tr>
<tr>
<td>H3</td>
<td>Call options priced at higher discount than put options</td>
<td>36.83%*</td>
<td>Confirmed</td>
</tr>
<tr>
<td>H4A</td>
<td>High probability-to-pay-off call options discounted more</td>
<td>-8.60%</td>
<td>Rejected</td>
</tr>
<tr>
<td>H4B</td>
<td>High probability-to-pay-off put options discounted more</td>
<td>38.09%*</td>
<td>Confirmed</td>
</tr>
<tr>
<td>H5A</td>
<td>Low probability-to-pay-off call options discounted less</td>
<td>-101.83%**</td>
<td>Confirmed</td>
</tr>
<tr>
<td>H5B</td>
<td>Low probability-to-pay-off put options discounted less</td>
<td>-139.38%**</td>
<td>Confirmed</td>
</tr>
</tbody>
</table>

*Denotes statistical significance at the \(p < .05\) level
**Denotes statistical significance at the \(p < .10\) level

4.5.1 _Hypothesis 1_

Hypothesis 1 was an expectation that call options with nonextreme probabilities \((.05 < P_i < .95)\) would be priced at a discount relative to expected value. In other words, the discount observed was neither zero nor negative (which would represent a premium). Testing this hypothesis was accomplished by constructing a 95% confidence interval for the mean discount observed and then determining if zero or any negative values existed within the confidence interval. The sample mean for discounts with call probabilities between .05 and .95, exclusively, was 62.65\%, with a 95% confidence
interval for the population mean of 53.14% to 72.17%, confirming the hypothesis. A relatively large (compared to the mean) standard deviation of 53.75% reflects the large variety of call payoffs and probabilities presented as well as a diverse set of risk preferences brought by the respondents.

4.5.2 Hypothesis 2

Hypothesis 2 was a prediction that put options with nonextreme probability (.05 < \( P < .95 \)) would also be priced at a discount relative to expected value. Testing this hypothesis was completed by constructing a 95% confidence interval for the mean discount observed for these put options and then determining if zero or any negative values existed within the confidence interval. The sample mean for discounts with probabilities between .05 and .95 exclusively was 25.82%, with a 95% confidence interval for the population mean of 11.72% to 39.92%, confirming the hypothesis. As with Hypothesis 1, a relatively large standard deviation of 79.31% may reflect the large variety of inputs and risk preferences.

4.5.3 Hypothesis 3

Hypothesis 3 predicted that call options would be priced at a greater discount than puts. This was tested by performing an independent samples t-test comparing the mean discount observed of calls and puts, producing a likelihood that the two means are the same. The test produced a statistically significant mean difference of +36.83% for calls with a 95% confidence interval for the mean difference between +19.90% and +53.77%; \( t(216.086) = 4.287, p = .000 \). Since call options were found to have greater discounts (relative to risk neutral expected values) than put options, Hypothesis 3 is confirmed.

It is of importance to note that that equal variances were not assumed in this test due to a statistically significant \((p < .05)\) result on Levene’s test for equality of
variances, that is, the variance for discount was different for call options than it was for put options.

### 4.5.4 Hypothesis 4

Hypothesis 4 stated that because small probabilities are overweighted in prospect theory, participants ought to price options with a near-certain probability of payoff at larger discounts than they would for options with less-certain probabilities, that is, respondents were expected to perceive the small chance of not paying off to be larger than it really was and price the option lower as a result. Hypothesis 4 was separated into 4A and 4B for call and put options, respectively, primarily so that each type of option could be tested independently. Each was tested by performing an independent samples equality of means test.

The independent samples test for Hypothesis 4A, that calls which are nearly certain to pay off would be discounted relatively more than other calls, did not find a statistically significant difference of means; \( t(145), p = .472 \). The finding was a mean difference of \(-8.60\%\) for call options with near-certain payoffs with a 95% confidence interval of \(-32.13\%\) to \(+14.95\%\). There was no significant difference in variance between the options with near-certain probabilities and those without (Levene’s test, \( p > .05 \)), so equal variances were assumed in the means test. Because the null hypothesis that there the two means are the same cannot be rejected, the hypothesis that the means are different is rejected.

The means test for Hypotheses 4B, that puts which were nearly certain to avoid losses would be discounted more relative to other puts, found a statistically significant, \(+38.09\%\) mean difference for discount for these put options; \( t(104.483)=4.025, p = .000 \). The 95% confidence interval for the difference was with a confidence interval of \(+19.39\%\) to \(+56.86\%\). Equality of variances was not assumed for this test because
Levene’s test for equal variances was significant ($p < .05$). Since mean difference was positive and statistically significant, Hypothesis 4B is confirmed.

### 4.5.5 Hypothesis 5

Hypothesis 5 posited that overweighting of small probabilities (according to prospect theory) should result in options with small probabilities of paying off being priced at a premium, compared to options with other probabilities. Hypothesis 5 was separated into 5A and 5B for call and put options, respectively, to test each with an independent samples equality of means test.

The statistical test for Hypothesis 5A, that call options with small probabilities of paying off would be priced relatively higher than others, resulted with an expected negative difference in mean discount. The mean difference was $-101.83\%$ with a 95% confidence interval of $-200.07\%$ to $+3.60\%$, without assuming equal variances (Levene’s test, $p < .05$). Although the significance was higher than the .05 threshold set before the analyses began, there is still a 94% probability that calls with a small probability of paying off were priced at a premium to other calls; $t(25.446) = 1.988, p = .058$. Additionally the boxplot in Figure 6 visualizes the tendency for respondents to price options with small (.05) probabilities of paying off at a premium (negative discount). The interquartile range (IQR) for options with a 5% chance of paying off extends much farther into negative territory than for the call options with other probabilities and several outliers can be seen indicating that, in some cases, respondents were willing to pay several times the options expected value.
The statistical test for Hypothesis 5B, that put options with small probabilities of paying off will be priced at a relative premium, resulted in an expected negative mean difference. Put options with small (.05) probabilities of paying off were priced at a premium relative to call options with greater probabilities. The mean difference was $-139.38\%$ with a 95% confidence interval of $-306.11\%$ to $+27.35\%$ without assuming equal variances, because Levene’s test indicated unequal variances; $t(18.293), p = .096$. Although once again the significance ($p$) value of .096 was higher than the .05 threshold, the boxplot in Figure 7 shows the tendency for puts with a small probability of paying off to be priced at a premium. The pattern is strikingly similar to that observed in the test for Hypothesis 5A, with the IQR and several outliers extending far into negative territory, indicating that respondents were willing to pay larger and in some cases, extreme, premiums for put options with small probabilities.

*Figure 6. Discount versus probability for call options*
Figure 7. Discount versus probability for puts
CHAPTER 5: DISCUSSION

The research questions which drive this project revolve around understanding the role of the utility function in options pricing as well as questioning whether or not the risk-neutral assumption is a realistic choice for real options modeling. This chapter provides a discussion on the answers to the research questions, the implications of the findings on real options theory and practice, and the limitations, recommendations, and opportunities for future research.

5.1 Evidence of Prospect Theory in Options Pricing

Consistent with the earlier conclusions of Miller and Shapira (2004), this research showed that individuals priced both calls and puts at a discount. This behavior was expected and can be explained by prospect theory’s uniquely shaped utility curve. Within the domain of gains, participants acting as option buyers exhibited risk aversion by reliably showing willingness to pay a maximum amount that was lower than the risk-neutral expected value. This finding is consistent with both prospect theory and other utility theories, such as Friedman-Savage (1948, 1952), where wealth provides decreasing marginal utility—each additional dollar gained provides individuals slightly less utility than the one before it. These decreasing marginal utility models manifest as risk aversion when humans are faced with risky situations, such as when considering a call option, where one must give up wealth that he or she already has in exchange for a chance at a gain. In other words, utility-heavy money that a person already has must be given up for the chance to gain money that is lighter on utility. Thus, for a lottery situation such as a call option to be attractive in terms of utility, the payoff will need to be comparatively large in monetary terms, resulting in pricing that is discounted relative to what it would have been if all money yielded the same utility.
In addition, as expected according to the hypotheses, subjects in this study exhibited the expected risk-seeking behavior in the domain of losses by consistently being willing to pay put option premiums that were below risk-neutral expected values. This finding is consistent with both prospect theory and other expected utility hypotheses where the utility curve for gains and losses is symmetric and invertible about the axis in a way similar to that assumed by Miller and Shapira (2004). In these utility models, disutility associated with monetary losses behaves in a similar fashion as utility does for gains with decreasing marginal disutility for losses, that is, the first few dollars lost result in proportionately greater utility loss than the next few, and so on.

With the first two hypotheses confirmed, the research findings at this point were essentially the same as those found by Miller and Shapira (2004). The findings support the theory that buyers of call and put options will bid at prices discounted relative to risk-neutral expected values, and that this behavior is the result of the risk biases explained by prospect theory. However, if prospect theory is truly at the root of this pricing behavior, then other hallmark characteristics of prospect theory should also be evident. In particular, this research hypothesized a steeper disutility curve and an overweighting of small probabilities, properties of prospect theory that should have a noticeable effect on options pricing behavior.

A distinctive characteristic of prospect theory is the notion that losses relative to the reference point will create more disutility than a gain of equal proportion will create utility. This feature was hypothesized to appear when research participants priced call options at a greater discount than they priced put options. This discrepancy occurred because the option premium was evaluated on the steeper losses curve, while payoffs were assessed on the shallower gains curve. The results of this research strongly
supported this hypothesis: The results showed a 95% probability that calls would be priced at least 19% higher than puts, with a mean difference of more than 38%.

Another hallmark feature of prospect theory is the concept that humans will overweight small probabilities for both good and bad outcomes. This helps to explain how the same individual can be comfortable with buying disaster insurance on his or her home and at the same time buy tickets to a lottery or raffle. In situations where the likelihood of an insured loss or lottery payoff is very small, people tend to perceive the probability of a payoff to be larger than it is; they either fear the worst or hope for the best in these circumstances (Kahneman & Tversky, 1979). Hypotheses H4 and H5 predicted that this cognitive bias would affect options pricing in such a way that options with small probabilities of paying off would be priced at a premium compared to options with larger probabilities (see H4A, H4B, H5A, and H5B).

In cases where respondents had the opportunity to buy call options that were very unlikely to pay off, the results showed a strong tendency for these to be priced at a smaller discount, and, in many cases, at a premium relative to risk-neutral value. Call options with less than a 5% chance of paying off were priced at an average premium to expected value of 39%, in sharp contrast to call options with more central odds of paying off (greater than 5%, but less than 95%) which were priced at an average discount to expected value of 62.65%.

Similarly, put options with a less than 5% chance of paying off were priced at an average premium to expected value of 113.56% compared to put options with more central probabilities being priced at an average discount to expected value of 25.92%. It is interesting to note that the relative relationship between call and put options discounting described earlier was maintained even for these small probability options, in which the call options were assigned a smaller premium than put options.
On the other side of the probability spectrum were call and put options that were very likely to pay off. Research subjects priced put options in this category at an average 63.91% discount to expected value, while other options with more moderate probabilities (greater than 5% and less than 95% chance of payoff) were discounted more shallowly at 25.82%. This result is consistent with prospect theory. The hypothesis that the small probability of not paying off would be overweighted in the minds of the subjects and would lead to the option being perceived as less valuable.

The only hypothesis that did not return expected results involved call options with a high probability of paying off. Hypothesis 4A predicted these call options would be priced at a smaller discount than other calls, but no significant difference or pricing signal was found. It is important to note, however, that this could be the result of the research design rather than because of a flaw in the general hypothesis. The research design included the assumptions that a 95% or greater chance of paying off would be perceived as “nearly certain” and a 5% or smaller chance of paying off would be perceived as “nearly impossible.” It is possible that these effects might yet be observable with different cut-offs—for example, 99% and 1% for “nearly certain” and “nearly impossible,” respectively. Follow-up research could focus directly on the topic of overweighting small probabilities.

5.2 Implications for Options Pricing in Practice

The chief contribution of this research was to highlight the major difference between what options are worth, according to normative risk-neutral models, compared to what human decision makers are willing to pay for them. Standard options valuation techniques, including the binomial lattice, partial differential equations, and simulation, all use formulae based on an assumption that the decision maker is risk-neutral. As a result, each of these methods may produce large errors in situations where humans
rather than computer models decide whether to purchase an option and how much should be paid for it.

The realization that options may be worth, at least probabilistically, more than most humans are willing to pay for them probably has little consequence for institutional traders operating on financial markets. These firms often have departments dedicated to risk management, employing highly specialized trading professionals and computer-based trading and decision-making platforms. Indeed, as much as 84% of all equity trading uses a computer to make the final decision to buy or sell. Thus, any pricing “errors” that might occur due to risk biases are likely to be quickly identified as an arbitrage opportunity by other market participants, human or otherwise (Demos, 2012).

On the other hand, real options are neither standardized nor traded on electronic markets. Indeed, real options often represent managerial flexibility in business projects such as mines, patents, competitive plans, and research and development projects. Compared to financial options, projects containing real options are likely to be far less liquid but have the potential to be much more valuable and strategic to firms. These traits, when combined with multiple sources of uncertainty make real options notoriously complicated to model.

Even if managers hire a team of professionals to perform the real options analysis, the managers may still need to overcome the significant cognitive biases present in prospect theory in order to trust the results. The findings of this research show that managers are not likely to have risk neutral attitudes towards risk, and as a result will form subjective valuations of real options that can differ greatly from the risk-neutral price that ROA says they are worth. Any gap between what the managers consider a fair price and the price calculated through real options could lead to rejection
the model and mistrust of the real options approach. To wit, this research provides an explanation as to why Teach (2003) observed that, despite being a theoretically more sound method for valuing flexibly business projects, real options analysis has yet to gain the trust of managers in practice.

5.3 Agency Issues

As discussed in Chapter 2, prospect theory postulates that the magnitude of a utility gain or loss is determined by the gain or loss of wealth relative to a reference point, which is generally a person’s state of affairs just before the gain or loss occurs. Because this reference point varies from person to person, so does the perceived change in utility. For instance, a gain of $5,000 may produce much utility for somebody with a net worth of $20,000, but almost no utility for somebody with a net worth of $1,000,000. Thus, these two individuals can be expected to arrive at very different valuations for an option with such a payoff.

These pricing differences can create an agency problem when an investor has a dissimilar net worth compared to the manager making investment decisions on his or her behalf. Leaving out other potential biases, when the investor’s wealth is higher than that of the manager, the manager will be likely to discount calls and puts more heavily, reflecting his or her stronger risk-averse and risk-seeking biases, respectively. Likewise, when an investor’s wealth is lower than that of his or her manager, the manager will be likely to discount calls and puts to a lesser degree than would the investor, reflecting the dampened strength of the risk-averse and risk-seeking biases.

5.4 Managerial Education

While this research has implications for many types of option buyers and sellers, these findings are most impactful for real options practitioners who face an uphill battle in trying to get managers to understand and accept real options valuations. Even when
managers fully intend to make decisions “by the numbers,” the cognitive biases described in prospect theory may be difficult to fully overcome (Fox et al., 1996). Educating managers not only about the relative strengths of real options, but also about the potential for cognitive biases toward the type of risk inherent in real options scenarios may help managers understand and accept projects even when mainstream valuation models suggest they should do otherwise (e.g., a negative net present value).

5.5 Limitations

A goal of this research project was to provide insight into the intersection of utility theory and options pricing while also keeping financial and time costs within the bounds of a doctoral dissertation. As a result, trade-offs were made that imposed some limitations on the analysis as well as on the scope in which the findings may be applicable. Primarily, these limitations involved the choice of sample selection (university students) and sample size. Other limitations included common issues faces by social science researchers, such as observer bias.

The most relevant limitation of this research involved the sample size. The sample size of 344 hypothetical options prices from 61 valid participants was large enough to test for general trends in the data, such as comparing discounting behavior between calls and puts with statistical significance. However, some of the tests required comparisons of means between small subsets of data, such as those with only a small percentage chance of paying off. Because the number of observations in these subsets was only a fraction of the entire sample, means could not be estimated within very tight bounds. In some cases where a pricing bias was found but did not quite reach the .05 threshold for statistical significance, a larger sample might have been especially beneficial. To overcome these issues, future research should include either a larger body of participants or the collection of more responses from each participant.
Another limitation pertaining to the sample was the potential that real managers facing actual investment decisions would behave differently than did the subjects of this research. This research relied on responses from The University of Newcastle student body and faculty, so it is likely that most of the individuals were not actual business decision makers. It is also possible that even if these individuals were actual managers, they would behave differently under hypothetical survey conditions compared to how they would behave in real life circumstances, thus exhibiting the so-called Hawthorne Effect (Mayo, 1945). These limitations might be avoided by observing business managers making real options decisions directly or retrospectively. Follow-up research with more time and resources than was available for a DBA dissertation might involve observing managers to investigate whether the trends found in the research exist in the real world.

5.6 Contribution Summary and Future Research Opportunities

In summary, the major finding of this research is that real options valuations of managers are likely to be more consistent with prospect theory than with risk neutrality. The three major areas of contribution are

- a confirmation of the discounting behavior observed by Miller and Shapira (2004),
- a finding that call options are perceived to have less value than put options of similar expected value, and
- a finding that the overweighting of small probabilities causes options to be priced at a premium.

Before a more in-depth investigation of prospect theory effects on options pricing is possible, the research conducted by Miller and Shapira (2004) should be repeated. Although a similar technique was used in this study, the data were collected
in a more controlled fashion by providing respondents with context about their hypothetical decision, including offering them items such as net worth and the timeframe for the investment. In every case examined in this research, the findings were fully consistent with Miller and Shapira (2004), adding support for their conclusions.

By removing the assumption of a symmetric and invertible utility curve, this research provided insight into how prospect theory’s steeper curve for losses and disutility might affect options pricing. The result was a new finding that call options will be discounted more than put options against similar risk-neutral expected values, due to their premiums being evaluated on the steeper disutility curve.

Finally, this research showed that options with outside chances of paying off will be valued at a premium, compared to options with more central probabilities. Although the research methods were not sufficient to find statistical significance in each test case, there nevertheless appeared to be a general shift in pricing behavior at these low probabilities.

This research, similar to the work that inspired it, focused on identifying general trends in the way humans price risky investments. However, making this knowledge useful for practitioners and decision makers remains a significant challenge. Even if it is true that all humans behave according to a similar, S-shaped utility curve, there is no evidence to indicate that all will have the same scale or strength of bias, meaning that individuals are likely to differ in their pricing preferences. Future researchers in this area are encouraged to investigate ways in which the pricing biases discovered in this paper can be measured for a specific individual or group of individuals so that real options models can be made more relevant and trustworthy to managers.
REFERENCES


Mayo, E. (1945). *The social problems of an industrial civilization*. Boston,: Division of Research, Graduate School of Business Administration, Harvard University.


Toronto: Macmillan.

Appendix A – Definitions
**Financial Option:** A contract which gives its holder an exclusive right, but not an obligation, to buy or sell an asset in the future at a specified price. The seller of an options contract receives a premium from the buyer from entering into this agreement (Copeland & Antikarov, 2003).

**Real Option:** A formal or informal business transaction that conveys to an investor an exclusive right, but not an obligation, to execute a business decision in the future. For example, research and development efforts can be considered real options because they convey a right, but not an obligation to develop an invention into a product (Copeland & Antikarov, 2003; Huchzermeier & Loch, 2001).

**Call Option:** Within the context of this paper, a call option refers generically to an exclusive right to invest, purchase, or expand.

**Put Option:** Within the context of this paper, a put option refers generically to an exclusive right to sell, divest, or dispose of an investment.

**Expected Value:** Expected values refer to the statistically predicted dollar value which is generally the sum of all possible outcomes each multiplied by their respective probabilities.

**Risk-neutrality:** A risk-neutral individual is concerned only with the statistically expected value of an investment regardless of the distribution of possible outcomes. For example, a risk-neutral person would be indifferent between an investment that yields $100 dollars for sure and an investment that has a 10 percent chance of yielding $1000 and a 90 percent chance of yielding zero (Kahneman & Tversky, 1979; Miller & Shapira, 2004).
Utility Function: Utility functions describe the relationship between the quantity of something and its perceived usefulness (Friedman & Savage, 1948; Kahneman & Tversky, 1979)
BUSINESS SCHOOL STUDENTS:
TAKE A 15 MINUTE SURVEY FOR A
CHANCE TO WIN AN iPAD MINI.

From: Professor Stephen Chen  Mr. Nathan Brady

To: MBA and MAcc Students

You are invited to participate in a survey involving risk preferences that affect business decision making. The 15-minute survey consists of a few demographic questions followed by six fictional scenarios where you will be asked to place a value on a hypothetical investment.

If you are interested in participating in this research, please visit the following link to access the information statement and survey:
http://www.optionsresearchsurvey.org

Completed surveys are eligible to be entered into a drawing for a Wi-Fi 16Gb iPad mini.

Participation in this research is entirely voluntary. If you do not wish to participate, you can simply discard this message.

Sincerely,
Professor Stephen Chen
Mr. Nathan Brady

One winner will be selected by random drawing of an email address from those provided by participants who completed the survey. The drawing will occur after all responses have been collected which is estimated to be on or around 30 November 2013. The winner will be notified by email to confirm and arrange delivery. If the winner does not confirm receipt within 3 months of notification another email address will be drawn and so on until a winner is confirmed.
Appendix C – Options Primer and Survey Instructions
Explanation of Real Options

A real option is similar to a financial option in that it represents the right, but the not obligation to buy or sell something in the future. While a financial option gives owners a right to buy or sell a financial instrument, such as a shares of stock, in the future, a real option grants owners an exclusive right to execute an exclusive business initiative in the future.

The most common types of real options are “calls” and “puts.” In the case of a call, the option buyer pays an up-front cost an opportunity to participate in an exclusive business opportunity that has an uncertain outcome. Similarly, buyer of a put gains an exclusive opportunity to sell an investment, effectively transferring its outcome to somebody else.

A practical example of real call options can be found in business investment in new product research and development. These types of investments generally don’t provide cash flows in the first phases of funding, but rather they yield real options in the form of proprietary knowledge. This knowledge (a product concept, perhaps) gives the investor an exclusive ability to bring the product to market based on the probability that doing so would lead to profits.

Put options, on the other hand, are essentially insurance. This generally involves paying a premium up-front in exchange for the ability to avoid further investment. Using the research and development example, a poor product concept also represents a put option as the investor has the ability to abandon the project, accepting certain expenses related to disposition of equipment, cancelling of contracts, and termination of employees in exchange for not putting a greater amount of investment at risk of loss by bringing the product to market.

Questionnaire Instructions

The options questionnaire provides six simplified, hypothetical options scenarios. The first section includes three call option scenarios, each providing you with the opportunity to buy into a project that has two potential outcomes each with a respective probability of occurring. You will be asked how much you would willing to pay for the option as if you were actually present with the scenario.

In the second set of questions, you will be provided with scenarios involving put options. In these cases you will have a hypothetical investment portfolio with two potential outcomes for the day, each with a respective probability of occurring. You will be asked how much you would actually be willing to pay to option to dispose of the investment’s outcome (insuring against any loss) if the scenario were real.

There are no right or wrong answers to these questions as each person has a different appetite for risk. Please feel free to perform any calculations that you might use if the scenario were real, but please keep in mind that this survey is most interested in what you would actually do, not calculate.
Appendix D – Ethics Approval Notification
HUMAN RESEARCH ETHICS COMMITTEE

Notification of Expedited Approval

To: Chief Investigator or Project Supervisor
Professor Stephen Chen

Cc: Co-investigators / Research Students:
Mr Nathan Brody

Re: Protocol:
Study on Risk Preferences and Real Options Pricing

Date: 08 Aug 2013
Reference No.: H.2013.0265
Date of Initial Approval: 06 Aug 2013

Thank you for your Initial Application submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under L1 Low Risk Research Expedited review by the Chair/Deputy Chair. I am pleased to advise that the decision on your submission is Approved effective 06 Aug 2013.

In approving this protocol, the Human Research Ethics Committee (HREC) is of the opinion that the project complies with the provisions contained in the National Statement on Ethical Conduct in Human Research, 2007, and the requirements within this University relating to human research.

Approval will remain valid subject to the submission, and satisfactory assessment, of annual progress reports. If the approval of an External HREC has been "noted" the approval period is as determined by that HREC.

The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal Certificate of Approval will be available upon request. Your approval number is H.2013.0265.

If the research requires the use of an Information Statement, ensure this number is inserted at the relevant point in the Complaints paragraph prior to distribution to potential participants. You may then proceed with the research.

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For noting and action:

1. Amendment to the Information Statement.
   Data storage - we note that the information statement advises potential participants that data will be retained for a minimum of 10 years. The minimum required period is generally lower at 5 years - the researchers can choose a longer time period if they wish. If the shorter time frame is decided, amend the Information Statement accordingly.

2. Prize draw
   There is now a requirement for researchers who are conducting a prize draw to refer the project to the University's Legal Unit (LegalOffice@newcastle.edu.au) to confirm terms and conditions, particularly in relation to information provided in the recruitment material. The HREC would need to be informed of any subsequent changes to the recruitment material.

3. Data management
   In order to protect the anonymity of participants, survey responses and email addresses should be separated to different file locations upon receipt.
Conditions of Approval

This approval has been granted subject to you complying with the requirements for Monitoring of Progress, Reporting of Adverse Events, and Variations to the Approved Protocol as detailed below.

PLEASE NOTE:

In the case where the HREC has "noted" the approval of an External HREC, progress reports and reports of adverse events are to be submitted to the External HREC only. In the case of Variations to the approved protocol, or a Renewal of approval, you will apply to the External HREC for approval in the first instance and then Register that approval with the University's HREC.

- Monitoring of Progress

Other than above, the University is obliged to monitor the progress of research projects involving human participants to ensure that they are conducted according to the protocol as approved by the HREC. A progress report is required on an annual basis. Continuation of your HREC approval for this project is conditional upon receipt, and satisfactory assessment, of annual progress reports. You will be advised when a report is due.

- Reporting of Adverse Events

1. It is the responsibility of the person first named on this Approval Advice to report adverse events.
2. Adverse events, however minor, must be recorded by the investigator as observed by the investigator or as volunteered by a participant in the research. Full details are to be documented, whether or not the investigator, or his/her deputies, consider the event to be related to the research substance or procedure.
3. Serious or unforeseen adverse events that occur during the research or within six (6) months of completion of the research, must be reported by the person first named on the Approval Advice to the (HREC) by way of the Adverse Event Report form (via RIMS at https://rims.newcastle.edu.au/login.asp) within 72 hours of the occurrence of the event or the investigator receiving advice of the event.
4. Serious adverse events are defined as:
   - Causing death, life threatening or serious disability.
   - Causing or prolonging hospitalisation.
   - Overdoses, cancers, congenital abnormalities, tissue damage, whether or not they are judged to be caused by the investigational agent or procedure.
   - Causing psycho-social and/or financial harm. This covers everything from perceived invasion of privacy, breach of confidentiality, or the diminution of social reputation, to the creation of psychological fears and trauma.
   - Any other event which might affect the continued ethical acceptability of the project.
5. Reports of adverse events must include:
   - Participant's study identification number;
   - date of birth;
   - date of entry into the study;
   - treatment arm (if applicable);
   - date of event;
   - details of event;
   - the investigator's opinion as to whether the event is related to the research procedures; and
   - action taken in response to the event.
6. Adverse events which do not fall within the definition of serious or unexpected, including those reported from other sites involved in the research, are to be reported in detail at the time of the annual progress report to the HREC.

- Variations to approved protocol

If you wish to change, or deviate from, the approved protocol, you will need to submit an Application for Variation to Approved Human Research (via RIMS at https://rims.newcastle.edu.au/login.asp). Variations may include, but
are not limited to, changes or additions to investigators, study design, study population, number of participants, methods of recruitment, or participant information/consent documentation. Variations must be approved by the (HREC) before they are implemented except when registering an approval of a variation from an external HREC which has been designated the lead HREC, in which case you may proceed as soon as you receive an acknowledgement of your Registration.

Linkage of ethics approval to a new Grant

HREC approvals cannot be assigned to a new grant or award (ie those that were not identified on the application for ethics approval) without confirmation of the approval from the Human Research Ethics Officer on behalf of the HREC.

Best wishes for a successful project.

Professor Allyson Holbrook
Chair, Human Research Ethics Committee

For communications and enquiries:
Human Research Ethics Administration

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The University of Newcastle
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T +61 2 492 18999
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Human-Ethics@uow.edu.au


Linked University of Newcastle administered funding:

<table>
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<th>Funding project title</th>
<th>First named investigator</th>
<th>Grant Ref</th>
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Appendix E – Information Statement
Information Statement

Stephen Chen

University of Newcastle
Faculty of Business and Law
SRS224 – Social Sciences Building
University Drive
Callaghan NSW 2308
Australia
(02) 4921 6680
Stephen.Chen@newcastle.edu.au

Information Statement for the Research Project:
Risk Preferences and Real Options Pricing

You are invited to participate in the research project identified above which is being conducted by Professor Stephen Chen and DBA candidate Nathan Brady at the University of Newcastle. Stephen Chen holds a MBA and PhD and has researched and published in the areas of International Business, Strategic Management, Entrepreneurship and Corporate Social Responsibility. Nathan Brady holds an MBA degree and has completed all coursework, including research related courses in the DBA programme at The University of Newcastle. This research is part of Mr. Brady’s dissertation research at the University of Newcastle and is being supervised by Professor Chen.

Why is the research being done?
The purpose of the research is to understand how an individual’s risk preferences are expressed in terms of an option price. Previous research has shown that people will make different investment choices than a computer that is programmed to optimize for the greatest expected return. This research will involve looking for patterns in human choices involving option prices as well as a comparison to the decision the computer would have made.

Who can participate in the research?
Because of their high potential to have a basic understanding of probability and the concept of an option, we are seeking business school students and faculty to participate in this brief survey. You must be over the age of 18 and be a current or former student or faculty member at a university-level business school.

What choice do you have?
Participation in this research is entirely your choice. Only those people who give their informed consent will be included in the project. Whether or not you decide to participate, your decision will not disadvantage you.

If you do decide to participate, you may withdraw from the project at any time without giving a reason and have the option of withdrawing any data which identifies you.

What would you be asked to do?
If you agree to participate, you will be asked to evaluate a given investment option scenario and record what price, if any, you would be willing to pay for it. The scenarios given to you will be generated at random including all probabilities and payoffs.

How much time will it take?
The single questionnaire should take less than 15 minutes to complete. After this, your participation is complete and you will not be contacted for additional questions or follow-up on this research.

What are the risks and benefits of participating?
Participants who are eligible and complete the survey can enter a prize draw to win an iPad Mini WiFi (16GB). Additionally by participating you may become more aware of options scenarios and better understand your own risk preferences. However, there is a chance that this awareness could lead to changes in your own behaviour for better or worse.

**How will your privacy be protected?**
Any information collected by the researchers which might identify you will be stored securely and only accessed by the researchers unless you consent otherwise, except as required by law. However, the only information collected that could be used to identify you would be your email address, if you choose to provide it. Email address data will be destroyed as soon as the prize drawing is completed and the prize has been accepted.

**How will the information collected be used?**
Your data will be used to construct theories and/or hypotheses on human risk preferences. These will be submitted in a dissertation for Mr. Brady’s degree which could be cited in other academic papers and scientific journals in the future. Individual participants will not be identified in any reports arising from the project.

The results of this project will be made available to the general public through the University of Newcastle, however it will not be possible to notify you when it becomes available because we have not collected or maintained information that could be used to contact you.

**What do you need to do to participate?**
Please read this Information Statement and be sure you understand its contents before you consent to participate. If there is anything you do not understand, or you have questions, contact the researcher.

If you would like to participate, please read the instructions and complete questionnaire that follow this information statement.

**Further information**
If you would like further information please contact Nathan Brady at Nathan.Brady@uon.edu.au or Stephen Chen at Stephen.Chen@newcastle.edu.au.

Thank you for considering this invitation.

Stephen Chen, Ph.D. Nathan Brady, M.B.A
Professor Candidate for the D.B.A.

**Complaints about this research**
This project has been approved by the University’s Human Research Ethics Committee, Approval No. H-2013-0255.
Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia, telephone (02) 49216333, email Human-Ethics@newcastle.edu.au.

Appendix F – Prize Draw Terms and Conditions
1. These terms and conditions of entry, including information on how to participate and prize details (Terms), apply to the competition and entry into the competition is deemed to be acceptance of these Terms.

2. The promoter of this competition is The University of Newcastle, ABN 15 736 57 735 located at University Drive, Callaghan, NSW 2308 (University).

3. The competition is free to enter and will be open from 12:00pm Australian Eastern Daylight Saving Time [AEDST] on 24 September, 2013 until 12:00pm on 4 November, 2013 (Competition Period).

4. Entry in the competition is open to staff and students of the University of Newcastle, excluding:
   
a. Persons who have used or attempted to use any more than one name in order to qualify to win a competition run by or on behalf of the University (except in the case of a legal change of name); and
b. Persons who have breached the terms and conditions of any competition run by or on behalf of the University.

Note: Eligible Entrant: The University is responsible for determining whether a person is an Eligible Entrant in its absolute discretion.

HOW TO ENTER

5. To enter and be eligible to win, Eligible Entrants must submit an eligible entry during the Competition Period by:
   
a. Providing an eligible email address in the box at the bottom of these terms and conditions; and
b. Completing the survey described in the preceding ‘Information Statement’.

DRAW AND PRIZE

6. A random prize draw will be conducted at the University of Newcastle by a nominated staff member using an online random sequence generator at midday AEDST on 11 November, 2013 from all Eligible Entries received during the competition (Draw).

7. The first Eligible Entrant with a valid Eligible Entry drawn in the Draw will win a Wi-Fi enabled 16GB iPad Mini (“the Prize”)

8. If the Prize remains unclaimed after 3 months (midday (AEST) Tuesday February 11, 2014) a second random re-draw will be conducted by a representative of the University, from all remaining Eligible Entries received in the competition, subject to any directions from the NSW Office of Liquor, Gaming & Racing.)
9. The winner will be notified immediately following the prize draw via the email address provided to the University on entry into the competition.

10. Upon being notified, the winner will be asked to provide contact and shipping details for prize fulfilment. The Promoter will deliver the Prize to the winner within 7 days of the Prize being drawn.

11. The Prize does not include cost of delivery outside of Australia.

GENERAL

12. Each Entrant understands that by entering in the Competition, the Promoter will be collecting their personal information, for the purposes of this competition and survey participation.

13. Personal details will remain confidential, in line with the protocol outlined in the Information Statement (attached), accessible only to employees of the Promoter who have the appropriate jurisdiction. Entrant’s details will not be provided to any third party not specified in this documents or the Information Statement for participants. Entrants’ details will be kept on secure servers at the University of Newcastle and will be destroyed as soon as the prize drawing is completed and the prize has been accepted.

14. Each Eligible Entry counts towards one entry only.

15. Prizes are not transferable, exchangeable or redeemable for cash. Prizes must be taken as offered and may not be varied.

16. The University accepts no responsibility for any variation in the value of the Prize.

17. To the maximum extent permitted by law, the Promoter makes no representations or warranties in relation to any Prize including but not limited to as to the quality, suitability or merchantability of any Prize or its fitness for any purpose.

18. The Promoter is not responsible for any incorrect or inaccurate information, whether caused by equipment or programming associated with or utilised in this Competition, or by any technical error which may occur in the course of the administration of this Competition.

19. If, for any reason, the competition is not capable of being run as planned, including due to tampering, unauthorised intervention, fraud or any other causes beyond the control of the University, which corrupt or affect the administration, security, fairness, integrity or proper conduct of the competition, the University reserves the right in its absolute discretion to take any action that may be
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available to it, including cancelling, terminating, modifying or suspending the competition.

20. Any entrant who, in the opinion of the University, tampers or interferes with the entry mechanism or Draw in any way, engages in any unlawful or improper conduct which jeopardises or is likely to jeopardise the fair or proper conduct of the competition, or who does not properly comply with the entry process, will be ineligible to win.

21. Incomplete, illegible, indecipherable or incorrect entries are not eligible to win.

22. The University reserves the right to disqualify entries in the event of non-compliance with these Terms. The University's decisions in relation to all aspects of the competition are final and binding on each entrant and no correspondence will be entered into.

23. The University, the University 's related entities associated with the competition; shall not be liable for any loss or claim, action, demand, liability, damage, cost, expense or personal injury whatsoever (including but not limited to any direct, indirect or consequential loss), incurred, suffered or sustained by any person or entity (without limitation) in connection with, or arising from, the competition or the acceptance or use of, or participation in, except that which cannot be excluded by law (in which case that liability is limited to the maximum extent allowable by law).

24. The University accepts no responsibility for any tax liabilities that may arise from winning or receiving the benefit of the competition.

**Institution Declaration**

I certify that I am a current or former student or faculty member of the following:

The University of Newcastle, Australia- All Australia locations The University of Newcastle, Australia - Hong Kong The University of Newcastle, Australia - All other locations Another institution

**Prize-Draw Opt-in**

If you wish to enter the prize draw and agree to these terms and conditions, enter your email address in the blue box below.

To opt-out you may leave this field empty.

[Exit without survey] [Continue to instructions]
Appendix G – Questionnaire Server Side Source Code
[Default Web Page]
Partial Class _Default
Inherits System.Web.UI.Page
Protected Sub Page_LoadComplete(sender As Object, e As EventArgs) Handles Me.LoadComplete
   Response.Redirect("InformationStatement.aspx")
End Sub
End Class

[Drawing Terms]
Partial Class DrawingTerms
Inherits System.Web.UI.Page
Protected Sub btnContinue_Click(sender As Object, e As EventArgs) Handles btnContinue.Click
   If Page.IsValid Then
      Session.Item("Institution") = rblInstitution.SelectedValue
      Session.Item("EmailAddress") = txtEmailAddress.Text
      Session.Item("TimeStampTerms") = Now.ToString
      Response.Redirect("Instructions.aspx")
   End If
End Sub
Protected Sub btnExit_Click(sender As Object, e As EventArgs) Handles btnExit.Click
   Session.Clear()
   Session.Abandon()
   Response.Redirect("Goodbye.aspx")
End Sub
Protected Sub Page_Load(sender As Object, e As EventArgs) Handles Me.Load
End Sub
End Class

[Termination of Survey]
Partial Class _Default
Inherits System.Web.UI.Page
Protected Sub Page_PreLoad(sender As Object, e As EventArgs) Handles Me.PreLoad
   Dim EmailAddress As String
   EmailAddress = Session.Item("EmailAddress") &"
   If Session.IsNewSession Then
      lblThankYou.Text = "You have successfully exited the questionnaire, your responses have not been recorded, and you have not been entered into the drawing. If you decide to participate at a later time you may visit this page again."
   Else
      lblThankYou.Text = "This concludes the questionnaire on risk preferences towards real options. Thank you for participating in this research."
   End If
   If EmailAddress.Length > 0 Then
      lblEmailConfirm.Text = "Your email address " & EmailAddress & " has been entered into the drawing for the iPad Mini."
   Else
      lblEmailConfirm.Text = ""
   End If
   Session.Clear()
   Session.Abandon()
End Sub
End Class

[Survey Instructions]
Partial Class Instructions
Inherits System.Web.UI.Page

Protected Sub btnExit_Click(sender As Object, e As EventArgs) Handles btnExit.Click
    Session.Clear()
    Session.Abandon()
    Response.Redirect("Goodbye.aspx")
End Sub

Protected Sub btnContinue_Click(sender As Object, e As EventArgs) Handles btnContinue.Click
    Dim InstructionsDone As Boolean
    InstructionsDone = True
    Session("InstructionsDone") = InstructionsDone
    Session("TimeStampInstructions") = Now.ToString
    Response.Redirect("Questionnaire1.aspx")
End Sub

Protected Sub Page_InitComplete(sender As Object, e As EventArgs) Handles Me.InitComplete
End Sub

Protected Sub Page_PreInit(sender As Object, e As EventArgs) Handles Me.PreInit
End Sub
End Class

[Demographic Questionnaire]

Partial Class Questionnaire1
Inherits System.Web.UI.Page

Protected Sub btnContinue_Click(sender As Object, e As EventArgs) Handles btnContinue.Click
    Dim Gender As Integer
    Dim AgeRange As Integer
    Dim Education As Integer
    Dim CapitalBudgetingKnowledge As Integer
    If rdoMale.Checked = True Then
        Gender = 1
    Else
        Gender = 2
    End If
    If rdo18to24.Checked = True Then
        AgeRange = 1
    ElseIf rdo25to34.Checked = True Then
        AgeRange = 2
    ElseIf rdo35to44.Checked = True Then
        AgeRange = 3
    ElseIf rdo45to54.Checked = True Then
        AgeRange = 4
    ElseIf rdo55to64.Checked = True Then
        AgeRange = 5
    ElseIf rdo65to74.Checked = True Then
        AgeRange = 6
    End If
End Sub
AgeRange = 6
ElseIf rdoOver74.Checked = True Then
  AgeRange = 7
End If

If rdoUndergraduateStudent.Checked = True Then
  Education = 1
ElseIf rdoUndergraduateDiploma.Checked = True Then
  Education = 2
ElseIf rdoGraduateStudent.Checked = True Then
  Education = 3
ElseIf rdoGraduateDiploma.Checked = True Then
  Education = 4
End If

If rdoNotFamiliar.Checked = True Then
  CapitalBudgetingKnowledge = 1
ElseIf rdoSomewhatFamiliar.Checked = True Then
  CapitalBudgetingKnowledge = 2
ElseIf rdoVeryFamiliar.Checked = True Then
  CapitalBudgetingKnowledge = 3
End If

If Page.IsValid Then
  Session.Item("Gender") = Gender
  Session.Item("AgeRange") = AgeRange
  Session.Item("Education") = Education
  Session.Item("CapitalBudgetingKnowledge") = CapitalBudgetingKnowledge
  Session.Item("TimeStampDemographics") = Now.ToString

  Response.Redirect("Questionnaire2.aspx")
End If
End Sub

Protected Sub Page_InitComplete(sender As Object, e As EventArgs) Handles Me.InitComplete
  End Sub
End Protected

Protected Sub btnExit_Click(sender As Object, e As EventArgs) Handles btnExit.Click
  Session.Clear()
  Session.Abandon()
  Response.Redirect("Goodbye.aspx")
End Sub
End Class

[Options Pricing Questionnaire]

Imports System.Data.SqlClient
Imports System.Data

Partial Class Questionnaire
  Inherits System.Web.UI.Page

  Public ConfigurationDatabase As SqlConnection
  Public SurveyItems As Collection

  Public Function getclientIPAddress() As String
    Dim clientIP As String
}

Imports System.Data.SqlClient
Imports System.Data

Partial Class Questionnaire
  Inherits System.Web.UI.Page

  Public ConfigurationDatabase As SqlConnection
  Public SurveyItems As Collection

  Public Function getclientIPAddress() As String
    Dim clientIP As String

clientIP = Context.Request.ServerVariables("HTTP_X_FORWARDED_FOR")
If clientIP Is Nothing Then
    clientIP = Context.Request.ServerVariables("REMOTE_ADDR")
End If

Return clientIP
End Function

Protected Sub btnNext_Click(sender As Object, e As EventArgs) Handles btnNext.Click
Dim ThisSurveyItem As SurveyItem

If Page.IsValid Then
    SurveyItems = Session.Item("SurveyItems")
    ThisSurveyItem = SurveyItems(Session.Item("SurveyItemNumber"))
    ThisSurveyItem.Answer = txtAnswer.Text
    ThisSurveyItem.EndTime = Now

    Session.Item("SurveyItemNumber") = Session.Item("SurveyItemNumber") + 1
    If Session.Item("SurveyItemNumber") <= SurveyItems.Count Then
        LoadItem(Session.Item("SurveyItemNumber"))
        Session.Item("SurveyDone") = "TRUE"
    Else
        'Survey is complete
        WriteResults()
    End If
End If
End Sub

Public Sub InitSurvey()
Dim SQLConnectionString As String
Dim SQLQueryString As String
Dim SQLAdapter1 As SqlDataAdapter
Dim SQLAdapter2 As SqlDataAdapter
Dim DTSurveyConfiguration As DataTable
Dim DTTemplateConfiguration As DataTable
Dim r As New Random(System.DateTime.Now.Millisecond)

'Initialize connection to the database and fill DTSurveyConfiguration with the question configuration
SQLConnectionString = "server=p3nwgdshsql8-v02.shr.prod.phx3.secureserver.net;database=RealOptions;uid=RealOptions;pwd=C@ll2522;"
ConfigurationDatabase = New SqlConnection(SQLConnectionString)
SQLQueryString = "SELECT * from Configuration ORDER BY NEWID()"
SQLAdapter1 = New SqlDataAdapter(SQLQueryString, ConfigurationDatabase)
DTSurveyConfiguration = New DataTable
SQLAdapter1.Fill(DTSurveyConfiguration)

Dim ThisSurveyQuestion As SurveyItem
Dim PMax, PMin, PIncrement, V1Min, V1Max, V2Min, V2Max, VIncrement As Single
Dim PIncrements As Integer
Dim x, y As Integer
SurveyItems = New Collection
Randomize()
For x = 0 To DTSurveyConfiguration.Rows.Count - 1
    ThisSurveyQuestion = New SurveyItem
    PMax = DTSurveyConfiguration.Rows(x).Item("PMax") * 100
    PMin = DTSurveyConfiguration.Rows(x).Item("PMin") * 100
    PIncrement = DTSurveyConfiguration.Rows(x).Item("PIncrement") * 100

    PIncrements = ((PMax - PMin) / PIncrement) + 1

    V1Min = DTSurveyConfiguration.Rows(x).Item("V1Min")
    V1Max = DTSurveyConfiguration.Rows(x).Item("V1Max")
    V2Min = DTSurveyConfiguration.Rows(x).Item("V2Min")
    V2Max = DTSurveyConfiguration.Rows(x).Item("V2Max")

    VIncrement = DTSurveyConfiguration.Rows(x).Item("VIncrement")

    ThisSurveyQuestion.QuestionType = DTSurveyConfiguration.Rows(x).Item("Type")
    ThisSurveyQuestion.Portfolio =
        DTSurveyConfiguration.Rows(x).Item("PortfolioValue")
    ThisSurveyQuestion.Probability = PMin + r.Next(0, 1 + (PMax - PMin) / PIncrement) *
        PIncrement

        'ThisSurveyQuestion.Probability = ((Math.Round((PMax / PIncrement - PMin / PIncrement + 1) * Rnd(), 0) + (PMin / PIncrement)) * PIncrement)

    ThisSurveyQuestion.V1Min = V1Min
    ThisSurveyQuestion.V1Max = V1Max
    ThisSurveyQuestion.V2Min = V2Min
    ThisSurveyQuestion.V2Max = V2Max
    thissurveyquestion.pmin = pmin / 100
    thissurveyquestion.pmax = pmax / 100
    ThisSurveyQuestion.VIncrement = VIncrement
    ThisSurveyQuestion.PIncrement = PIncrement

    If V1Max > 0 Then
        ThisSurveyQuestion.V1 = V1Min + r.Next(0, 1 + (V1Max - V1Min) / VIncrement) *
            VIncrement

        'ThisSurveyQuestion.V1 = ((Math.Round((V1Max / VIncrement - V1Min / VIncrement + 1) * Rnd(), 0) + (V1Min / VIncrement)) * VIncrement)
    End If

    If V2Max > 0 Then
        ThisSurveyQuestion.V2 = V2Min + r.Next(0, 1 + (V2Max - V2Min) / VIncrement) *
            VIncrement

        'ThisSurveyQuestion.V2 = ((Math.Round((V2Max / VIncrement - V2Min / VIncrement + 1) * Rnd(), 0) + (V2Min / VIncrement)) * VIncrement)
    End If

    SurveyItems.Add(ThisSurveyQuestion)
Next x

'Initialize connection to the database and fill DTTemplateConfiguration with the template configuration
SQLConnectionString = "server=p3nwgdshsql-v02.shr.prod.phx3.secureserver.net;database=RealOptions;uid=RealOptions;pwd=C@ll2522;"
ConfigurationDatabase = New SqlConnection(SQLConnectionString)

SQLQueryString = "SELECT * from Scenarios"
SQLAdapter2 = New SqlDataAdapter(SQLQueryString, ConfigurationDatabase)

DTTTemplateConfiguration = New DataTable
SQLAdapter2.Fill(DTTTemplateConfiguration)

For x = 1 To SurveyItems.Count
    ThisSurveyQuestion = SurveyItems(x)
    For y = 0 To DTTTemplateConfiguration.Rows.Count - 1
        If ThisSurveyQuestion.QuestionType = DTTTemplateConfiguration.Rows(y).Item("Name") Then
            'Question type matches scenario name, copy information to template variables
            ThisSurveyQuestion.ScenarioTemplate = DTTTemplateConfiguration.Rows(y).Item("Text")
            ThisSurveyQuestion.QuestionTemplate = DTTTemplateConfiguration.Rows(y).Item("Question")
        End If
    Next
    lblScenario.Text = ThisSurveyQuestion.Scenario
Next

Session.Item("SurveyItems") = SurveyItems
End Sub

Public Sub StartSurvey()
    Session.Item("SurveyItemNumber") = 1
    LoadItem(Session.Item("SurveyItemNumber"))
End Sub

Public Function RandomNumber(ByVal MaxNumber As Integer, _
Optional ByVal MinNumber As Integer = 0) As Integer
    'initialize random number generator
    Dim r As New Random(System.DateTime.Now.Millisecond)
    'if passed incorrect arguments, swap them
    'can also throw exception or return 0
    If MinNumber > MaxNumber Then
        Dim t As Integer = MinNumber
        MinNumber = MaxNumber
        MaxNumber = t
    End If
    Return r.Next(MinNumber, MaxNumber)
    r.Next()
End Function

Public Sub WriteResults()
    Dim SQLConnectionString As String
    Dim ItemIndex As Integer
    Dim SQLConn As New SqlConnection

Dim SQLCmd As SqlCommand
Dim thisSurveyItem As SurveyItem

SQLConnectionString = "server=p3nwgdhsq18-v02.sh.prod.phx3.secureserver.net;database=RealOptions;uid=RealOptions;pwd=C@ll2522;"

SQLConn.ConnectionString = SQLConnectionString
SQLConn.Open()
SurveyItems = Session("SurveyItems")
For ItemIndex = 1 To SurveyItems.Count
    thisSurveyItem = SurveyItems(ItemIndex)
    'Initialize connection to the database and fill DT SurveyConfiguration with the question configuration
    SQLCmd = New SqlCommand
    SQLCmd.CommandText = "INSERT INTO Results (IPAddress, SessionID, Gender, AgeRange, Education, CapitalBudgetingKnowledge, Institution, TimeStampIS, TimeStampTerms, TimeStampInstructions, StartTime, EndTime, QuestionType, PMin, PMax, V1Min, V1Max, V2Min, V2Max, " & _
    "PortfolioValue, V1Increment, P1Increment, V1, V2, P, Question, Answer) VALUES (" & _
    " & getClientIPAddress() & ",", "," & _
    "," & _
    Session.Item("Gender") & ",", "," & _
    Session.Item("AgeRange") & ",", "," & _
    Session.Item("Education") & ",", "," & _
    Session.Item("CapitalBudgetingKnowledge") & ",", "," & _
    " & Session("Institution").ToString & ",", "," & _
    " & Session("TimeStampIS").ToString & ",", "," & _
    " & Session("TimeStampTerms").ToString & ",", "," & _
    " & Session("TimeStampInstructions").ToString & ",", "," & _
    " & thisSurveyItem.StartTime.ToString & ",", "," & _
    " & thisSurveyItem.EndTime.ToString & ",", "," & _
    " & thisSurveyItem.QuestionType & ",", "," & _
    thisSurveyItem.PMin & ",", "," & _
    thisSurveyItem.PMax & ",", "," & _
    thisSurveyItem.V1Min & ",", "," & _
    thisSurveyItem.V1Max & ",", "," & _
    thisSurveyItem.V2Min & ",", "," & _
    thisSurveyItem.V2Max & ",", "," & _
    thisSurveyItem.Portfolio & ",", "," & _
    thisSurveyItem.V1Increment & ",", "," & _
    thisSurveyItem.V2Increment & ",", "," & _
    thisSurveyItem.Probability / 100 & ",", "," & _
    " & thisSurveyItem.Scenario.Replace(Chr(39), Chr(39) & Chr(39)) & ",", "," & _
    thisSurveyItem.Question.Replace(Chr(39), Chr(39) & Chr(39)) & ",", "," & _
    thisSurveyItem.Answer & "")"
    SQLCmd.Connection = SQLConn
    SQLCmd.ExecuteNonQuery()
    SQLCmd.Dispose()
Next ItemIndex
If Session("EmailAddress").ToString.Length > 0 Then
  SQLCmd = New SqlClient.SqlCommand
  SQLCmd.CommandText = "INSERT INTO EmailEntries (EmailAddress) VALUES (" & Session("EmailAddress") & ")"
  SQLCmd.Connection = SQLConn
  SQLCmd.ExecuteNonQuery()
End If

SQLConn.Close()
End Sub

Public Sub LoadItem(Index As Integer)
  Dim ThisSurveyItem As SurveyItem

  If Index <= SurveyItems.Count Then
    lblQNo.Text = Index.ToString
    ThisSurveyItem = SurveyItems(Index)
    lblTotalQuestions.Text = SurveyItems.Count
    txtAnswer.Text = ""
    lblQuestion.Text = ThisSurveyItem.Question
    lblScenario.Text = ThisSurveyItem.Scenario

    If Index < SurveyItems.Count Then
      btnNext.Text = "Next item"
    Else
      btnNext.Text = "Finish"
    End If

    ThisSurveyItem.StartTime = Now
  Else
    Response.Redirect("Goodbye.aspx")
  End If
End Sub

Class SurveyItem
  Public QuestionNumber As Integer
  Public QuestionType As String
  Public Probability As Single
  Public V1 As Long
  Public V2 As Long
  Public Answer As Double
  Public Portfolio As Long
  Public QuestionTemplate As String
  Public ScenarioTemplate As String
  Public V1Min, V1Max, V2Min, V2Max, VIncrement As Long
  Public PMax, PMin, PINcrement As Double
  Public StartTime, EndTime As Date

  Private TempQuestion, TempScenario As String

  Public ReadOnly Property Question() As String
    Get
      TempQuestion = Me.QuestionTemplate
    End Get
Return TempQuestion
End Get

End Property

Public ReadOnly Property Scenario As String
Get
    TempScenario = Me.ScenarioTemplate
    TempScenario = TempScenario.Replace("<V1>", FormatCurrency(Me.V1, 0))
    TempScenario = TempScenario.Replace("<V2>", FormatCurrency(Me.V2, 0))

    If Me.QuestionType = "PriceCall" Then
        TempScenario = TempScenario.Replace("<T>", "by the end of the day")
    Else
        TempScenario = TempScenario.Replace("<T>", "By the end of the day")
    End If
End Get
End Property

End Class

Protected Sub Page_InitComplete(sender As Object, e As EventArgs) Handles Me.InitComplete
    If Session.Item("SurveyItemNumber") Is Nothing And Session.Item("InstructionsDone") = True Then
        InitSurvey()
        StartSurvey()
    ElseIf Session.Item("SurveyItemNumber") Is Nothing And Session.Item("InstructionsDone") Is Nothing Then
        Session.Clear()
        Session.Abandon()
        Response.Redirect("Index.aspx")
    Else
        'Page is not valid
    End If
End Sub

Protected Sub btnExit_Click(sender As Object, e As EventArgs) Handles btnExit.Click
    Session.Clear()
    Session.Abandon()
    Response.Redirect("Goodbye.aspx")
End Sub

Protected Sub Page_Load(sender As Object, e As EventArgs) Handles Me.Load
End Sub
End Class
Appendix H1 – SPSS output for Hypotheses 1 testing
## Descriptives

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<thead>
<tr>
<th>Statistic</th>
<th>Statistic</th>
<th>Std. Error</th>
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</thead>
<tbody>
<tr>
<td>Discount</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>.04806</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
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</tr>
<tr>
<td></td>
<td>Upper Bound</td>
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<tr>
<td>5% Trimmed Mean</td>
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Appendix H2 – SPSS output for Hypotheses 2 testing
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<td>Lower Bound</td>
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<td></td>
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<tr>
<td>Upper Bound</td>
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<td></td>
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<tr>
<td>5% Trimmed Mean</td>
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<td></td>
</tr>
<tr>
<td>Median</td>
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<tr>
<td>Variance</td>
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<tr>
<td>Std. Deviation</td>
<td>.79311</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>-4.00</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>5.00</td>
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</tr>
<tr>
<td>Interquartile Range</td>
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<td></td>
</tr>
<tr>
<td>Skewness</td>
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<td>.217</td>
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<tr>
<td>Kurtosis</td>
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Appendix H3 – SPSS output for Hypotheses 3 testing
### Independent Samples Test

<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
<th>95% Confidence Interval of the Difference</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
</tr>
<tr>
<td>Discount</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>10.319</td>
<td>.001</td>
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<tr>
<td>Equal variances not assumed</td>
<td>4.287</td>
<td>210.866</td>
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Appendix H4 – SPSS output for Hypotheses 4A testing
## Group Statistics

<table>
<thead>
<tr>
<th>Probability</th>
<th>N</th>
<th>Mean</th>
<th>Std Deviation</th>
<th>Std Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount &gt; .95</td>
<td>22</td>
<td>.6406</td>
<td>.35969</td>
<td>.07710</td>
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<tr>
<td>Discount &lt; .95</td>
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<td>.52737</td>
<td>.04906</td>
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## Independent Samples Test

<table>
<thead>
<tr>
<th></th>
<th>Levene’s Test for Equality of Variances</th>
<th>Student’s t Test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
</tr>
<tr>
<td>Discount Equivanences assumed</td>
<td>.063</td>
<td>.902</td>
<td>-7.21</td>
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<tr>
<td>Discount Equivanences not assumed</td>
<td>.185</td>
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Appendix H5 – SPSS output for Hypotheses 4B testing
### Group Statistics

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<th>Probabilities</th>
<th>N</th>
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<th>Std Deviation</th>
<th>Std. Error</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>≥ .5</td>
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<td>.29311</td>
<td>.03122</td>
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### Independent Samples Test

<table>
<thead>
<tr>
<th>Levene's Test for Equality of Variances</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>Sig.</td>
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<td>----------------------------------------</td>
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</tr>
<tr>
<td>Discount</td>
<td>Equivariances assumed</td>
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<td></td>
<td>Equivariances not assumed</td>
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Appendix H6 – SPSS output for Hypotheses 5A testing
### Group Statistics

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<th>Std Deviation</th>
<th>Std Error Mean</th>
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</thead>
<tbody>
<tr>
<td>Discount &lt; 05</td>
<td>125</td>
<td>0.6265</td>
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<td>0.0406</td>
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<td>&gt; 05</td>
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<td>0.24902</td>
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### Independent Samples Test

<table>
<thead>
<tr>
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<th>Levene's Test for Equality of Variances</th>
<th>t Test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
</tr>
<tr>
<td>Discount</td>
<td></td>
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</table>

**Discount** assumed

**Equal variances not assumed**
Appendix H7 – SPSS output for Hypotheses 5B testing
Group Statistics

<table>
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<tr>
<th>Probability</th>
<th>N</th>
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<th>Std. Deviation</th>
<th>Std. Error Mean</th>
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</thead>
<tbody>
<tr>
<td>Discount</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5.00</td>
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<td>7931</td>
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Independent Samples Test

Levene's Test for Equality of Variances

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Equal variances assumed</td>
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<td>.000</td>
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Boxplot

Discount vs. Probability_Binned