Fourfold Pattern of Risk-taking

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Abstract
Majority of past studies on managerial risk-taking have examined the determinants of risk-taking from the agency perspective. However, a substantial body of evidence has shown that Expected Utility Theory (EUT) provides inadequate description for decision-making under risky prospects. This study investigates whether the managerial incentives to take risks follow the fourfold pattern of risk-attitude as implied by Cumulative Prospect Theory (CPT) – risk-taking is higher over low-probability reference gains or high-probability reference losses, and is lower over high-probability reference gains or low-probability reference losses. Reference gains and losses are respectively defined as positive and negative deviations from peers’ performance. This study considers risk-taking in terms of risky projects and provides evidence for CPT’s fourfold incentive pattern.

Keywords: Managerial risk-taking; Prospect theory.
JEL classification: G30.
Introduction
Risk taking is fundamental to the survival and development of a firm [Shapira (1995)], and thus determinants of risk taking have been a long standing interest in the corporate governance literature. The majority of previous studies on this topic have examined the determinants of risk taking from the agency perspective [e.g., Lambert et al. (1991), Hemmer et al. (1999), and Rajgopal and Shevlin (2002)], which typically assumes that agents (e.g., top executives) are expected utility maximizers.

Nevertheless, a substantial body of evidence has shown that expected utility theory (EUT), first formulated by von Neumann and Morgenstern (1944), does not provide an adequate description for individuals’ decision-making under risky prospects. As Greer (1974) has pointed out, there exists a conflict between expected utility theory and actual risk-tolerance decision processes. The results from his study, based on information provided by 100 corporate executives, revealed that the minimum possible outcome associated with a risky project is an important factor in real-world decision processes – decision makers are under great pressure to avoid any chance of a project outcome being lower than some pre-specified minimum. Schoemaker (1982) and Machina (1987) have also discussed in detail how actual economic behaviors systematically deviate from those predicted by expected utility theory.¹ Or, as Starmer (2000) stated, “put bluntly, the standard theory did not fit the facts”.

Many descriptive models have been proposed in an attempt to better describe individuals’ behaviors under risky prospects. Recent work has concentrated on variations of what Edwards (1955) originally called “subjective expected value”, which is also known as “subjective expected utility” (SEU). SEU-type models propose that when assigning values to prospects that involve risks, people evaluate the outcomes by decision weights that are functions of objective probabilities. Perhaps the most accepted theory of these SEU alternatives is cumulative prospect theory (CPT) developed by Tversky and Kahneman (1992), which is an extension of Kahneman and Tversky’s (1979) prospect theory.²

Two main elements of CPT are a reference-dependent value function and a non-linear probability weighting function. First, capturing the finding that individuals

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¹ A typical example is the well-known Allais Paradox [Allais (1953), Morrison (1967), Slovic and Tversky (1974), and Kahneman and Tversky (1979)]. As a special case of this paradox, for instance, Kahneman and Tversky (1979) observed from their experiments that outcomes obtained with certainty loomed disproportionally larger than those that were uncertain. This so-called “certainty effect” violates the invariance axiom of EUT.

² Prospect theory violates first-order stochastic dominance. That is, prospect A might be preferred to prospect B even if the probability of receiving a value x or greater is at least as high under prospect B as it is under prospect A for all values of x, and is greater for some values of x. CPT overcomes this problem by using a probability weighting function derived from the rank-dependent function of Quiggin (1982) and Schmeidler (1989). CPT also extends the theory to risky prospects with any number of (or continuous) outcomes.
are risk averse over gains and risk seeking over losses, the value function is assumed to be concave for gains and convex for losses. The way in which outcomes are framed as gains or losses cognitively affects individuals’ attitude toward risk. This is the so-called framing effect. Such an effect has been found in investors’ behaviour [e.g., Pinello (2008) and Barberis and Xiong (2009)]. Second, CPT postulates that individuals weight objective probabilities by a non-linear probability weighting function, rather than responding linearly to objective probabilities as in EUT. Risk attitude governed by CPT’s value and weighting functions is characterized by risk seeking over low-probability gains or high-probability losses, and risk aversion over high-probability gains or low-probability losses. This is the so-called fourfold pattern of risk attitude. Evidence from experiments for such fourfold pattern has been documented by, inter alia, Tversky and Kahneman (1992), Kachelmeier and Shehata (1992), Harbaugh et al. (2002, 2010), Holt and Laury (2002), and Laury and Holt (2008).

The objective of this study is to investigate managerial risk-taking attitude under risky prospects. Defining reference gains and losses as positive and negative deviations of own performance from the mean rival performance, this study hypothesizes the fourfold pattern of managerial risk attitude as follows – the manager tends to take: (1) high risks over low-probability reference gains; (2) low risks over high-probability reference gains; (3) high risks over high-probability reference losses, and; (4) low risks over low-probability reference losses. This pattern is empirically supported by the study’s findings. The remainder of this paper is organized as follows. Sections 2 and 3 develop the major hypotheses and formulate the empirical framework for hypothesis testing, respectively. Section 4 describes the measurement of major variables and the data set. Section 5 presents the major findings. Section 6 concludes the paper.

Hypotheses

Let $p_{i,t+1}$ be firm $i$’s actual performance in period $t+1$, $p_{i,t+1}^r$ the reference performance, and $y_{i,t+1} = p_{i,t+1} - p_{i,t+1}^r$ the deviation of actual performance from the reference performance. Reference loss or gain occurs in period $t+1$ if $y_{i,t+1} < 0$ or $y_{i,t+1} > 0$, respectively. Risk attitude under EUT is solely determined by the shape of the utility function because expected utility is linear in the objective probabilities of all possible outcomes. Past research on corporate governance typically assumed a concave utility function for the manager. Unlike EUT, CPT describes preferences by a reference-dependent value function $v(y_{i,t+1})$ that relates outcomes to utilities, where
outcomes are framed as positive or negative deviations (i.e., gains or losses) from the reference performance. As shown in Figure 1(a), $v(y_{i,t}+1)$ is assumed to be concave for gains and convex for losses. Moreover, $v(y_{i,t+1})$ is kinked at the reference point $(p_{i,t+1} = p'_{i,t+1}, \text{ or } y_{i,t+1}=0)$ with a steeper slope for losses than for gains, which captures the finding that losses loom larger than gains. The shape of $v(y_{i,t+1})$ implies that the manager is risk-averse over gains, risk-seeking over losses, and loss averse. The way in which outcomes are framed as gains or losses (i.e., the choice of $p'_{i,t+1}$) cognitively affects the manager’s attitude toward risk. Similar framing effects have been found in some accounting studies. For instance, Greer (1974) found that decision makers are under great pressure to avoid any chance of a project outcome being lower than some pre-specified minimum. In addition, an experiment conducted by Kim (1992) to simulate public accountants’ budgeting of billable hours showed that the subordinate prefers a tight budget when below, and a safe budget when above, the average performance of other workers.

Let $Pr$ be the objective probability of a possible performance outcome (gain or loss). Rather than responding linearly to $Pr$, the manager is assumed to weight $Pr$ by a non-linear probability weighting function $w(Pr)$ as depicted in Figure 1(b). Impossible events are discarded such that $w(0)=0$ and the scale is normalized such that $w(1)=1$. To capture the postulate that individuals are insensitive to changes in probability, $w(Pr)$ is assumed to be regressive (i.e., concave near 0 and convex near 1) and to cut the diagonal from above. As such, when making decisions under risky prospects, the manager tends to overweight low-probability events and underweight high-probability ones.

The fourfold pattern of risk attitude is a joint effect of $w(Pr)$ and $v(y_{i,t+1})$: individuals are risk-averse for gains and risk-seeking for losses at high probability, and are risk-seeking for gains and risk-averse for losses at low probability. Tversky and Kahneman (1992) showed that this fourfold pattern occurs when the magnitude of $w(Pr)$ is large relative to $v(y_{i,t+1})$. That is, when the overweighting of low probabilities is large enough such that individuals are risk-seeking for lotteries with low-probability gains and risk-averse for low-probability losses. Evidence for the fourfold pattern of risk attitude has been well documented by past laboratory experiments [e.g., Tversky and Kahneman (1992), Kachelmeier and Shehata (1992), Harbaugh et al. (2002, 2010), Holt and Laury (2002), and Laury and Holt (2008)].

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3 Probability weighting alone will give rise to the fourfold pattern if individuals are risk neutral.
Placing the fourfold pattern into the context of managerial decision-making under risky performance prospects provides the following testable hypotheses:

Hypothesis 1: The manager tends to take high risks over low-probability reference gains, and tends to take low risks over high-probability reference gains.

Hypothesis 2: The manager tends to take high risks over high-probability reference losses, and tends to take low risks over low-probability reference losses.

3. Empirical framework

For the purpose of this study, the reference performance for firm $i$, $p_{i,t+1}$, is defined as the mean rival performance in period $t+1$, and thus $y_{i,t+1} = p_{i,t+1} - p_{i,t+1}^{r}$ can be interpreted as firm $i$’s “relative performance”. First, the theory of relative performance evaluation (RPE) suggests that optimal compensation contracts may base managerial compensation on performance relative to other firms in the industry in order to filter common risks from the compensation of risk-averse managers [see, for example, Antle and Smith (1986), Gibbons and Murthy (1990), Janakiraman et al. (1992), Rajgopal et al. (2006), and Albuquerque (2009)]. As such, the mean rival performance is likely to be an important performance target/reference for evaluating managerial performance. Second, the behavioral theory of the firm suggests that “aspirations” represent a “success reference” used to judge the quality of actual performance [see, for example, Lant and Montgomery (1987), Cyert and March (1992), and March and Shapira (1992)], and have been commonly coded as the mean industry performance in previous studies [e.g., Lev (1974), Fiegenbaum and Thomas (1988), Bromiley (1991), Wiseman and Bromiley (1996), and Palmeri and Wiseman (1999)]. The use of the mean rival performance as a reference is in fact consistent with Fishburn’s (1977) notion that people tend to perceive the average performance of others in the same task as their reference point. That is to say, managers are likely to consider rivals’ performance as a reference point. According to the fourfold pattern of risk attitude, if the manager is faced with a high probability of underperforming the rivals, he/she tends to adopt risky strategies that offer an opportunity to reach, or even surpass, the mean rival performance. As Singh (1986) and March and Shapira (1992) demonstrated, underperforming firms can improve the probability of attaining the reference performance level by increasing performance variability. In contrast, when the manager is faced with a high probability of outperforming the rivals, he/she tends to prefer conservative strategies that avoid jeopardizing the current favorable situation.

Define an indicator variable, $I_{i,t+1}$, such that the probabilities of $y_{i,t+1} < 0$, $y_{i,t+1} = 0$, and $y_{i,t+1} > 0$.
and $y_{i,t+1} > 0$ in period $t+1$ are denoted by $\Pr(I_{i,t+1}=1)$, $\Pr(I_{i,t+1}=2)$, and $\Pr(I_{i,t+1}=3)$, respectively. To project these probabilities, this study employs a discrete choice regression model that has been commonly used in the sports economics literature for modelling match results [see, for example, Forrest and Simmons (2000a, b), Koning (2000), and Goddard and Asimakopoulos (2004)]. In any period $t$, firm $i$’s (a home football team’s) performance (match result) in period $t+1$ is uncertain and has three possible outcomes – reference gain (home win), reference loss (away win), and reference breakeven (draw match). It is assumed that the performance outcome in period $t+1$ depends on a latent variable $x_{i,t+1}$, which is a function of firm $i$’s period-$t$ relative performance ($y_{i,t}$), managerial risk-taking ($R_{i,t}$), and growth opportunity ($GROW_{i,t}$), as follows:

$$x_{i,t+1} = F(y_{i,t}, R_{i,t}, ..., R_{i,t}, GROW_{i,t}, u_{i,t+1}) \quad (1)$$

where $u_{i,t+1}$ is white noise and $R_{i,t}, ..., R_{i,t}$ are measures of managerial risk-taking.

Past relative performance, $y_{i,t}$, enters Equation (1) as an explanatory variable for two reasons. First, previous research suggests that decision makers’ expectation of potential gain or loss is strongly influenced by own-performance history [Kahneman and Lovallo (1993) and Greve (1998)], especially for informed decision makers [Benartzi and Thaler (1999) and Benartzi (2001)]. Second, $y_{i,t}$ is likely to be correlated with longer lags ($t-1, t-2, ...$) of past performance, risk taking, and growth opportunities, and thus including $y_{i,t}$ in Equation (1) can capture any possible effects of these longer lags on $x_{i,t+1}$. An appropriate empirical methodology for estimating Equation (1) is an ordered logit model specified as:

- Reference loss $\Rightarrow I_{i,t+1} = 1$ if $x_{i,t+1} \leq c_1$
- Reference breakeven $\Rightarrow I_{i,t+1} = 2$ if $c_1 < x_{i,t+1} < c_2 \quad (2)$
- Reference gain $\Rightarrow I_{i,t+1} = 3$ if $c_2 \leq x_{i,t+1}$

where $c_1$ and $c_2$ are threshold levels to be estimated. Suppose the actual observations of $R_{i,t}, ..., R_{i,t}$ indicate the optimal level of risk taking chosen by the manager. The ordered logit model can then be estimated to project the “realized” probabilities of the three performance outcomes, namely, $\Pr(I_{i,t+1}=1)$, $\Pr(I_{i,t+1}=2)$, and $\Pr(I_{i,t+1}=3)$, with $R_{i,t}, ..., R_{i,t}$ all chosen optimally.

Prospect theory postulates that value (or, utility) is assigned to the deviation of performance from a reference point (i.e., $y_{i,t+1}$) rather than to the absolute performance level ($p_{i,t+1}$). Assuming that the relationship between the probabilities of performance
outcomes and their determinants as governed by Equations (1) and (2) are known to the manager, and that the optimal level of \( R_{it}^h \) is chosen with the level of \( R_{it}^g \) (for all \( g \neq h \)) taken as given, Hypotheses 1 and 2 can be tested by estimating a separate equation for each measure of risk taking as follows:

\[
R_{it} = \alpha + \beta_L \Pr(I_{i,t+1}=1|R_{it}=r) + \beta_G \Pr(I_{i,t+1}=3|R_{it}=r) + \varepsilon_{i,t}
\]  

(3)

for \( R_{it} = R_{it}^1, \ldots, R_{it}^n \), where \( \varepsilon_{i,t} \) is white noise. \( \Pr(I_{i,t+1}=1|R_{it}=r) \) and \( \Pr(I_{i,t+1}=3|R_{it}=r) \) are the “baseline” probabilities of reference loss and gain, respectively, in period \( t+1 \) if firm \( i \)'s manager sets \( R_{it} \) at any arbitrary level, \( r \geq 0 \), in period \( t \).\(^4\) For the rest of this paper, \( r \) is set to zero.\(^5\) In other words, the manager is assumed to evaluate the baseline probabilities of future performance outcomes under the condition that he/she does not take any risks associated with \( R_{it} \) (i.e., \( R_{it}=0 \)), which in turn forms a basis for choosing the optimal level of \( R_{it} \). Multicollinearity in Equation (3) is a possible concern because \( \Pr(I_{i,t+1}=1|R_{it}=r) \) and \( \Pr(I_{i,t+1}=3|R_{it}=r) \) are supposed to be negatively correlated.\(^6\) This concern is addressed in Section 5.1.

CPT’s fourfold pattern of risk attitude implies that, when the baseline probability of suffering a reference loss is high (low), the manager tends to be risk seeking (averse), and thus the optimal level of risk taking, \( R_{it} \), tends to be high (low). On the other hand, when the baseline probability of attaining a reference gain is high (low), the manager is likely to be risk averse (seeking), and thus the optimal level of risk taking tends to be low (high). Hypotheses 1 and 2 therefore imply \( \beta_L > 0 \) and \( \beta_G < 0 \), respectively.\(^7\) Note that the use of baseline instead of realized probabilities in Equation (3) avoids endogeneity because the former are by construction independent of the actual variations of \( R_{it} \).

**Data**

Firm performance is measured by return on assets (i.e., \( p_{i,t+1} = ROA_{i,t+1} \)). As is usual practice, growth opportunity (\( GROW_{i,t} \)) is proxied by the firm’s market-to-book ratio.

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\(^4\) The “baseline” is typically defined as the starting point (or, point of departure) from where implementation begins, improvement is judged, or comparison is made.
\(^5\) Alternatively, \( r \) can be set to any non-zero constant without changing the results of subsequent analyses.
\(^6\) \( Pr(I_{i,t+1}=1) \) and \( Pr(I_{i,t+1}=3) \) can be weakly correlated if their shocks are substantially absorbed by \( Pr(I_{i,t+1}=2) \).
\(^7\) Holding \( Pr(I_{i,t+1}=3) \) constant, \( \beta_L > 0 \) implies that the manager tends to take higher (lower) risks if the probability of a reference loss in the next period is high (low). By the same token, holding \( Pr(I_{i,t+1}=1) \) constant, \( \beta_G < 0 \) implies that the manager tends to take lower (higher) risks if the probability of a reference gain in the next period is high (low).
The reference performance ($p_{it+1}'$) was computed as the mean performance (excluding firm $i$) of the industry in which firm $i$ resides. The four-digit industry code from COMPUSTAT was used to group firms into industries. The empirical framework conceptually defines the performance indicator as $I_{it+1} = 1, 2, \text{ and } 3$ for $y_{it+1} < 0$, $y_{it+1} = 0$, and $y_{it+1} > 0$, respectively, where $y_{it+1} = p_{it+1} - p_{it+1}'$. Not surprisingly, very few observations of $y_{it+1}$ are exactly equal to zero, but a large number of them cluster around that value. In particular, about one-fifth of the observations of $y_{it+1}$ falls between $-0.1\sigma_y$ and $0.1\sigma_y$, where $\sigma_y$ is the sample standard deviation of $y_{it+1}$. The empirical strategy of this study is to partition the observations of $y_{it+1}$ into three clusters, namely, reference loss ($I_{it+1} = 1$), reference breakeven ($I_{it+1} = 2$), and reference gain ($I_{it+1} = 3$), where the middle cluster contains observations of $y_{it+1}$ that are sufficiently close to zero. Instead of setting ad hoc cut-off points for the middle cluster, each observation of $y_{it+1}$ was assigned iteratively to one of the three clusters whose median is closest, with Euclidean distance as the dissimilarity measure.

Following the practice of past studies [e.g., Opler and Titman (1994), Coles et al. (2006), Wright et al. (2007), and Bargeron et al. (2010)], this study employs three measures of managerial risk taking, namely, R&D intensity ($R_{it} = RND_{it}$), financial leverage ($R_{it} = LEV_{it}$), and asset tangibility ($R_{it} = TAS_{it}$). R&D intensity is defined as R&D expenses scaled by total assets. Griliches (1981) and Hall (1993) concluded that R&D expenses are positively associated with process or product innovations and corporate value. R&D are risky, however, because the prospects of many R&D-intensive companies, particularly those that have few tangible assets, are tied to the success of new, untested technologies and hence are highly unpredictable. Fixed expenditures on R&D are usually required at the outset in order to develop a new technology into a new product, but the outcome is far from assured. The return on R&D, if any, is likely to take a long time to materialize, but the life-cycle of the resulting product may be short in the face of fast-changing technology. A study by Schwert (2002) shows that technology can explain the unusual volatility of the Nasdaq portfolio (relative to the S&P portfolio) since mid-1999, but firm size and firm immaturity cannot. Hollifield (2002) provides an explanation for this phenomenon: technologies have the flavor of a real option, and the volatility of an option can be much higher than the volatility of the underlying assets because the former represents a highly leveraged position [see also Schwartz and Moon (2000) and Berk et al. (2000)].

Financial leverage is defined as the book value of debt scaled by total assets. Highly leveraged firms are financially vulnerable and thus are exposed to higher risk.
of financial distress. However, the relationship between financial leverage and performance is theoretically ambiguous. Debt financing raises the pressure on managers to perform [Jensen (1986)]. As a consequence, firms with higher leverage should be the most inclined to improve their performance. However, higher leverage means higher agency costs because of the diverging interests between shareholders and debt holders: this moral hazard problem suggests that leverage may be inversely related to performance [Jensen and Meckling (1976)]. In particular, Opler and Titman (1994) found that highly leveraged firms that engage in R&D suffered the most during economically distressed periods. On the other hand, some studies have pointed out that financial distress may improve firm performance by forcing managers to make difficult value-maximizing choices, which they would otherwise avoid [e.g., Jensen (1989) and Wruck (1990)].

Asset tangibility is defined as the book value of the firm’s property, plant, and equipment scaled by total assets, which can be interpreted as an inverse measure of managerial risk taking. For instance, Coles et al. (2006) found that stock return volatility is positively related to R&D expenses and financial leverage, and is negatively related to investment in property, plant, and equipment. The reason for this is that capital expenditures on property, plant, and equipment are typically viewed as low risk investments compared to R&D expenditures [Bhagat and Welch (1995) and Kothari et al. (2002)]. Therefore, managers can take higher risks by reallocating investment dollars away from tangible assets, such as property, plant, and equipment, toward intangible assets, such as R&D activities.

The sample containing 2,871 firms was taken from COMPUSTAT. The sample period is 1992-2006. Table 1 provides summary statistics of $y_{it}$, $RND_{it}$, $LEV_{it}$, and $TAS_{it}$ for $I_{it} = 1, 2$ and $3$.

**As a result of the clustering procedure, around 17% of the sample was classified as reference loss, 48% as reference breakeven, and 34% as reference gain. Among the three clusters, firms belonging to the loss cluster in any period $t$ (i.e., $I_{it} = 1$) appear to have the highest average R&D intensity in the same period. This phenomenon is probably caused by the “full-expense-as-incurred” treatment of R&D expenses under the Generally Accepted Accounting Principles (GAAP) [see, for example, Lev and Sougiannis (1996)]. The levels of financial leverage and asset tangibility are not remarkably different across the three clusters.**

**Results**

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8 Options data from ExecuComp for the calculation of vega, which is a control variable for hypothesis testing, are available only up to 2005.
Probabilities of performance outcomes

The realized probabilities of performance outcomes, namely, Pr(I_{i,t+1}=1), Pr(I_{i,t+1}=2), and Pr(I_{i,t+1}=3), were projected from the ordered logit model as defined by Equations (1) and (2). Assuming that Equation (1) is linear, the estimated coefficients are presented in Equation (4) as follows:

\[
\begin{align*}
\text{Pr}(I_{i,t+1}=1) &= 0.0922'y_{i,t} + 1.5196'RND_{i,t} + 0.2374'LEV_{i,t} + 0.0696'TAS_{i,t} + 0.0081'GROW_{i,t} \\
\text{Pr}(I_{i,t+1}=2) &= 0.0012'y_{i,t} + 1.5196'RND_{i,t} + 0.2374'LEV_{i,t} + 0.0696'TAS_{i,t} + 0.0081'GROW_{i,t} \\
\text{Pr}(I_{i,t+1}=3) &= 0.0012'y_{i,t} + 1.5196'RND_{i,t} + 0.2374'LEV_{i,t} + 0.0696'TAS_{i,t} + 0.0081'GROW_{i,t}
\end{align*}
\]

(4)

The values in parentheses are standard errors. The number of firm-year observations is 12,690. The estimated threshold levels are \( c_1 = -0.9391 \) and \( c_2 = 0.7681 \). As expected, the probability of attaining a reference gain in any period increases with the last-period performance and growth opportunities. A comparison of the coefficients on \( RND_{i,t} \) and \( TAS_{i,t} \) suggests that risky investment (in R&D) is more effective than conservative investment (in tangible assets) in terms of improving the chance of outperforming the rivals. Summary statistics for the realized and baseline probabilities projected from the ordered logit model are presented in Table 2.

**insert Table 2 here**

Table 2 suggests that the probability projection makes reasonable ex ante predictions about the firm’s ex post performance: the mean of Pr(I_{i,t+1}=1) is largest for firms classified into the loss cluster, and is smallest for firms classified into the gain cluster. This pattern is reversed for Pr(I_{i,t+1}=3). In other words, firms falling into the cluster of reference gain or loss in period \( t+1 \) tend to have a higher realized probability of \( I_{i,t+1}=3 \) or \( 1 \), respectively. Table 2 also displays a similar pattern for the baseline probabilities, Pr(.|R_{i,t}=0). Multicollinearity in Equation (3) is a possible concern because Pr(I_{i,t+1}=1|R_{i,t}=0) and Pr(I_{i,t+1}=3|R_{i,t}=0) are supposed to be negatively correlated. The correlation coefficients as reported in the fourth column of Table 2 show that the (realized or baseline) probability of a reference gain is only weakly correlated with the probability of a reference loss, suggesting that the reliability of this study’s findings is unlikely to be substantially influenced by multicollinearity.\(^9\)

Fourfold pattern of risk attitude

To test for Hypotheses 1 and 2, Equation (3) was estimated by fixed-effect regression using three alternative dependent variables, namely, \( R_{i,t}=RND_{i,t} \), \( LEV_{i,t} \), or \( TAS_{i,t} \). By including total assets (\( SIZE_{i,t} \)) as an explanatory variable, the basic model specification controls for the possible relationship between firm size and managerial risk taking. Free cash flows (\( CASH_{i,t} \)) scaled by total assets is also included as a control variable because capital market frictions may impede the ability of

\(^9\) According to the “rule of thumb test” [see, for example, Anderson et al. (2007, p.644)], multicollinearity is a potential problem if the absolute value of the sample correlation coefficient exceeds 0.7 for any two of the explanatory variables.
management to raise cash from external capital markets, and thus some investment expenditures have to be financed by internally generated cash flows [see Richardson (2006)]. Results from the basic model specification are reported in Table 3(a).

** insert Table 3 here **

The results as reported in Table 3(a) are supportive of Hypotheses 1 and 2 concerning the fourfold pattern of managerial risk attitude. For $R_{i,t} = RND_{i,t}$ or $LEV_{i,t}$, the significantly positive coefficient on $Pr(I_{i,t+1}=1|R_{i,t}=0)$ indicates that the manager’s incentives to take higher risks in period $t$ by raising the firm’s R&D intensity or financial leverage are positively related to the baseline probability of suffering a reference loss in the next period. Moreover, the significantly negative coefficient on $Pr(I_{i,t+1}=3|R_{i,t}=0)$ suggests that the manager tends to lower firm risks by reducing R&D activities and financial leverage as the baseline probability of attaining a reference gain in the next period increases. Using asset tangibility ($R_{i,t} = TAS_{i,t}$) as the dependent variable, the signs of the coefficients for $Pr(I_{i,t+1}=1|R_{i,t}=0)$ and $Pr(I_{i,t+1}=3|R_{i,t}=0)$ are dramatically reversed because asset tangibility is an inverse measure of managerial risk taking.

Additional tests for Hypotheses 1 and 2 were conducted by estimating Equation (3) with additional explanatory variables that control for top management characteristics. As in most of the past studies on corporate governance, the CEO is considered the most influential decision-making authority on important agenda such as risk taking. The CEO’s gender ($GENDER_{i,t}$), age ($AGE_{i,t}$), and equity ownership of the firm ($OWN_{i,t}$), and the sensitivity of the CEO’s wealth to stock return volatility ($VEGA_{i,t}$), are therefore included to capture the effects of top management characteristics on managerial risk taking. $GENDER_{i,t} = 1$ if the CEO is male, and = 0 if female. $OWN_{i,t}$ is defined as the aggregate number of shares (excluding stock options) held by the CEO divided by the number of common shares outstanding. $VEGA_{i,t}$ is the change in value of the CEO’s wealth for a one percentage point change in equity volatility.10 Data for calculating these control variables were taken from ExecuComp.

$GENDER_{i,t}$ and $AGE_{i,t}$ are expected to have a positive effect on managerial risk taking because male (vis-a-vis female) or younger (vis-a-vis elder) managers are more inclined to take risks [see, for example, Eaton and Rosen (1983), Barker and Mueller (2002), and Kalleberg and Leicht (1991)]. Managerial risk taking is expected to be inversely related to $OWN_{i,t}$ because equity ownership increases the sensitivity of the manager’s wealth to firm performance and thus increases his/her incentives to avoid risks [e.g., Fama (1980), Amihud and Lev (1981), and Knopf et al. (2002)]. On the

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10 As Guay (1999) showed that option vega is many times higher than stock vega, the total vega of the CEO’s stock and option portfolio is measured by the vega of the option portfolio [see also Rajgopal and Shevlin (2002) and Coles et al. (2006)]. The calculation of $VEGA_{i,t}$ follows Core and Guay (2002a).
other hand, $VEGA_{i,t}$ is expected to be positively related to managerial risk taking because the convexity of option-based compensation may offset managerial risk aversion. Coles et al. (2006) found that higher vega is associated with more investment in R&D, less investment in tangible assets, and higher leverage.

Results from fixed-effect regressions that include control variables for top management characteristics are reported in Table 3(b). As shown in the table, the baseline probabilities of performance outcomes all have statistically significant effects on managerial risk taking and such effects have the same signs as those reported in Table 3(a), which renders additional support for Hypotheses 1 and 2. The results concerning top management characteristics are mixed. CEO age, as expected, is negatively related to financial leverage and is positively related to asset tangibility. However, the positive relationship between CEO age and R&D intensity is counter-intuitive. A possible explanation is that the relationship between CEO age and R&D spending is non-monotonic [see, for example, Ryan and Wiggins (2002)]. Moreover, the CEO’s equity ownership is negatively associated with asset tangibility, which is inconsistent with the agency theory. In common with the findings of Coles et al. (2006), vega has a negative effect on asset tangibility. The effect of vega on risk taking, however, become statistically insignificant if R&D intensity or financial leverage is used as the dependent variable.

The economic significance of the fourfold pattern can be evaluated based on the face values of the estimated coefficients. In Table 3(b), for example, for every 0.1 or 10% increase in the baseline probability of a reference loss, the firm’s R&D intensity and financial leverage will rise by 0.0041 and 0.0062, respectively, and its asset tangibility will fall by 0.0063. These represent 15%, 1.9%, and -1.3% changes from the sample median of the three risk-taking measures, respectively. By the same token, for every 10% increase in the baseline probability of a reference gain, the median firm’s R&D intensity and financial leverage will fall by 4.2% and 2.1%, respectively, and its asset tangibility will rise by 0.5%. The results as reported in Tables 3(a) and (b) also display a special feature of CPT: individuals are more sensitive to potential losses than they are to potential gains. Except for the equation using financial leverage as the dependent variable, the estimated coefficient on the baseline probability of a reference loss is significantly larger than that on a reference gain in absolute value, which implies that potential losses have a more profound impact than have potential gains on the manager’s risk-taking attitude.

**Conclusions**

Previous studies in the accounting and finance literature have examined the determinants of risk taking mainly from the agency perspective, which typically
assumes that agents (e.g., top executives) are expected utility maximizers. However, a substantial body of evidence shows that expected utility theory (EUT) does not provide an adequate description for individuals’ decision-making under risky prospects. Results from past experiments showed that individuals tend to be loss averse and tend to overweight low-probability events and underweight high-probability ones. Capturing these realistic behavioural characteristics of decision making under risky prospects, cumulative prospect theory (CPT) implies the following fourfold pattern of managerial risk attitude – the manager tends to take: (1) high risks over low-probability reference gains; (2) low risks over high-probability reference gains; (3) high risks over high-probability reference losses, and; (4) low risks over low-probability reference losses. This pattern is empirically evidenced by the findings from this study over a wide range of specifications. In particular, the manager’s incentives to take higher risks in any period by investing more in R&D, investing less in tangible assets, and raising financial leverage, are positively related to the baseline probability of suffering a reference loss in the next period. On the other hand, the manager tends to lower firm risks by investing less in R&D, investing more in tangible assets, and lowering financial leverage, as the baseline probability of attaining a reference gain increases.

Risk attitude under EUT is solely determined by the shape of the utility function, and past research on corporate governance typically assumed a concave utility function for the manager. A risk-averse manager is likely to pass up some positive-NPV but risky projects that the risk-neutral shareholders would like undertaken. A convex incentive scheme, by offsetting the concavity of the manager’s utility function, is expected to mitigate the effect of managerial risk aversion and provide the manager with increased incentives to take on risky projects. Analogous to a concave utility function, CPT assumes a concave reference-dependent value function over potential gains. The findings from this study demonstrate that, if the manager is faced with high-probability gains or low-probability losses, he/she tends to act conservatively. Under such a situation, option-based compensation may help motivate the manager to take the optimal risk level, provided that the convex pay structure does not over-correct the concavity of his/her utility function [Guay (1999)].

According to CPT, nevertheless, preference is characterized by a convex value function, i.e., individuals are risk seeking, over potential losses. The fourfold pattern of managerial risk attitude as evidenced by this study suggests that, even in the absence of a convex pay structure, the manager can be risk seeking if he/she is faced with a sufficiently high probability of suffering a future reference loss, or with a sufficiently low probability of attaining a future reference gain. Under such a situation, the manager’s holdings of the firm’s stock options reinforce the effect of managerial
risk seeking and may lead to excessive risk taking. The fourfold pattern of managerial risk attitude warrants a possible extension of research on this issue.

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List of Figures

Figure 1(a): Value function.

Figure 1(b): Probability weighting function.
Table 1: Summary statistics of relative performance and risk taking.

<table>
<thead>
<tr>
<th>Observation</th>
<th>Number of Observation</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( I_{i,t} = 1 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y_{i,t} )</td>
<td>2475</td>
<td>-13.981</td>
<td>-11.01433</td>
<td>8.280741</td>
</tr>
<tr>
<td>( RND_{i,t} )</td>
<td>2475</td>
<td>0.090791</td>
<td>0.0562227</td>
<td>0.102894</td>
</tr>
<tr>
<td>( LEV_{i,t} )</td>
<td>2475</td>
<td>0.335006</td>
<td>0.2909181</td>
<td>0.238338</td>
</tr>
<tr>
<td>( TAS_{i,t} )</td>
<td>2475</td>
<td>0.45137</td>
<td>0.3824413</td>
<td>0.320776</td>
</tr>
<tr>
<td></td>
<td>( I_{i,t} = 2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y_{i,t} )</td>
<td>6962</td>
<td>-0.60891</td>
<td>-0.4394982</td>
<td>2.152633</td>
</tr>
<tr>
<td>( RND_{i,t} )</td>
<td>6962</td>
<td>0.036802</td>
<td>0.0171244</td>
<td>0.051895</td>
</tr>
<tr>
<td>( LEV_{i,t} )</td>
<td>6962</td>
<td>0.330434</td>
<td>0.3191085</td>
<td>0.153048</td>
</tr>
<tr>
<td>( TAS_{i,t} )</td>
<td>6962</td>
<td>0.519227</td>
<td>0.4679174</td>
<td>0.321421</td>
</tr>
<tr>
<td></td>
<td>( I_{i,t} = 3 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y_{i,t} )</td>
<td>4955</td>
<td>7.938754</td>
<td>6.361909</td>
<td>4.93594</td>
</tr>
<tr>
<td>( RND_{i,t} )</td>
<td>4955</td>
<td>0.060591</td>
<td>0.0416108</td>
<td>0.144493</td>
</tr>
<tr>
<td>( LEV_{i,t} )</td>
<td>4955</td>
<td>0.29528</td>
<td>0.278673</td>
<td>0.140783</td>
</tr>
<tr>
<td>( TAS_{i,t} )</td>
<td>4955</td>
<td>0.469462</td>
<td>0.4142749</td>
<td>0.299004</td>
</tr>
</tbody>
</table>

Note: \( y_{i,t} = p_{i,t} - \bar{p}_{i,t} \) is the deviation of actual performance from the reference performance, where \( p_{i,t} \) is firm \( i \)'s performance (ROA) and \( \bar{p}_{i,t} \) is the mean rival performance. By clustering analysis, observations of \( y_{i,t} \) were partitioned into three clusters, namely, reference loss (\( I_{i,t} = 1 \)), reference breakeven (\( I_{i,t} = 2 \)), and reference gain (\( I_{i,t} = 3 \)). \( RND_{i,t}, LEV_{i,t} \) and \( TAS_{i,t} \) are respectively R&D intensity, financial leverage and asset tangibility.
Table 2: Probabilities of reference gain and loss.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
<th>Correlation</th>
</tr>
</thead>
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<tr>
<td></td>
<td>( I_{t+1} = 1 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1) )</td>
<td>0.32228</td>
<td>0.2354285</td>
<td>0.261065</td>
<td>-0.2244</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3) )</td>
<td>0.199313</td>
<td>0.1620464</td>
<td>0.181862</td>
<td></td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>LEV_{i,t} = 0) )</td>
<td>0.341013</td>
<td>0.2584825</td>
<td>0.263446</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>LEV_{i,t} = 0) )</td>
<td>0.18441</td>
<td>0.1447688</td>
<td>0.175616</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>RND_{i,t} = 0) )</td>
<td>0.35079</td>
<td>0.2581419</td>
<td>0.271389</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>RND_{i,t} = 0) )</td>
<td>0.177809</td>
<td>0.1450088</td>
<td>0.167621</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>TAS_{i,t} = 0) )</td>
<td>0.339075</td>
<td>0.2581649</td>
<td>0.263108</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>TAS_{i,t} = 0) )</td>
<td>0.18408</td>
<td>0.1449926</td>
<td>0.177239</td>
</tr>
<tr>
<td>( I_{t+1} = 2 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1) )</td>
<td>0.158363</td>
<td>0.1280512</td>
<td>0.131742</td>
<td>-0.2481</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3) )</td>
<td>0.294839</td>
<td>0.283825</td>
<td>0.140364</td>
<td></td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>LEV_{i,t} = 0) )</td>
<td>0.175678</td>
<td>0.1457934</td>
<td>0.136183</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>LEV_{i,t} = 0) )</td>
<td>0.270731</td>
<td>0.2570322</td>
<td>0.136524</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>RND_{i,t} = 0) )</td>
<td>0.170104</td>
<td>0.1362685</td>
<td>0.139123</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>RND_{i,t} = 0) )</td>
<td>0.278526</td>
<td>0.2709545</td>
<td>0.133811</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>TAS_{i,t} = 0) )</td>
<td>0.174291</td>
<td>0.1441994</td>
<td>0.135106</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>TAS_{i,t} = 0) )</td>
<td>0.272122</td>
<td>0.259293</td>
<td>0.136623</td>
</tr>
<tr>
<td>( I_{t+1} = 3 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1) )</td>
<td>0.07024</td>
<td>0.0461448</td>
<td>0.10463</td>
<td>-0.2571</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3) )</td>
<td>0.508042</td>
<td>0.4905356</td>
<td>0.196749</td>
<td></td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>LEV_{i,t} = 0) )</td>
<td>0.078532</td>
<td>0.0533149</td>
<td>0.109494</td>
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<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>LEV_{i,t} = 0) )</td>
<td>0.483531</td>
<td>0.4626977</td>
<td>0.19774</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>RND_{i,t} = 0) )</td>
<td>0.08104</td>
<td>0.0535891</td>
<td>0.116741</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>RND_{i,t} = 0) )</td>
<td>0.478863</td>
<td>0.4616965</td>
<td>0.194568</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=1</td>
<td>TAS_{i,t} = 0) )</td>
<td>0.077934</td>
<td>0.0538428</td>
<td>0.107975</td>
</tr>
<tr>
<td>( Pr(I_{i,t+1}=3</td>
<td>TAS_{i,t} = 0) )</td>
<td>0.484751</td>
<td>0.4607741</td>
<td>0.198459</td>
</tr>
</tbody>
</table>

Note: By clustering analysis, observations of \( y_{it} \) were partitioned into three clusters, namely, reference loss \( (I_{i,t} = 1) \), reference breakeven \( (I_{i,t} = 2) \), and reference gain \( (I_{i,t} = 3) \), where, \( y_{it} \) is the deviation of actual performance from the reference performance. \( RND_{i,t} \), \( LEV_{i,t} \), and \( TAS_{i,t} \) are respectively R&D intensity, financial leverage and asset tangibility. Figures in the fourth column are correlation coefficients between the probabilities of reference loss and gain.
Table 3: Fourfold pattern of managerial risk attitude.

3(a): Fixed-effect model (basic).

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>$R_{i,t} = RND_{i,t}$</th>
<th>$R_{i,t} = LEV_{i,t}$</th>
<th>$R_{i,t} = TAS_{i,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Pr(I_{i,t+1}=1</td>
<td>R_{i,t} = 0)$</td>
<td>0.047324* (0.0018565)</td>
<td>0.0681888* (0.0051694)</td>
</tr>
<tr>
<td>$\Pr(I_{i,t+1}=3</td>
<td>R_{i,t} = 0)$</td>
<td>-0.0200088* (0.0026544)</td>
<td>-0.0553097* (0.0073101)</td>
</tr>
<tr>
<td>$SIZE_{i,t}$</td>
<td>-1.30e-07* (2.92e-08)</td>
<td>-4.53e-07* (8.09e-08)</td>
<td>-1.28e-06* (1.18e-07)</td>
</tr>
<tr>
<td>$CASH_{i,t}$</td>
<td>0.0178818* (0.0038302)</td>
<td>0.0121079* (0.0093638)</td>
<td>-0.0161617 (0.0135989)</td>
</tr>
<tr>
<td>F-test for Ho: fixed effect = 0</td>
<td>30.55 reject</td>
<td>23.05 reject</td>
<td>52.39 reject</td>
</tr>
</tbody>
</table>

3(b): Fixed-effect model (control for top management characteristics).

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>$R_{i,t} = RND_{i,t}$</th>
<th>$R_{i,t} = LEV_{i,t}$</th>
<th>$R_{i,t} = TAS_{i,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Pr(I_{i,t+1}=1</td>
<td>R_{i,t} = 0)$</td>
<td>0.041239* (0.0020384)</td>
<td>0.0624176* (0.0058764)</td>
</tr>
<tr>
<td>$\Pr(I_{i,t+1}=3</td>
<td>R_{i,t} = 0)$</td>
<td>-0.0113584* (0.0028409)</td>
<td>-0.0685138* (0.0080784)</td>
</tr>
<tr>
<td>$SIZE_{i,t}$</td>
<td>-2.13e-07* (3.99e-08)</td>
<td>-5.75e-07* (1.14e-07)</td>
<td>-1.51e-06* (1.71e-07)</td>
</tr>
<tr>
<td>$CASH_{i,t}$</td>
<td>0.0139484* (0.0037101)</td>
<td>0.0178018 (0.0106268)</td>
<td>0.007788 (0.0158588)</td>
</tr>
<tr>
<td>$AGE_{i,t}$</td>
<td>0.000118* (7.69e-06)</td>
<td>-0.0003892* (0.0001401)</td>
<td>0.0011359* (0.0002091)</td>
</tr>
<tr>
<td>$GENDER_{i,t}$</td>
<td>0.0024749 (0.0036587)</td>
<td>-0.0151542 (0.000022)</td>
<td>-0.0182945 (0.0104768)</td>
</tr>
<tr>
<td>$OWN_{i,t}$</td>
<td>0.0000123 (7.69e-06)</td>
<td>0.0000256 (0.000022)</td>
<td>-0.0000875* (0.0000329)</td>
</tr>
<tr>
<td>$VEGA_{i,t}$</td>
<td>0.0035909 (0.0047979)</td>
<td>0.0381401 (0.023926)</td>
<td>-0.0465377* (0.0107657)</td>
</tr>
<tr>
<td>F-test for Ho: fixed effect = 0</td>
<td>25.40 reject</td>
<td>21.53 reject</td>
<td>43.78 reject</td>
</tr>
</tbody>
</table>

Note: The equation, $R_{i,t} = \alpha + \beta_1 \Pr(I_{i,t+1}=1|R_{i,t} = 0) + \beta_2 \Pr(I_{i,t+1}=3|R_{i,t} = 0) + \epsilon_i$, was estimated by the fixed-effect method. The three alternative dependent variables are $R_{i,t} = RND_{i,t}$ (R&D intensity), $LEV_{i,t}$ (financial leverage), and $TAS_{i,t}$ (asset tangibility). $\Pr(I_{i,t+1}=1|R_{i,t} = 0)$ and $\Pr(I_{i,t+1}=3|R_{i,t} = 0)$ are the baseline probabilities of reference loss and gain in period $t+1$. Reference loss and gain in period $t+1$ are respectively defined as the negative and positive deviations of $1, \pm \epsilon_i$ (performance measured by ROA) from the mean rival performance. $SIZE_{i,t}$ is total assets. $AGE_{i,t}$ is CEO age. $GENDER_{i,t}$ = 1 if the CEO is male, and = 0 otherwise. $OWN_{i,t}$ is defined as the aggregate number of shares (excluding stock options) held by the CEO divided by the number of common shares outstanding. $CASH_{i,t}$ is free cash flows. $VEGA_{i,t}$ is the change in the value of the CEO’s wealth for a one percentage point change in equity volatility. The constant term is not reported. Values in parentheses are standard errors. * stands for significance at 1% level. # stands for significance at 5% level.