Measuring and Utilizing Corporate Risk Tolerance to Improve Investment Decision Making

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Abstract

Strategic investment decisions are generally characterized by financial risk as well as an irrevocable commitment of significant amounts of capital. The firm's willingness to undertake financial risks plays an important role in the investment decision making process. A comprehensive economic decision analysis to evaluate these types of investment decisions requires a measure of the firm's tolerance for financial risk. This paper describes a decision-analysis based methodology for assessing managerial risk tolerance as well as managers' ability to be consistent in terms of their financial risk taking. These assessments are then utilized to assist the firm in establishing a corporate risk policy that can guide strategic decisions under uncertainty. The study firm is a business unit within a U.S.-based major oil company with an annual capital budget of

approximately $400 million. Our findings suggest that managers are generally risk averse but struggle in terms of being consistent in their financial risk-taking decisions. We also find similar levels of financial risk tolerance among groups of managers with disparate responsibilities enabling us to gain a consensus about the appropriate firm-level risk tolerance. This work enabled the firm to implement a financial risk tolerance that could be utilized in the economic decision analysis of investment decisions. Moreover, it provided the firm a basis for communication about risk and risk tolerance and a better understanding of how risk and risk policy can influence strategic investment decisions and business strategies.

Introduction

Economic decision analysis has become an increasingly important technique applied to strategic capital investment problems. The integration of decision analysis and engineering economics can lead to an exceptionally robust decision support model for managers faced with significant risk and uncertainties in their capital investment decisions. The successful integration of engineering economics and decision analysis often requires a clear understanding of the firm's willingness to take financial risk. Application of the firm's financial risk propensity in the capital investment decision making process can go a long way towards improving the quality of decision making under conditions of risk.

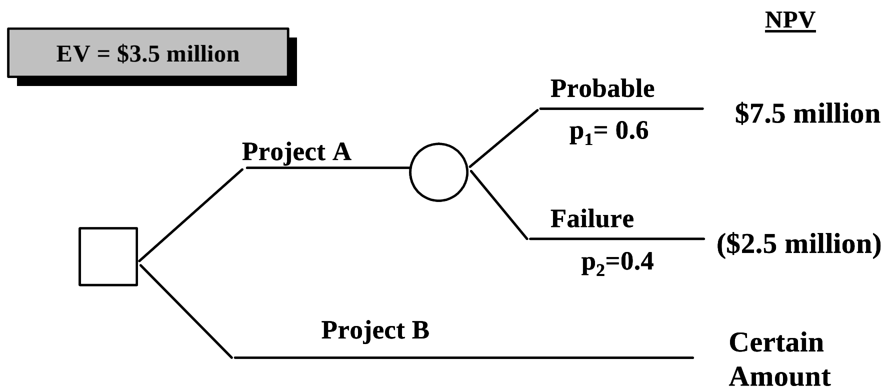
Previous work [1, 2, 3, 4] has demonstrated how corporate risk tolerance can be used to provide guidance about important capital investment decisions under uncertainty. Properly assessing corporate risk tolerance, however, remains a challenging aspect with regard to applying these economic decision analysis techniques. This paper describes a decision-analysis based methodology for assessing managerial risk tolerance and measuring managers' ability to be consistent in terms of their financial risk taking. These assessments can then be utilized to assist the firm in establishing a corporate risk policy that can guide strategic decisions under uncertainty. We provide a description of an application of this methodology at a business unit within a U.S.-based major oil company. During the period of study, the exploration business unit had an annual capital budget of approximately $400 million. The risk tolerance assessment study involved 34 senior managers in the firm including a senior vice president responsible for the exploration business unit.

The technique described in this paper provides a basis for the firm to establish a corporate risk policy and to incorporate the firm’s tolerance for financial risk when evaluating capital investment decisions. It also provides a sound basis for risk communication within the firm enabling managers/decision-makers to have a common basis of understanding about financial risk and risk tolerance. Application of the firm’s risk tolerance in capital investment decisions can have broad implications with regard to choices about projects and the firm’s participation in those projects. This work contributes to the decision analysis and engineering economy literature by (1) providing a sound and practical methodology for measuring corporate risk tolerance; (2) informing the academic community about the practice of economic decision analysis; and (3) describing an actual application with demonstrable value to the participating organization.

The Concept of Corporate Risk Tolerance

Extension of von Neumann-Morgenstern [5] and Savage [6] rational decision making ideas to the level of the firm, where firms make choices among risky alternatives based on preference theory, provides the framework for incorporating the firm's risk attitude into their capital allocation decision process. The basic principles of preference analysis imply that the attractiveness of alternatives should depend on the likelihood of the possible consequences of each alternative and the preferences of the decision maker for those consequences. By utilizing preference analysis, decision makers can incorporate their firm’s financial risk propensity into their choices among alternative capital investment choices. Though managers are evaluating projects which are very different in terms of their risk characteristics, the firm's strength of preference for outcomes and aversion to risk can be consistently applied in the choice process.

The valuation measure we utilize is known in preference theory as the *certainty equivalent*; it is defined as that certain value for an uncertain event which a decision maker is just willing to accept in lieu of the gamble represented by the event [7]. It is, in essence, the "cash value" attributed to a decision alternative which involves uncertain outcomes. The certainty equivalent of a risky investment is a function of the risk characteristics of the investment and the risk preferences of the decision maker. Figure 1 shows a relatively simple example of a certainty equivalent approach. Consider that a firm holds the risky project opportunity shown in Figure 1 (Project A) and assume that the decision makers have a choice of either participating in the risky project or selling the project for some cash value (Project B). Consider that this cash value is their minimum selling price for this asset they hold. Manager A indicates that his minimum selling price is $3.5 million – as a result, he is a *risk-neutral* decision maker since his minimum selling price (certainty equivalent) is equal to the expected value of the risky investment opportunity. On the other hand, Managers B and C are *risk averse* as their minimum selling prices are less than the expected value. In this case, Manager B is more risk averse than Manager C as he is willing to take less cash for this risky project. Another way to think of this is that he is willing to forego more of the expectation associated with this project in order to avoid the financial risk – the risk of losing $2.5 million. Manager D exhibits *risk-seeking* behavior as his certainty equivalent is actually larger than the expected value. Risk-seeking behavior is not often observed in the context of firm risk taking behavior.



	Certain Amt.	***Risk Attitude***
Manager A	$3.5 million	**Risk Neutral**
Manager B	$1.0 million	**Risk Averse**
Manager C	$2.0 million	**Less Risk Averse**
Manager D	$5.0 million	**Risk Seeking**

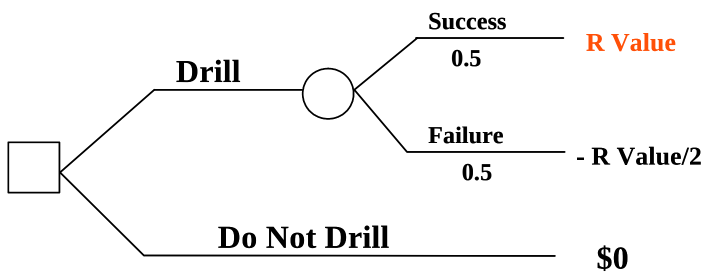
Figure 1

Preference analysis is appealing in that it enables the firm's decision makers to utilize a relatively consistent measure of valuation across a broad range of capital investments characterized by uncertainty. In addition, this approach provides a true measure of the financial expectation foregone when firms act in a risk-averse manner. Preference analysis provides a practical way for the firm to formulate and affect a consistent risk policy. It provides us a means of mapping the firm's attitude about taking on risky projects in the form of a utility function. One functional form of utility which is dominant in both theoretical and applied work in the areas of decision theory and finance is the exponential utility function, and is of the form $u(x) = 1\text{-}e^{-x/R}$, where R is the risk tolerance level, x is the variable of interest, and e is the exponential constant. A value of $R < \infty$ implies risk averse behavior and as the R value approaches ∞, risk neutral behavior is implied (expected value decision making).

In the preference theory approach, the risk tolerance value, *R*, has a considerable effect on the valuation of a risky project. So at this point it may be useful to provide a definition and some intuition to the term risk tolerance. By definition, the *R* value represents the sum of money such that the decision makers are indifferent as a company investment to a 50-50 chance of winning that sum and losing half of that sum [8].

Consider that the notion of risk involves both uncertainty and the magnitudes of the dollar values involved. The central issue associated with measuring corporate risk tolerance (*R*) is one of assessing tradeoffs between potential upside gains versus downside losses under conditions of uncertainty. The decision maker's attitude about the magnitude of capital being exposed to the chance of loss is an important component of this analysis. Figure 2 provides some intuition to the risk tolerance measure, in terms of decisions about risky choices. Consider, for example, that the decision maker is presented three lotteries with a 50-50 chance of winning a certain sum and losing half that sum. The decision to reject Lottery #3 which has an even chance of winning $30MM versus losing $15MM implies that the decision maker would view this investment as too risky. Conversely, the decision to accept Lottery #1 implies that the risk-return tradeoff associated with this lottery is acceptable, given the decision maker’s risk propensity. This iterative procedure is continued until we identify the lottery such that the decision maker is *indifferent* between a 50-50 chance of winning a certain sum versus losing half that sum. In our example, that sum is $25MM and represents the risk tolerance of the decision maker. The risk tolerance value represents a close approximation to the risk tolerance, *R*, in the exponential utility function described earlier. In an empirical study of U.S.-based

RISK TOLERANCE (R) MEASURE



Lottery	R Value	- R Value/2	Decision
#1	$20 MM	- $10 MM	Accept
#2	**$25 MM**	**- $12.5 MM**	***Indifferent***
#3	$30 MM	- $15 MM	Reject

Figure 2

oil companies, Walls and Dyer [9] have shown that firms are risk averse and that the level of financial risk tolerance does significantly impact firm performance.

Measuring Risk Tolerance - Methodology

In order to elicit the risk preferences of individual managers we develop an industry-specific survey that is completed by each of the participating managers. The survey is designed to imitate the types of decisions under uncertainty that managers face in their normal decision making activity. In the context of the petroleum exploration firm, managers are often faced with risky investment projects where they may elect to take varied participation interests. The manager's or firm's level of financial risk tolerance can have a significant influence on what level of interest is selected.

Figure 3a shows an example of the Risk Tolerance Survey utilized in our study and Figure 3b shows an example computational analysis for Prospect #2 of that worksheet.

Each decision maker at the firm was presented 10 investment opportunities as part of his or her annual capital budget considerations. Each of these investments has a value of success and a value of failure that represents the NPV of all future cash flows, both inflows and outflows. The probability value provided represents the chance of occurrence of the specific outcome (success or failure). The decision maker, as an agent for the firm, has a choice of six discrete participation choices ranging from 100% to 0% and is asked to choose the level of participation that would be most preferred by the firm. On the basis of the decision maker's choices for each of the risky investment opportunities, an implied risk tolerance value (R) is approximated. Based on this survey, we also evaluate the decision maker's consistency in terms of risk propensity as well as an estimate of his/her absolute risk tolerance level.

Risk Tolerance Survey

Assume you are presented the following ten exploration prospects as part of your annual budgetary considerations.

Given each prospect's risk characteristics and the option to participate in each venture, ***select your participation level recommendation for each prospect***. Make your choices based on your normal annual drilling budget constraints.

Prospect	Outcome	Value ($million)	Probability	Choice (circle one) Participation Level					
1	Success	45.0	15%	100%	75%	50%	25%	15%	0%
	Failure	-3.0	85%						
2	Success	75.0	50%	100%	75%	50%	25%	15%	0%
	Failure	-30.0	50%						
3	Success	14.5	35%	100%	75%	50%	25%	15%	0%
	Failure	-8.0	65%						
4	Success	16.0	70%	100%	75%	50%	25%	15%	0%
	Failure	-10.0	30%						
5	Success	22.0	25%	100%	75%	50%	25%	15%	0%
	Failure	-5.0	75%						
6	Success	200.0	10%	100%	75%	50%	25%	15%	0%
	Failure	-5.0	90%						
7	Success	60.0	40%	100%	75%	50%	25%	15%	0%
	Failure	-7.0	60%						
8	Success	100.0	20%	100%	75%	50%	25%	15%	0%
	Failure	-9.0	80%						
9	Success	7.5	45%	100%	75%	50%	25%	15%	0%
	Failure	-6.5	55%						
10	Success	150.0	15%	100%	75%	50%	25%	15%	0%
	Failure	-7.0	85%						

Figure 3a

Certainty Equivalent Analysis ($MM)

Prospect #2

Probability of Success	0.5
Probability of Failure	0.5
NPV of Success ($MM)	75
NPV of Failure ($MM)	-30
Expected Value ($MM):	22.5000

	PARTICIPATION LEVEL				
RT	100% W.I.	75% W.I.	50% W.I.	25% W.I.	15% W.I.
1000	21.1225	16.1000	10.9055	5.5389	3.3440
500	19.7488	15.3262	10.5613	5.4528	3.3130
300	17.9295	14.2984	10.1030	5.3380	3.2717
200	15.6871	13.0238	9.5323	5.1946	3.2200
100	9.3089	9.3154	7.8435	4.7661	3.0652
75	5.4547	6.9817	6.7471	4.4824	2.9623
50	-1.1186	2.7501	4.6544	3.9218	2.7574
40	-5.0716	-0.0023	3.1921	3.5092	2.6048
30	-10.0981	-3.8037	0.9877	2.8411	2.3531
20	-16.2417	-9.0232	-2.5358	1.5961	1.8631
15	-19.6165	-12.1813	-5.0490	0.4938	1.3963
10	-23.0688	-15.5723	-8.1209	-1.2679	0.5500
5	-26.5343	-19.0343	-11.5344	-4.0604	-1.2441

Figure 3b

For this procedure to be effective it is critical that the set of risky investment opportunities presented to the manager closely approximate actual decision situations faced by the manager. Note that decisions about participation levels in exploration investments is a very common decision made by managers in the petroleum sector. The questionnaire is designed to replicate as closely as possible the types of decisions managers would face. Both the probability distributions and the scale of the projects, in terms of success and failure costs, should be representative of the manager's typical decision situation. Design of the survey was coordinated with the sponsoring group at the firm in order that the hypothetical projects were consistent with the types of investment decisions that managers would typically face. We constructed three different surveys in order to accommodate for the differences in budget constraints or level of responsibility faced by the respondents. The form of the surveys was identical but the scale of the projects included in each survey differed based on the group's responsibilities. Those three groups were defined as follows:

- **Group A** - Designed for managers with specific drilling budget responsibility. Area managers such as Africa, Asia, Algeria, etc. who have a specific budget amount which served as a frame of reference for their exploration decisions.
- **Group B** - Designed for managers whose frame of reference is the entire exploration budget. Those who fell in this category were the group vice president as well as 5 members of his executive committee.
- **Group C** - Designed for managers of the firm's support groups such as managers from Tax, Human Resources, Law, Operations Support, etc. In the questionnaire we asked the respondent to assume a budget level of $30 million, and make choices on the basis of that capital constraint.

In order to compute an implied risk tolerance for each decision, we utilize the exponential form of utility function, defined as $u(x) = 1\text{-}e^{-x/R}$. This form of utility is concave and thus can be used to represent risk-averse preferences. The *R* value in the exponential defines the level of risk tolerance and the degree of concavity of the utility function. If we know the utility function of an individual we can also determine the *certainty equivalent* of an uncertain gamble for that same individual. As defined earlier in this paper, the certainty equivalent is, in essence, the "cash value" attributed to a decision alternative that involves uncertain outcomes. The closed form-expression for the certainty equivalent, assuming an exponential utility function, has been shown by Cozzolino [10] to be as follows:

$$C_x = -R\ln\left(\sum_{i=1}^{n} p_i e^{-x_i/R}\right) \qquad (1)$$

where C_x is the certainty equivalent, R is the risk tolerance value, p is the probability of outcome i, x is the payoff associated with outcome i, and e is the exponential constant.

We can utilize the example in Figure 3b to demonstrate the computation of the decision maker's implied R value based on a particular decision. Utilizing equation (1), the table of computations in Figure 3b shows a summary of the computed certainty equivalent (C_x) values for five participation choices in Prospect #2 at selected risk tolerance, R, values ranging from $5 million to $1 billion. The risk tolerance values are shown in column 1 of Figure 3b. Each prospect's payoffs (x_i) are linearly adjusted based on the different participation levels and utilized in equation (1) to compute a certainty equivalent. Note that as the risk tolerance level decreases for each interest level (moving down the column) that the certainty equivalent decreases also. Intuitively, because the decision maker is more and more risk averse he/she is willing to give up more expectation to avoid a loss. We use the survey and worksheet to estimate an implied risk tolerance given the respondent's choice about participation on this prospect.

Consider, for example, that in the Risk Tolerance Survey the decision maker selects the 50% participation level in Prospect #2. Note in Figure 3b that at only the $50 million R value does the certainty equivalent value at the 50% working interest dominate all other participation levels. Since this was the decision maker's preferred alternative for Prospect #2 and the preferred alternative must have the highest certainty equivalent, we are able to imply a level of risk propensity consistent with that decision. In the case of Prospect 2 and the decision maker's choice of the 50% interest, his implied risk tolerance would be approximately $50 million. We utilize the same technique for each of the 10 prospects and compute an implied risk tolerance for each based on the decision maker's choice of participation level for each prospect.

As is evident, this represents an approximation technique for assessing the decision maker's risk tolerance. Note that if the decision maker had selected the 75% working interest we could only say that his risk tolerance level falls somewhere in the range of $75-$100 million. Moreover, if he selects the 100% working interest we have an unbounded solution and can only say that his risk tolerance is something greater than $200 million. Careful consideration must be given to development of the risk tolerance questionnaire so as to gain the best assessment of the decision maker's actual tolerance for financial risk.

Results of Study

The results of the risk tolerance survey provide insights into (1) the level of financial risk tolerance exhibited by each of the managers based on their responses to the survey; and (2) the relative consistency by each manager in terms of financial risk-taking across the set of 10 projects presented in the survey. This analysis enables us to provide valuable feedback to the participating managers in terms of how they compare with their peers in terms of financial risk-taking and their ability to be consistent in terms of exposure to financial risk. It also provides a strong basis for communication among managers with regard to risk and risk tolerance.

Figure 4 shows the results of the risk tolerance survey for 20 managers at the firm, as specified by their position responsibility. Recall that each manager responds to 10 different questions on the risk tolerance survey. The risk tolerance value shown in column 4 of Figure 4 represents the *median* implied risk tolerance (in millions of dollars) from the set of project selections made by each respondent in the risk tolerance survey. We choose the median risk tolerance value as it represents a better measure of central tendency when the data set contains a few extreme values, as in the case of very high implied risk tolerances. Recall that when a respondent chooses the 100% working interest level the implied risk tolerance computation results in an unbounded solution. For this reason the median is a much more representative value of the distribution of risk tolerance outcomes for each respondent.

No.	Name	Group	Risk Tol. ($ MM)	Stand. Dev. ($MM)	CM	Consistency Rating
1	VP - Africa	A	**60**	69	1.2	**High**
2	VP - Planning	A	**60**	460	7.7	**Low**
3	VP - Eurasia	A	**74**	381	5.2	**Low**
4	VP - Egypt	A	**60**	53	0.9	**High**
5	VP - UK	A	**35**	25	0.7	**High**
6	VP - Far East	A	**68**	464	6.9	**Low**
7	VP - Canada	A	**60**	73	1.2	**High**
8	VP - Finance	B	**20**	31	1.6	**Moderate**
9	Manager - PAPT	B	**64**	386	6.1	**Low**
10	Manager - PAPT	B	**28**	30	1.1	**High**
11	Senior VP - Expl.	B	**80**	456	5.7	**Low**
12	Manager - Legal	C	**15**	30	2.0	**Moderate**
13	Manager - Land	C	**10**	31	3.1	**Moderate**
14	Manager - Land	C	**40**	397	9.9	**Low**
15	Manager - Technical	C	**60**	73	1.2	**High**
16	Manager - Technical	C	**53**	26	0.5	**High**
17	Manager - Legal	C	**18**	25	1.4	**High**
18	Manager - Geology	C	**68**	463	6.9	**Low**
19	Manager - Geology	C	**50**	391	7.8	**Low**
20	Manager Geophysics	C	**53**	26	0.5	**High**

Figure 4

Column 5 of Figure 4 shows the statistical standard deviation (in millions of dollars) of the implied risk tolerances from the 10 survey questions for each respondent. This gives us a measure of dispersion or variability around the center of location. The standard deviation allows us to provide some informed feedback as to how consistent each manager is in terms of his financial risk-taking. The Consistency Measure (CM) in column 6 represents a measure defined as the standard deviation divided by the risk tolerance (column 5 divided by column 4). The consistency measure is similar to the statistical measure knows as the coefficient of variation. In the case of the consistency measure, however, we utilize the median rather than the mean in the denominator of this computation. The coefficient of variation is used as a measure of relative dispersion around the measure of central tendency, in our case, the median. This measure can be used to compare the relative dispersion of two or more distribution and is a particularly useful measure to compare the relative consistency in risk-taking by the respondents in this study. The Consistency Rating shown in column 7 of Figure 4 represents a relative rating of consistency (High, Medium, Low) in terms of the respondent's implied risk tolerance among each of the prospect selections, where:

- ***High*** denotes a CM value < 1.5;
- **Moderate** denotes 1.5 < CM < 3.5; and
- **Low** denotes a CM value > 3.5

The high, moderate, and low consistency ratings provide a somewhat arbitrary but qualitative measure that can be communicated to the firm's managers. It is a simple categorization of consistency in risk taking that communicates to the manager how consistent he or she was in terms of their financial risk-taking across a set of ten different project decisions.

In order to provide a bit more clarification, consider the analysis of respondents 5 (vice president of the UK region) and 11 (senior vice president of exploration). Note that respondent 5 has an implied risk tolerance of $35 million while respondent 11 has a risk tolerance of $80 million. Based on the definition of risk tolerance, this suggests that respondent 5 is willing to risk up to $17.5 million at an even chance of making $35 million. Respondent 11, however, is willing to risk up to $40 million at an even chance of making $80 million. Respondent 11, in absolute risk terms, is much more willing to take financial risk than respondent 5.

In terms of consistency we see that respondent 5 has a consistency measure of 0.7 while respondent 11 has a consistency measure of 5.7. Though respondent 5 has a lower financial risk tolerance he has exhibited much higher level of consistency in risk-taking across the 10 project selections. Respondent 11, on the other hand, is very inconsistent in terms of his financial risk-taking. Note that the standard deviation of responses for respondent 11 is $456 million and his consistency rating falls in the *Low* category.

Figure 5 summarizes the aggregate results for the entire population (34 individuals), as well as by designated group. The risk tolerance measure in column 2 represents the mean risk tolerance value of all the respondents in the survey. It is, in essence, the mean

Aggregate Risk Tolerance Analysis

Survey Group	R ($ MM)	CM	Consistency Rating
Population	**49**	3.6	**Low**
Group A	**59**	3.0	**Moderate**
Group B	**48**	3.6	**Low**
Group C	**41**	3.8	**Low**

Figure 5

of the median values utilized in the assessment of each respondent's risk tolerance. Note that the mean values across groups do not show wide variation in values. The consistency ratings, however, are relatively low for the population as well as each of the groups. Only Group A has a *moderate* consistency rating which suggests that some action needs to be taken to enable managers to exhibit more consistency in terms of their financial risk taking.

Discussion and Conclusions

There are a number of important findings associated with this risk tolerance study. In terms of the methodology, the survey approach provides a realistic basis for eliciting managerial risk preferences in the petroleum setting. Managers who participated in the survey were generally comfortable with the approach which can significantly improve the validity of the results. The methodology allows us to estimate an implied risk tolerance for each of the respondents and also provide some reliable feedback with regard to the level of consistency in financial risk-taking. This methodology was particularly useful in developing a language of risk and risk-taking for managers after the analysis and study results were presented to the firm.

In terms of the risk tolerance findings, it is apparent that a complex set of investment opportunities can lead to inconsistencies in risk-taking with individual managers. As with most individuals and managers, acting on a consistent risk policy without some formal analysis is very difficult. The results of the Risk Tolerance Survey confirm this finding. The complexity associated with uncertain outcomes and the magnitudes of those outcomes limits our ability to exhibit and act on a consistent risk-taking basis. Economic decision analysis techniques are designed to improve that part of the decision making process. A second issue associated with the study results is that a number of managers selected participation levels in projects with negative expected monetary values. Note that the probabilities and payoffs for prospects #3 and #9 on the risk tolerance survey will lead to slightly negative expected values for each of these projects. Nevertheless, nine of the respondents selected interest levels in either one or both of these projects. In later discussions, these managers indicated that they selected these projects either because of their "high" probabilities of success or benefits from added diversification. In either case, this logic is faulty. One must consider both the probabilities as well as the payoffs in terms of the overall risk characteristics of the project and negative expected value projects do not provide any benefits to diversification and should be avoided in all cases.

Another important result is that differences in risk tolerance by group were relatively small (Figure 5) suggesting an opportunity to agree on a risk tolerance level for the business unit. Given the relatively small differences in group risk tolerances, the firm has a unique opportunity to bring about some consensus on setting an acceptable risk tolerance value. In the case of this exploration business unit they utilized a range of risk tolerances to evaluate future investment decisions under uncertainty. That range was set at $60 - $70 million. All future investment decisions were evaluated on an economic decision analysis basis utilizing this range of risk tolerance. The risk tolerance and certainty equivalent analysis provided the firm guidance regarding accept and reject decisions as well as recommendations regarding the optimal share of a project. It is important to note that corporate risk tolerance changes over time as the firm grows or shrinks in terms of size as well as capital structure. The risk tolerance range established by this business unit represented a starting point for establishing a firm risk tolerance; however, updating this policy on at least a year-to-year basis is essential.

Finally, it is important to point out that this approach to establishing a corporate risk policy provides managers a unique opportunity to openly discuss risk and risk tolerance issues. It provides managers an opportunity to talk about individual differences in risk-taking and what effect their particular decision domain may have on those differences. The study approach and results also provided additional clarification in terms of the complex issues associated with risk and risk-taking. The firm's managers can now openly discuss risk policy in a clear and concise language and understand better its effects on decisions and business strategies in the company.

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