# Risk Analysis and Power Project Capital Structures

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**Abstract:**

The problems experienced recently in the power generation sector have permeated through from project sponsors to the financial institutions that invested, whether through debt or equity, in power projects. In many cases, insufficient attention to the careful measurement and management of risks exacerbated, if not caused, these problems. Now, as financial institutions and investors face the task of restructuring these troubled assets, it is critically important to prevent history from repeating itself by ensuring that any restructuring activities not only recognize the risks facing power generating assets, but also that those risks are communicated effectively among the various stakeholders. In addition, it is important for all of the stakeholders to understand how the restructuring process itself is influenced by risk and risk-taking behavior. This paper develops a framework for using simulation analysis as a common platform from which to communicate about financing risks and capital structure.

**Keywords:** Credit Risk, Power Generation, Project Finance, Restructuring, Risk Management, Simulation, Valuation

## INTRODUCTION

Beginning with the California Energy Crisis in 2000 and continuing through to today, the power generation sector has faced unprecedented tumult. Projects were initially structured with substantial[1] leverage, leaving little margin for error in forecasts of electricity and fuel prices that often extended ten or twenty years into the future. The tremendous volatility in these commodities only compounded the financial challenges facing investors and lenders in power projects. In addition to comparatively straightforward commodity risks, power investors also faced the shifting sands of a regulatory environment still in the throes of massive transformation.

Today, the financial institutions that financed these projects face tens of billions of dollars in debt coming due with dubious prospects for repayment.[2] Equity investors have lost tens, if not hundreds of billions of dollars as the market values of power project sponsors have plunged. The impact of unknown and unmanaged risks has been catastrophic. Confronted with risks that are only all-too-apparent in hindsight, the questions now are (*i*) could better analysis could have prevented these problems from occurring and (*ii*) what can be done to avoid similar problems in the future? How can the industry better measure and manage risks?

Traditionally, the analysis of uncertainty in corporate finance has focused on "scenario analysis" or "best case-base case-worst case" (BBW) studies. Instead, in this article, we outline a framework that uses Monte Carlo simulation to improve understanding of uncertainty in firm values. In highly uncertain environments, BBW analysis does not provide sufficient resolution to inform decision makers properly about risks. This is almost always a consequence of its inattention to the probabilistic nature of risk. In contrast, simulation analysis makes explicit risk's probabilistic nature.

[1] Although initial appearances were often complex and deceptive, once fully unraveled, it was not uncommon to see projects structured with more than 90% debt.
[2] According to Standard & Poor's, over $90 billion in merchant project debt will be coming due between 2003 and 2006, with over $40 billion due in late 2003 alone (Standard & Poor's *RatingsDirect*, November 6, 2003).

In this article, we will begin by examining some of the potential problems with BBW analysis and the advantages of simulation analysis. Then, by way of an example, we will illustrate the simulation approach for two application environments: (*i*) capital structure decision-making for a credit-worthy firm, with management/equity in control, and (*ii*) capital structure decision-making for a firm in financial distress or restructuring, with lenders/debt in control. The different objectives of the controlling stakeholders in each of these cases highlight the important role uncertainty plays in any analysis of firm valuations, whether those efforts are directed at maximizing (equity in control) or preserving (debt in control) firm values. In each case, the simulation approach we outline here provides important insights into risks and opportunities not captured by the BBW or scenario approaches. These insights include estimation of default probabilities, determination of reserve account levels and/or operating limitations, initial design of appropriate capital structures, and how best to restructure a project's capital in the event of financial distress.

## SCENARIO ANALYSIS VS SIMULATION AS A TOOL FOR RISK ANALYSIS

Scenario/BBW analysis begins with noble-enough motives. Recognizing that uncertainty exists, analysts sought to capture the range of possible outcomes in a simple, tractable manner. Although specific approaches may vary, in general the "base case" corresponds to the assumed most likely outcome.[3] Whether the best and worst case outcomes actually refer to "nirvana" and "end-of-the-world" outcomes, or merely "good" and "bad" states often depends on the analyst. In any case, however, rarely are there specific probabilities assigned to these scenarios (*e.g.*, what is the probability of the base case occurring?). In those cases for which probabilities *are* assigned, they are typically assigned (subjectively) to the scenarios themselves, rather than letting them emerge

[3] Formally, "most likely" would imply the modal outcome. Some, however, may assume it refers to the average or "expected" or median outcome. For many complex problems, the mode, median, and average need not be similar, exacerbating risk communication problems. Outcomes here may be NPV, IRR, debt service coverage ratios, *etc*.

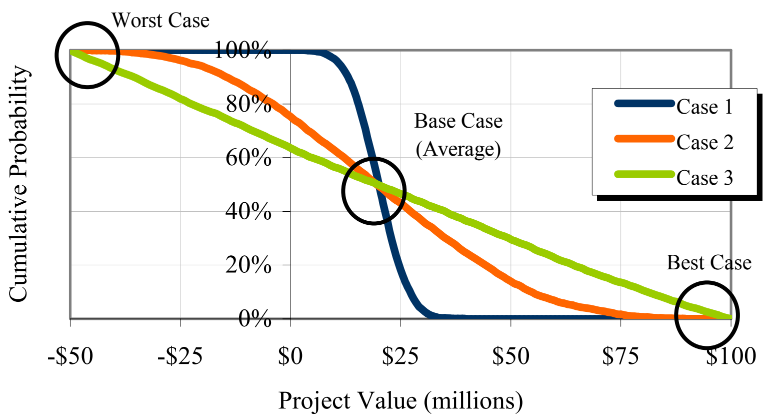
"bottom up" from the fundamental uncertainties involved (electricity prices, fuel costs, load duration curve shapes, *etc*.).

Let us, at the outset, illustrate a key drawback of the BBW approach that highlights the power of simulation. Characterizing a project with uncertain cash flows by only three points is insufficient; an infinite number of possible cash flow risk scenarios exist that satisfy any three chosen points. Figure 1a illustrates this principle using three representative probability distributions of project values. Suppose, for this example, that the best, base, and worst-case scenarios correspond to the maximum, average, and minimum realizations of the distribution of project values.[4] There are an infinite number of possible distributional shapes that *also* include those same three points! More importantly, there is an enormous range in the consequences of the various distributional shapes. In comparing Case 1 and Case 3, Case 3 is more than *fifty times* as likely to result in a below-zero outcome as Case 1 despite having identical best case, base case, and worst case points.

Alternatively, if we were to consider the "base" case as the modal outcome, a similar picture emerges. In Figure 1b, the three cases each have identical minimum, maximum, and modal values. Nevertheless, they have substantially different skewness and significantly different probabilities of realizing below-zero outcomes. More notably, the variance of Case 1 is more than ten times that of Case 3. These profound differences in risk are invisible to BBW analysis. The result is a profound misrepresentation of the risks faced by project investors and lenders. Having an understanding of the entire distribution of possible outcomes is critically important and easily provided by simulation analysis.

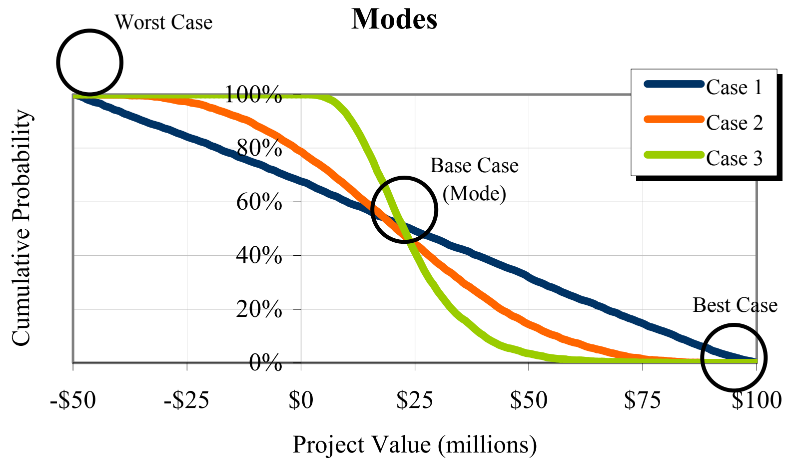
[4] An easy criticism of the BBW approach is that there is little standardization as to what is meant by "best," "base," and "worst" outcomes. Many perceive the "base" case to be the average, which is often confused with the "most likely" outcome (modal outcome). In the presence of significant skewness or kurtosis, the average is likely to be biased away from a representative outcome (*i.e.*, a more stable measure of central tendency, such as the mode or median).

**Figure 1a: Lack of Resolution in BBW Analysis - Averages**




| | *"Worst"* Min | *"Best"* Max | *"Base"* **Average** | Skewness | Mode | Pr(<0) |
|---|---|---|---|---|---|---|
| Case 1 | -50.000 | 100.000 | 20.000 | 0.019 | 19.946 | 0.007 |
| Case 2 | -50.000 | 100.000 | 20.000 | 0.083 | 18.079 | 0.246 |
| Case 3 | -50.000 | 100.000 | 20.000 | 0.114 | -40.870 | 0.375 |

**Figure 1b: Lack of Resolution in BBW Analysis - Modes**




| | *"Worst"* Min | *"Best"* Max | *"Base"* **Mode** | Skewness | Variance | Pr(<0) |
|---|---|---|---|---|---|---|
| Case 1 | -50.000 | 100.000 | 20.000 | 0.010 | 1760.441 | 0.335 |
| Case 2 | -50.000 | 100.000 | 20.000 | 0.060 | 644.541 | 0.219 |
| Case 3 | -50.000 | 100.000 | 20.000 | 0.849 | 107.264 | 0.000 |

In spite of its weaknesses, the BBW approach has been popular in project finance circles for two main reasons: salience and cost-effectiveness. The salience argument is simply that many project decisions were sufficiently clear-cut that sophisticated risk analysis was perceived as unnecessary – projects were not exposed to significant risks or the risks had been dealt with. For example, many power project sponsors believed that the presence of an off-take agreement ("particularly with a large counterparty like Enron") eliminated risks – even when the agreement was with another subsidiary of the sponsor's parent company. While this line of reasoning may still be true for some regulated projects, most investments worth making are not "sure things"; risk *is* salient. The cost-effectiveness argument against simulation reflected, historically, the high cost of computing power. Extending risk analysis beyond simple cases (like BBW) required significant monetary and time investment in analytical hardware and expertise. This is no longer true. Computing prices continue to fall, and the availability of off-the-shelf spreadsheet-based simulation software has made risk analysis tools broadly available.

As a result, investors and lenders can *and should* use simulation to analyze projects. The various sources of uncertainty facing a project should be modeled probabilistically. This is already widely done in banks for market and trading risks; there is no reason why these same techniques cannot be extended to the banking side of the business. Simulation-based techniques such as value-at-risk, now encouraged under the latest Basel Accord standards, represent a looming frontier for corporate credit and project finance groups. Traditional reasons for avoidance of simulation approaches, such as concerns about "garbage in, garbage out" (*where do the input distributions come from?*) and questions about how to use and interpret the results are less criticisms of the methodology than they are an invitation to create more "user-friendly" means of communication between analysts, investors, and managers.

The methods examined in this paper use Monte Carlo simulation analysis to allow "fundamental" uncertainties, such as the price of natural gas or demand, to be incorporated into project values (see Rode, Fischbeck, and Dean [2001] for an example).

For example, natural gas prices might be assumed to be log-normally distributed.[5] A simulation model would randomly select tens or hundreds of thousands of prices from a particular log-normal distribution and thereby calculate a corresponding probability distribution of firm values. On its face, this is a far more sensible approach than subjectively assigning probabilities to scenarios (as in BBW analysis) as a reflection of some underlying uncertainty; prices, after all, can typically be measured, but project values cannot (easily). Rather than having a "high oil price" scenario, for example, we could instead estimate the stochastic process driving crude oil prices using the decades of actual price data available.

In addition to empirically-based distributional characterizations, the second key element of a simulation analysis is recognizing the correlations between influential factors. One problem with BBW analysis is that the best and worst cases often reflect "perfect storm" assumptions. To be sure, perfect storms certainly *do* occur, but not with the frequency that BBW analysis would lead one to believe. Because many correlations are less than 1, it's overly cautious (optimistic) to presume that everything fails (succeeds) contemporaneously. Likewise, inattention to correlation structure in "base" cases is equivalent to assuming that all uncertainties are uncorrelated. This is equally unrealistic. And, as we noted above, there are no longer any reasons *not* to include these factors in project risk analysis. For those applications for which actual data are scarce, we must ask ourselves: *am I better able to estimate simple, fundamental building-block elements, or complex, aggregated scenarios?* Too often, elaborate "scenarios" serve to obfuscate uncertainties, not elucidate them. Clarity is key. Beginning with the next section, we'll illustrate some basic principles of simulation analysis in the context of our discussion of capital structures.

[5] The lognormal specification is commonly used because, among other reasons, it rules out negative prices. Naturally, of course, it is not merely a computational convenience; it also has empirical support for many commodities.

## A SIMPLE VALUATION EXAMPLE

In order to facilitate our discussion, we will use the following simple example. Consider a simple gas-fired power generation firm. It incurs a fixed cost (capital costs) and also an uncertain unit cost (fuel and variable O&M expenses). In return, it receives (in this example) a fixed contract price for the sale electricity.[6] We will assume for simplicity that the firm has one year of operation remaining, and we will assume away taxes, transaction costs, and so forth [Table 1]. Because this is the final year of the firm, we shall refer to the profit as the *terminal payout*. Suppose we were to finance this project with a combination of debt and equity. Specifically, we will capitalize the project with $1 million, of which 60% consists of debt with a cost of $r_D = 8\%$ and the remainder is equity with a cost of $r_E = 15\%$.

**Table 1: Operating Cash Flows**

| | | |
|---|---|---|
| *Revenue* | | |
| Units (MWh) | | 100,000 |
| Price/Unit ($/MWh) | $ | 50.00 |
| Total Revenue | $ | 5,000,000 |
| *Costs* | | |
| Fixed Costs | $ | 2,500,000 |
| Cost/Unit ($/MWh) | $ | 13.92 |
| Total Costs | $ | 3,892,000 |
| **Profit** | **$** | **1,108,000** |

At this point, we must comment briefly on the classic Modigliani and Miller [1958; Miller and Modigliani, 1961] results on the irrelevance of capital structure. We are making no claims that simulation will determine the "optimal" capital structure for a

[6] Naturally, we could also assume that the price received for the good was market-based or otherwise uncertain. Further, we may wish to assume a correlation between prices and costs or quantity demanded, *etc*. Simulation is highly robust to all these augmentations; we ignore them here for clarity of exposition. Even this simple characterization is relevant, however, as it captures many key elements of power generators during the California energy crisis of 2000-2001.

project in a strict economic sense. Our focus is on communicating how operating risks to the firm can impact its various claimants – regardless of the capital structure employed (and regardless of its optimality). That said, the simulation methodology employed here generates information useful to the pricing of various claims, and therefore may be of use in determining which forms of financing are expensive or inexpensive relative to the market, and may be considered "optimal" by specific classes of stakeholders.[7]

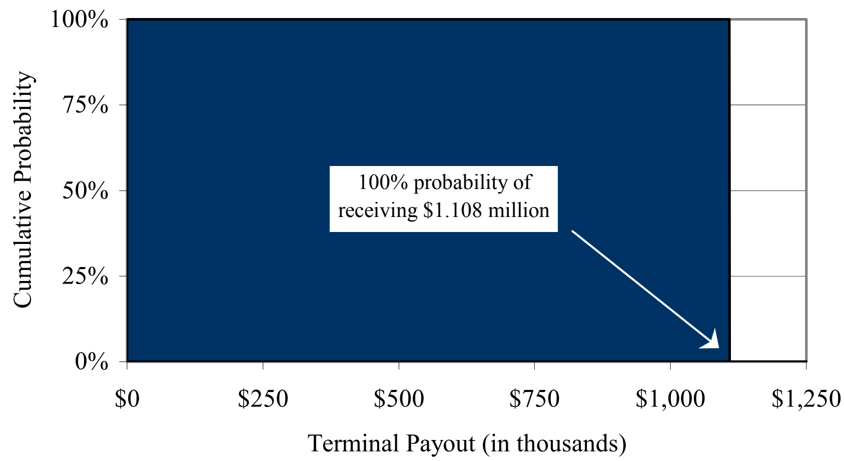
## UNCERTAINTY IN FIRM VALUE: MANAGERIAL DECISION MAKING

When the value of the firm's future cash flows is known with certainty, capital structure issues become essentially irrelevant. For example, in Figure 2, the probability of realizing any terminal payout up to $1.108 million is certain. In such a case, one might pursue 100% debt financing, since there is no risk of default.[8] Further, without a risk of default, the cost of such financing might be expected to be the riskless rate. Of course, the idea of a truly riskless stream of future cash flows is generally relegated to classroom examples.

[7] For example, our simulation model is capable of calculating default probabilities, which can determine appropriate credit spreads and thus prices for various claims.

[8] Again, we shall temporarily assume away such complications as the loss of managerial flexibility and agency problems that may arise from 100% debt financing.

**Figure 2: Project Terminal Payout with No Uncertainty**




The intended role of equity is to bear some of the risk in the project in return for a greater expected profit. To illustrate this distinction, we will include both senior debt (very low default probability) and equity (moderate "default" probability). Of course, uncertainty works in both directions; equity owners (unlike debt claimants) also benefit from deviations in the firm's value *above* the average.

To explore these possibilities, let us begin to model the uncertainties in the generator's operations. We shall assume that the generator's variable costs (fuel) are uncertain and follow a bell-shaped distribution (technically, a truncated normal distribution with a mean of $13.92 and a standard deviation of $2.00). Here, this characterization is simple and hypothetical, but in practice the distributional form could be estimated from historical data, based on a market study, or subjectively determined by analysts.

As a result of this assumption, we are left with the distribution in Figure 3 of the unit operating margin (or "spark spread" of electricity prices minus fuel costs) unit price less unit cost) earned by the firm, which reflects the underlying uncertainty. Together with the firm's fixed costs, the variable operating margin is what determines the free cash flow (and thus NPV) of the project. Consequently, the NPV also reflects that uncertainty. The resulting distribution of net present values (assuming a weighted average cost of capital of 10.8%) in Figure 4 stands in marked contrast to Figure 2, where there was no uncertainty.[9] Instead, although the *expected* NPV equals initial capital at $1 million, actual *realized* NPV ranges from less than half that amount to over $1.5 million. We can also assess the likelihood of obtaining any outcome. For example, there is a 13.4% probability that the realized NPV will be less than $0.8 million.

**Figure 3: Distribution of Operating Margin**

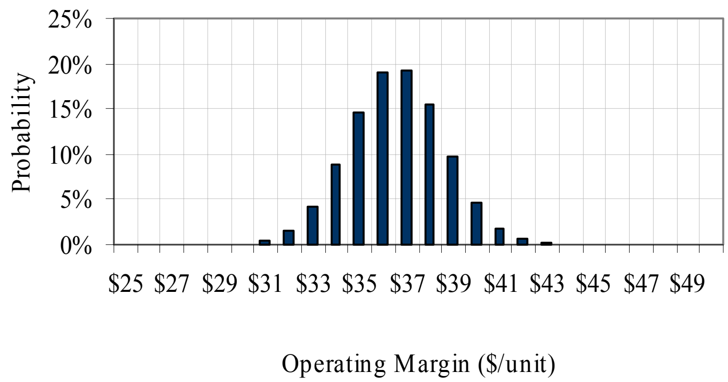
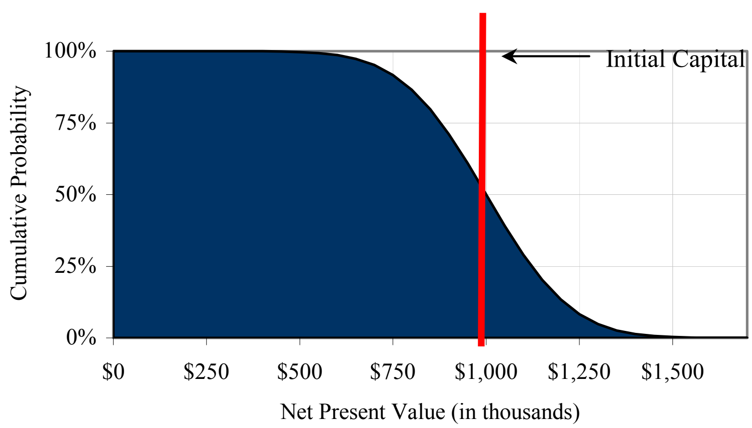



**Figure 4: Distribution of Project NPV with Uncertainty**




[9] The weighted average cost of capital is calculated as (60% × 8%) + (40% × 15%) = 10.8%. We are assuming no taxes in this example. The simulation model was run for 5,000 iterations.

Onto this distribution of capital values, let us now superimpose our capital structure. As one would expect, the different levels of priority implicit in the debt and equity commitments will be manifest in the resulting distribution of uncertain cash flows. Table 2 summarizes the results of the simulation in this respect. For example, at the 25th percentile, the terminal payout of \$973,149 (present value of \$878,294 at 10.8%), is allocated first toward meeting the debt obligation (principal and interest) of \$648,000, with any remainder (\$325,149) belonging to the equity. Note first that \$648,000 + \$325,149 = \$973,149, indicating that the total value of the firm is preserved. Note also, however, that the equity holders suffer a loss (-18.71%) because the value of the firm net of debt is less than their initial equity investment.

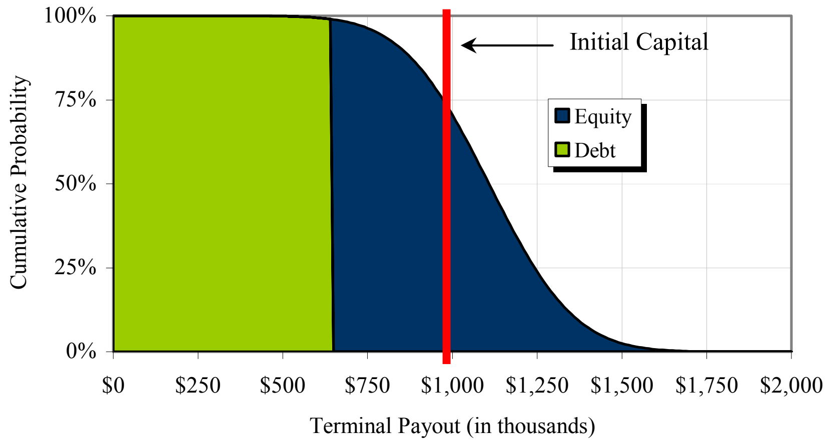
**Table 2: Probability of Achieving Various Capital Structure Values**

*Results from simulation using 5,000 iterations*

| | 5th Percentile | 25th Percentile | Average | 75th Percentile | 95th Percentile |
|---|---|---|---|---|---|
| Terminal Payout | \$ 779,280 | \$ 973,149 | \$ 1,108,006 | \$ 1,315,262 | \$ 1,436,898 |
| NPV | \$ 703,321 | \$ 878,294 | \$ 1,000,005 | \$ 1,187,060 | \$ 1,296,839 |
| Debt Value | \$ 648,000 | \$ 648,000 | \$ 647,280 | \$ 648,000 | \$ 648,000 |
| Return to Debt | 8.00% | 8.00% | 7.88% | 8.00% | 8.00% |
| Equity Value | \$ 131,280 | \$ 325,149 | \$ 460,726 | \$ 667,262 | \$ 788,898 |
| Return to Equity | -67.18% | -18.71% | 15.18% | 66.82% | 97.22% |
| Return on Capital | -22.07% | -2.69% | 10.80% | 31.53% | 43.69% |

It is important to be clear about what the results in Table 2 mean. The results presented for the 25th percentile, for example, indicate that there is a 25% chance that equity holders will lose *at least* 18.71%. Likewise, if we were to examine the 75th percentile, we would observe that equity holders stood to make 66.82% or less three-quarters of the time. Stated differently, there is only a 25% chance that equity returns will exceed 66.82%. Further, it is important to understand the difference between the information conveyed by the percentiles and that conveyed by the average results. How, for example, could the 75th percentile of debt values be \$648,000, but the average debt value be only $647,280? Simulation analysis can make precise statements that remain ambiguous when looking only at averages.[10]

**Figure 5: Capital Structure by Priority of Claim**




Let us now redisplay Figure 4 with our capital structure superimposed (and using terminal payout in place of net present value). Figure 5 illustrates how the *uncertain* future capital of the firm will be distributed. It becomes clear in Figure 5 that the equity is exposed to much greater risk than debt, as one would expect. In fact, we can precisely describe this risk by breaking apart the composite firm distribution of values into its distinct debt and equity components. Figures 6a and 6b illustrates the payoff probability profiles of the debt and equity components, clearly illustrating the different risk profiles.

[10] Considering this question highlights several of the most useful types of information available in the simulation data. Arithmetic averages, as a measure of central tendency, often exaggerate extreme or unlikely influences. Consider, for example, two sequences: (*i*) {1, 2, 3}, and (*ii*) {1, 2, 300}. The second sequence could emerge, for instance, through the erroneous transcription of a decimal point. The impact, however, is substantial. The average of the first sequence is 2 and the average of the second is 101. Other, more stable measures of central tendency, such as the median, are less sensitive. In this example, the average is reflecting the fact that there is a very small chance that the firm will default on its debt. This probability is less than 75%, so it is not reflected in the 75th percentile, but it does bias the average downward.

**Figure 6a: Debt Value Distribution Detail**

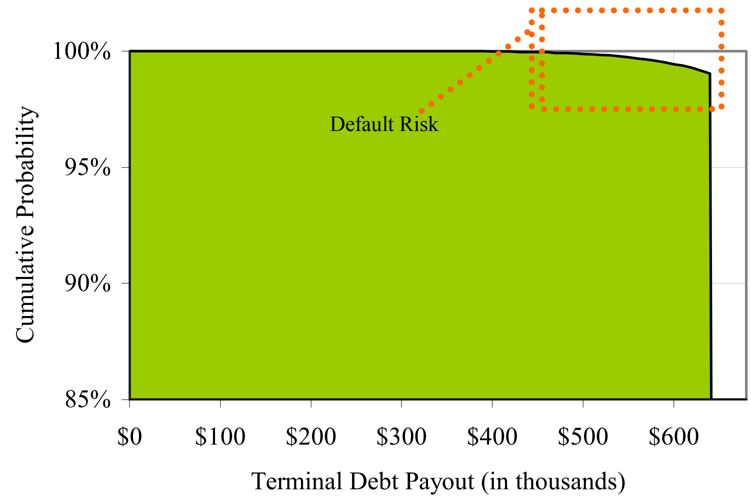
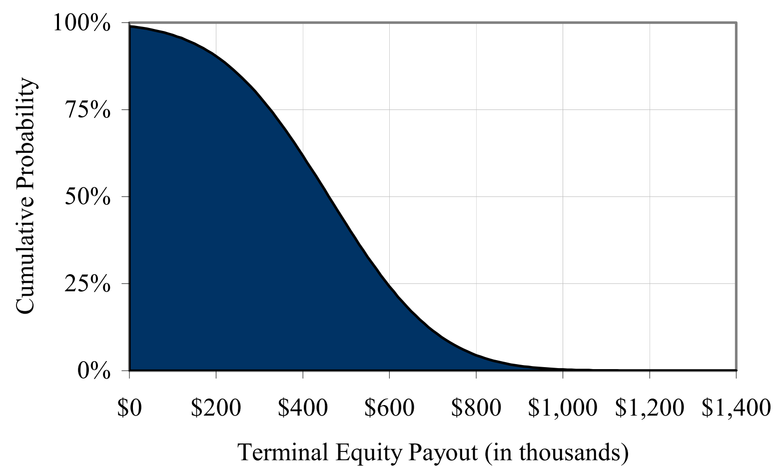
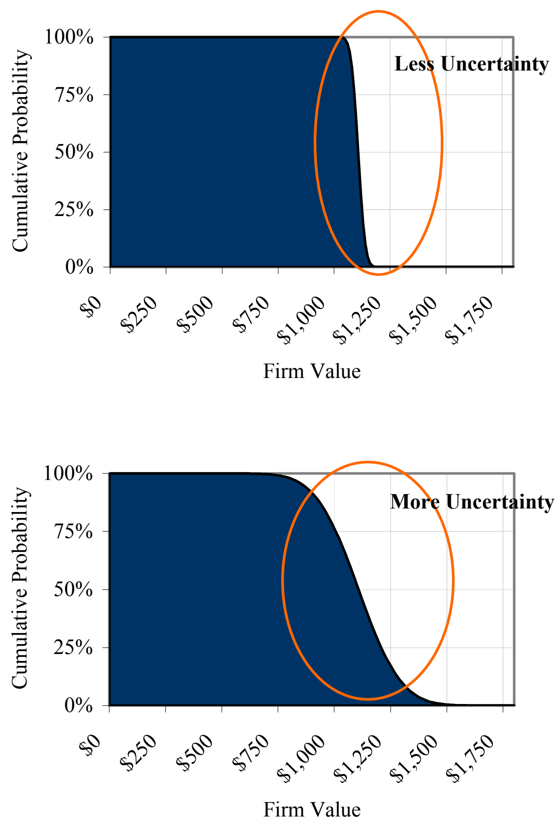



**Figure 6b: Equity Value Distribution Detail**




It is here where we can clearly begin to see the advantage of using simulation to understand firm risks. Unlike conventional BBW analyses, simulation highlights the interplay between risk and value along a continuum, providing far greater information concerning the likelihoods of various possible outcomes. This information is contained graphically in the "slope" of the payoff probability profile. The steepness of this slope indicates the uncertainty present in the firm's value. For example, Figure 7 compares two different profiles. The profile on the top has a very steep slope, reflecting a low degree of uncertainty in the firm's value. In contrast, the profile on the bottom has a comparatively flat (less steep) slope, reflecting a high degree of uncertainty in the firm's value. Statistically, this "slope" reflects the variance of the underlying distribution.

**Figure 7: Payoff Probability Profile Slope as a Measure of Firm Risk**



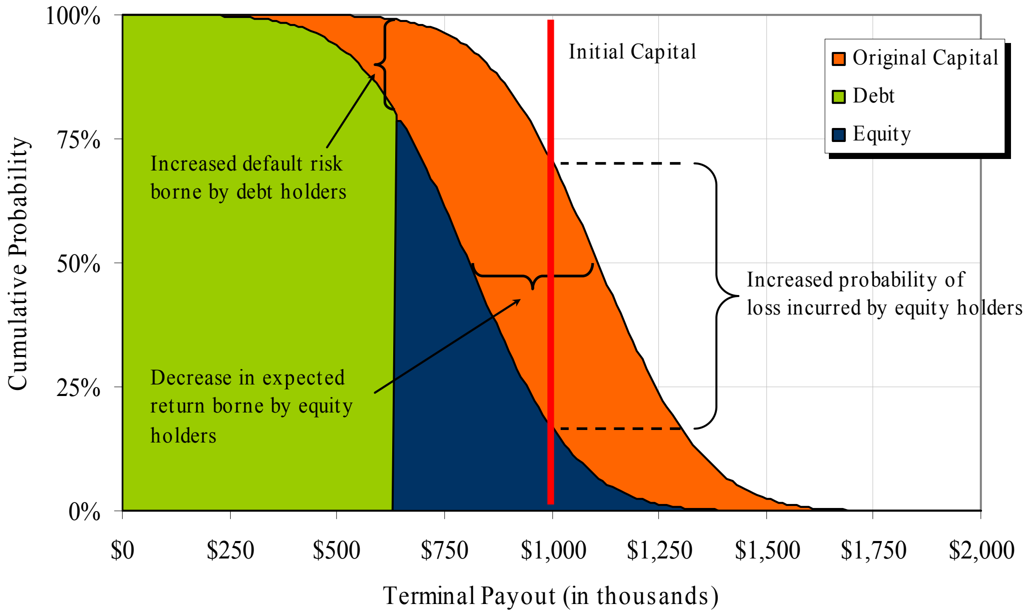

The additional information about risk provided by simulation analysis is not merely an academic exercise. Project objectives and values are influenced directly by the controlling stakeholder class's attitude toward risk. For equity, risk represents opportunity and should be embraced; for debt, it is instead the potential for loss and should be avoided. These attitudes do not change, but depending on which stakeholder class is in control (*i.e.*, whether or not the firm is placed under creditor control), one or the other of these approaches will govern firm behavior. Among other influences, this can often cause abrupt changes in firm values during periods of financial distress – changes that simulation analysis is uniquely suited to address.

For this section, we shall assume that our firm is under normal operation, with equity/management in control and the objective being to maximize the expected value of the equity. We will assume that one of two changes could occur to our one uncertain cost input: (*i*) its mean level could change, while leaving its uncertainty unaffected, or (*ii*) its mean level could remain unaffected while experiencing a change in the level of uncertainty surrounding it.[11]

Suppose, for example, that the firm experienced a sudden increase in the price of its variable input (*e.g.*, from a sudden supply shock or transportation constraint). Specifically, instead of facing an average cost of $13.92/unit, the new average cost became $16.92/unit. In this case, the uncertainty around that average price (the standard deviation of $2/unit) remains unchanged. Consequently, the impact on the firm's overall value is a parallel shift in the payoff probability profile. Although it is obvious that the firm is worse off as a result, it may be less obvious *how* each of the claimants is affected. Figure 8 illustrates the original and new payoff probability profiles.

[11] For the sake of clarity here, we will ignore the various possible combinations of these two events. Examining them would be a trivial extension to the existing examples.

**Figure 8: Capital Structure Impact of Increase in Average Variable Cost without Change in Variance**




A change in the *location* of the sloped part of the profile (but not the slope itself) changes the default probability of the debt and changes the expected payoff to the equity holders *while leaving their risk (variance) unchanged*. This is a key observation, since in risk-adjusted terms, the equity holders are, in a sense, penalized twice (lower returns *without* lower risk). While the debt holders face a substantially increased risk of default[12] (21.2% versus 1.1% previously), the equity holders face both an increased probability of loss and a diminished up-side potential.

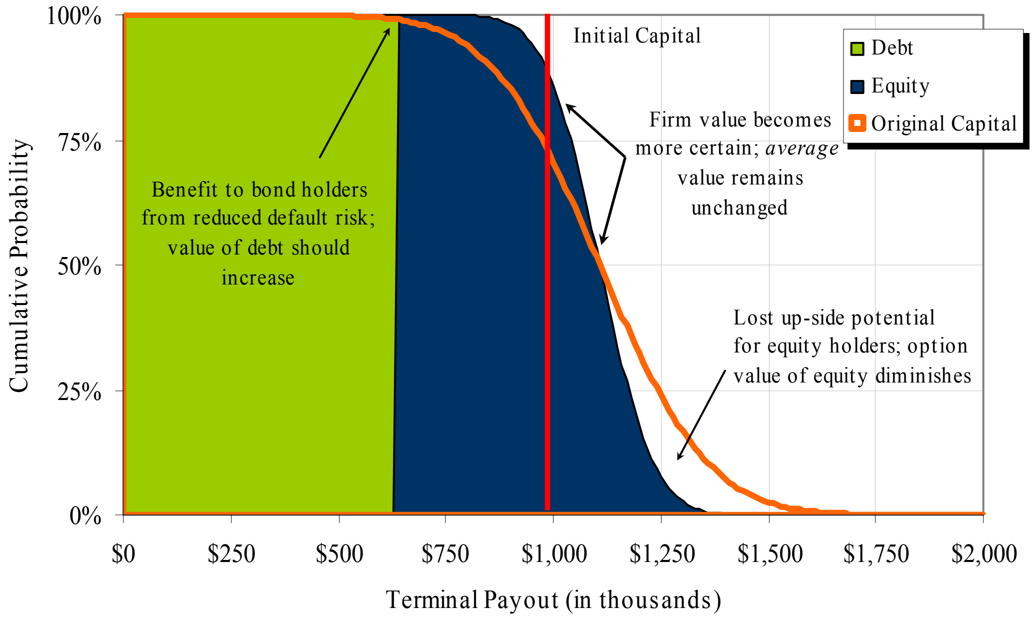
In contrast to the above example, suppose instead that the firm faced a change in the uncertainty surrounding the variable input, but not in the mean price level of its variable input (*e.g.*, by exerting greater control over the supply chain producing its variable input). We will model this as a reduction in the standard deviation of the distribution of variable unit costs from \$2/unit to \$1/unit (with the mean unchanged at

[12] We are defining a default to include any event in which debt holders fail to recover their entire principal and interest due (because of the zero-coupon nature of the debt assumed). Depending on the specific circumstances involved, one may wish to consider a default to include only a failure to repay principal, to allow interest to be deferred, *etc.*

\$13.92/unit). The general belief about the impact of such an event would be that the firm was better off – reducing risks is a good thing. While this is true in general, the real question to ask is "*who* is better off?" It may be possible, in many cases, for one class of stakeholders to be much better off while another class of stakeholders is made worse off. Because of the relative sizes of their positions, however, the firm as a whole remains better off. Of course, the critical issue here involves agency and managerial discretion. Unless bankruptcy occurs, management works for the equity holders. Any decisions made by management should be to maximize the value of the *equity* holders' claims (within any covenants imposed by the debt holders).

As this example will demonstrate, however, decisions that seem prudent (reducing the uncertainty surrounding the key variable cost) may *not* clearly support that objective. Figure 9 illustrates the original payoff profile, along with a new one reflecting the lower variance in variable input costs. Note that as the firm's value became more certain, the consequences were twofold: (*i*) the debt holders' position was strengthened by the reduction in default probability, and (*ii*) the equity holders' position was *weakened* by the reduction in upside opportunity. The second consequence is non-intuitive.

**Figure 9: Capital Structure Impact of Decrease in Variance of Variable Cost without a Change in the Average**




The reasoning behind this consequence makes clear the option-like role of equity. Consider how our equity is defined as the capital remaining after satisfaction of the debt obligation. If we let $E$, $D$, and $V$ represent, respectively, the values of the equity, debt, and the total firm, we can represent the equity payoff as $E = \max[0, V - D]$. But this is precisely the payoff function of a call option and volatility is the biggest driver of option values!

If management acts to reduce the firm's volatility, they will also reduce the firm's option value, which belongs to the equity. Although there are often contracting and transaction cost arguments for reducing volatility, it is imperative that managers understand exactly how any change in the firm's uncertainty profile will affect not only overall firm values, but especially its relative influences on debt and equity. A well-intentioned manager, taking action to reduce volatility, may unintentionally benefit the debt at the expense of the equity by destroying option value.[13] Many power generators, after all, are essentially nothing but a portfolio of spark spread options [Cavus, 2002].

Finally, let us consider an asymmetric shift in the terminal payout probability profile. Our initial assumption that unit costs were distributed normally produced a symmetric distribution of project values. Equity holders would prefer instead that this distribution were skewed to the right, which is to say that up-side potential was enhanced without sacrificing the financial stability of the firm. Immediately, we realize that *positive* skewness is valuable; projects that promote up-side potential benefit the equity holders directly (even if variance is unchanged). More significantly for our purposes in this paper, however, is the observation that skewness is often invisible to conventional best case-base case-worst case assessments of projects because (*i*) such analysis gives insufficient attention to probabilities, and (*ii*) the representation of projects via only three stylized outcomes admits a virtual continuum of possible outcomes, all of which could share the same three points yet remain vastly different.

One common source of asymmetry in firm values is derived from management's ability to respond to negative events in a way that minimizes their impact (or, similarly, to respond to positive events in a way that maximizes their impact). This is precisely the claim of the widely-recognized real options literature (*e.g.*, Amram and Kulatilaka [1999]): flexibility has (option) value. For example, suppose we were to assume that instead of a single pipeline delivering natural gas to the facility, our firm had the flexibility to switch between two different pipelines. We will assume that both suppliers provide the firm with the same average unit cost (normally distributed with a mean of $13.92 and a standard deviation of $2), but that their prices need not be the same at the same time (*i.e.*, on any given day, one of the vendors will charge a higher price). However, averaged over the entire year, their *average* prices are equal.

[13] We must take special note here that "volatility," in a pure statistical sense, refers to deviations both below *and above* the mean. Many individuals, however, perceive "risk" almost exclusively as associated with "loss" or downside risk. In these cases, use of the semivariance may be preferred. With semivariance, however, there is certainly no value in preserving downside volatility. Again, simulation modeling can be used here to make these important differences, however subtle, explicit.

While our intuition may tell us that if average costs remain the same, the firm is no better off, we may also intuitively believe that the addition of flexibility somehow adds strategic value; the firm is now able to pay the *lower* of the two costs. Our simulation analysis enables us to precisely quantify that value – and analyze it as a function of our beliefs about how strongly the two suppliers' prices are correlated (we are assuming a relatively strong 0.5 correlation for this example). The addition of this flexibility creates an option, and this option increases the value of the firm.[14] Most importantly, it increases the firm's value in a way that primarily benefits equity, but without negatively affecting debt.

Figure 10 illustrates how this operating flexibility changes the distribution of the firm's operating margin by "skewing" the distribution toward more profitable outcomes. As noted above, the increase in value is almost entirely captured by equity. Figure 11 once again illustrates our firm's capital structure diagram, now with the impact of this asymmetric shift in the terminal payout probability profile. While the position of the debt remains largely unchanged (there is a modest reduction in default probability), the equity clearly benefits both by an increase in the expected payoff, but also by an increase in the *probability* of obtaining higher payouts. In contrast to the mixed results of the reduction in variance example discussed earlier, the gains to equity here are unambiguous.

[14] This option value is not new. It is an exact analog to a (call) option on the minimum of two risky assets [Haug, 1997]. Simulation, however, provides us with a more accommodating pricing framework than the traditional analytical formula.

**Figure 10: Operating Margin Distribution with and without Option**

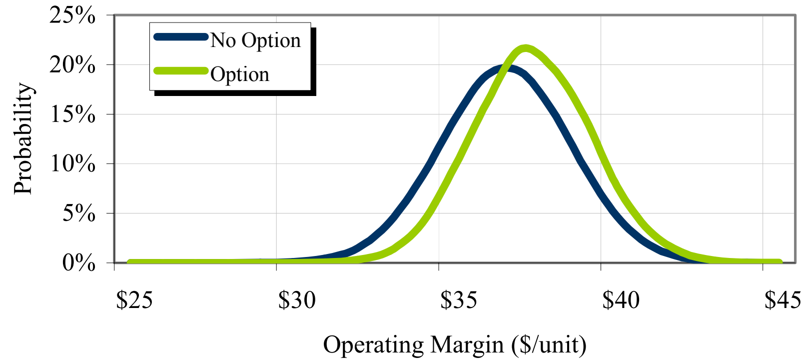
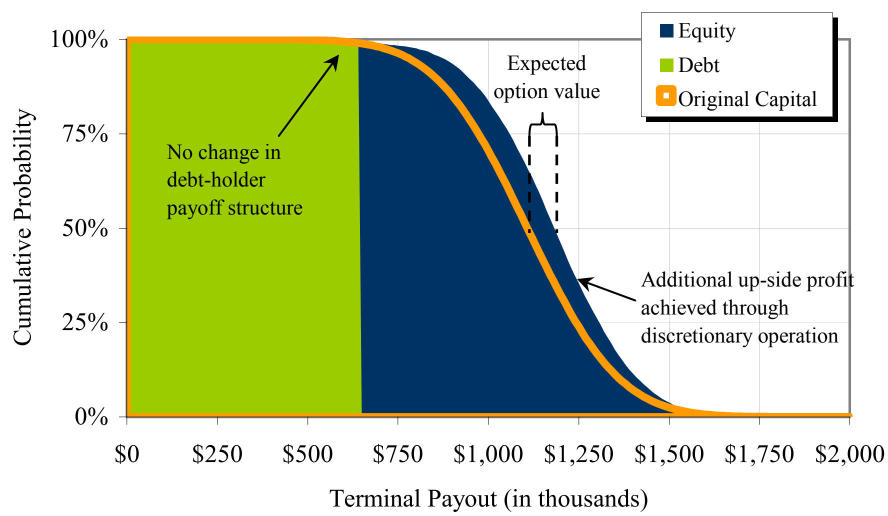



**Figure 11: Capital Structure Impact of Asymmetric Shift in Variable Cost Structure**




Managers, as representatives of the equity holders, face the question "how should I act to maximize the value of the equity?" Consider the following two possible responses: (*i*) reduce risk, (*ii*) increase positive (reduce negative) skewness. It is tempting to reduce risk – and there are often compelling reasons for doing so. However, equity can often be most benefited by pursuing projects that introduce skewness into the payoff probability profile, such as those with real options components. Positive skewness increases equity up-side potential and therefore the option value of equity. The key, then, is not to avoid all risks, but rather to have a thorough understanding of them. This understanding is virtually impossible with conventional forms of analysis, however, since they often lack the resolution required to observe valuation dynamics at the level of individual capital structure components. The simulation approach we outline here, however, not only precisely illustrates the possible outcomes to specific stakeholders, but also provides a powerful tool for "testing" managerial responses to uncertainties in the business environment.

## UNCERTAINTY IN FIRM VALUE: RESTRUCTURING & CREDITOR CONTROL

In the previous section, we examined the impact of firm decision-making on capital structure when the firm was under the control of equity. As firms encounter financial distress and begin to violate debt covenants, and especially during a default event or bankruptcy, the equity holders lose their authority to operate the firm and the debt holders assume control. Clearly, there is a vast array of subtleties involved in such a transition that we will not address here. Our intent, instead, is to illustrate that simulation analysis can be used to examine the impact of these changes and reveal insights that would not be apparent under more traditional forms of analysis.

In contrast to the equity holders' objective, debt holders typically act to minimize the probability of default. Given a default event, they then act to maximize the recovery value of the firm. These new objectives change how the firm is operated and, as a result, can *substantially* influence firm and stakeholder values. For example, whereas in the previous section we saw that volatility was desirable for equity (because it increased the option value of equity), volatility is anathema to debt holders because it can *only* increase the likelihood of default. If, under the control of debt, however, a firm acts to minimize volatility (and thereby minimize default probabilities), it will result in a substantial (additional) diminution of value to equity holders.

To illustrate the ability of simulation analysis to capture and clarify these changes, in this section we will examine a typical scenario: the calculation of default probabilities and what the Basel standards would refer to as the *loss in event of default* (LIED) as a function of uncertain operational parameters (*i.e.*, how does the LIED change as variable costs change). We will "create" financial distress for this example by lowering the unit revenue assumed in Table 1 from $50 to $45 (*e.g.*, realized electricity prices are actually lower than forecasted prices). Table 3 outlines this cash flow structure – all other details remain unchanged from Table 1. The average profit is now insufficient to pay the debt holders both principal *and* interest, which would constitute a technical default. While the firm has not yet actually defaulted, we will assume that creditor influence has increased (perhaps because debt covenants have been violated).

**Table 3: Operating Cash Flows**
**Under Financial Distress**

| | | |
|---|---|---|
| *Revenue* | | |
| Units (MWh) | | 100,000 |
| Price/Unit ($/MWh) | $ | 45.00 |
| Total Revenue | $ | 4,500,000 |
| *Costs* | | |
| Fixed Costs | $ | 2,500,000 |
| Cost/Unit ($/MWh) | $ | 13.92 |
| Total Costs | $ | 3,892,000 |
| **Profit** | **$** | **608,000** |

The first problem may simply be the determination of the default probability. The fact that the *average* outcome is default does not imply that default is inescapable. Figure 12 illustrates the probability profile of the capital structure under financial distress. Figure 13a and 13b illustrate this structure by individual component. It is trivial to see, as a result of the simulation, that the probability of default is 57.9% if we define default to include failure to pay the full interest due (even if principal is paid) and 48.4% if we define default to represent a failure to repay principal.[15]

**Figure 12: Capital Structure by Priority of Claim under Financial Distress**

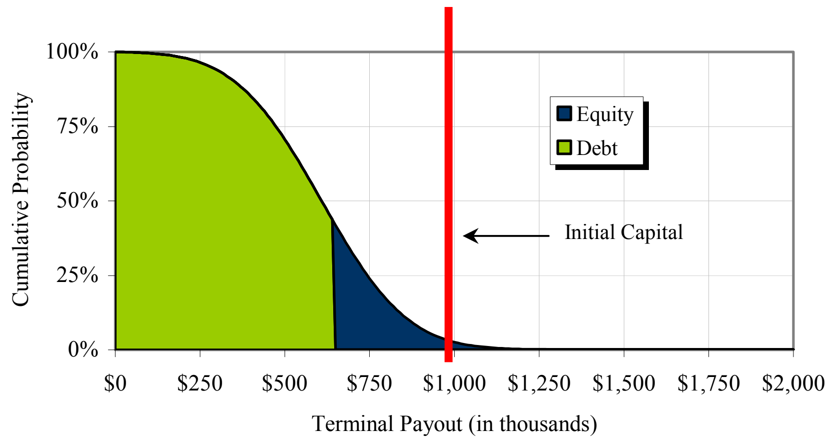
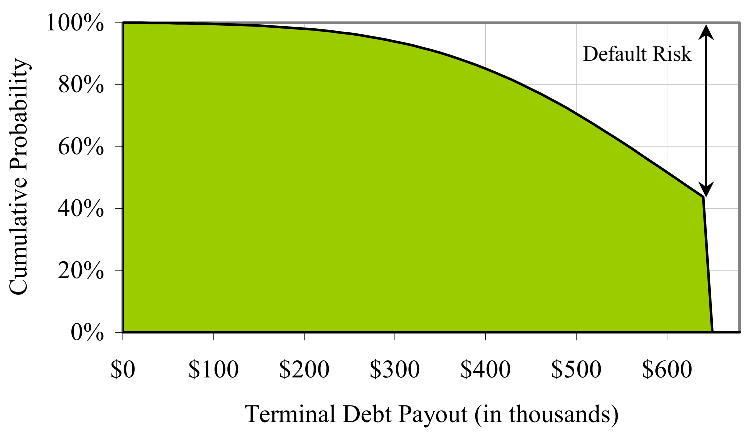
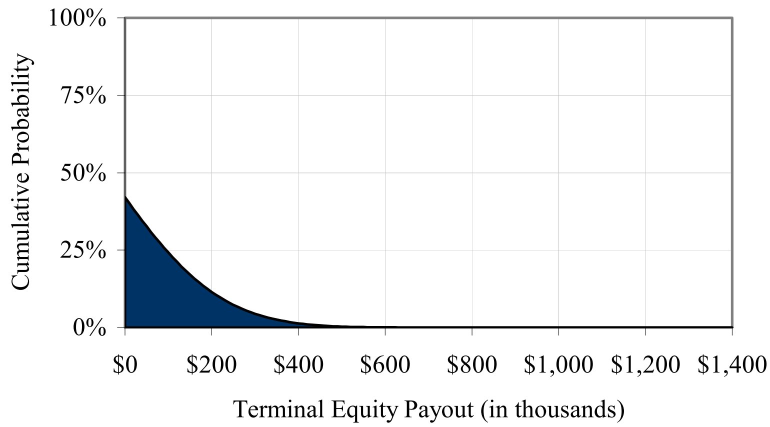



**Figure 13a: Debt Value Distribution Detail Under Financial Distress**




[15] These figures can be seen in the accompanying figures as the distance between 100% and the top of the distribution of values since the probability of default is 1 – Pr(Full Repayment).

**Figure 13b: Equity Value Distribution Detail Under Financial Distress**




If, as these conditions suggest, default is probably imminent, questions may turn to calculation of expected recovery by the debt holders. This calculation is obviously related to the determination of LIED. In our simulation analysis, the equivalent question involves calculation of a conditional probability: *conditional on default, what is the expected value that the debt holders can recover?* Alternatively, *in the event of a default, what is the expected loss borne by the debt holders?* For this calculation, we will assume that failure to pay interest does *not* constitute a technical default (only a failure to repay principal constitutes a default event). As a result, *if* there is a default, we can calculate that debt holders can expect to recover, on average, $443,374. Equivalently, *if* there is a default, debt holders can expect to lose $156,626 of their original $600,000 principal (the loss in event of default).

One important advantage of simulation analysis is that we can continue to extend the study of conditional probabilities easily to more exploratory questions. For example, what is the default probability *given* that variable costs are above average (*i.e.*, above $13.92/unit; one might think of this as the default probability in a "high cost" case, except with far greater precision in this analysis)? 96.9% of the time, when costs are above average, the firm will experience a default. From this information, it is now easy to see that controlling the variable cost (fuel price) uncertainty of the facility is critical under the financial distress scenario. As a result, the firm may wish to study the possibility of hedging their natural gas exposure. Suppose that the natural gas supplier was willing to guarantee a price within ±$1 of the average in return for a fixed fee. Given that the variable cost exposure was now “hedged” to be between $12.92 and $14.92 per unit, the expected recovery in a default scenario increases to $555,003 – an increase of $111,629 over the unhedged expected recovery. This amount puts a ceiling on the amount the debt would be willing to have the firm pay for such a guarantee. If the vendor offered the guarantee for $50,000, the debt holders could strengthen their position by accepting it.

However, in the above example, no mention was made of the value to equity. With debt in control and the objective of the firm shifted to minimizing default probabilities and LIED, the equity can be significantly penalized. The hedging offer above is a way of limiting the volatility of the firm’s value. Although this can be beneficial to the debt holders, any reduction in volatility reduces the option value of equity. From the equity’s perspective, *paying* for such a loss in option value is merely adding insult to injury. Clearly, perspective matters, and simulation analysis can make explicit the bottom line impact of a change in operating perspective to each of the firm’s stakeholders, perhaps enabling them to identify strategies that are mutually favorable.

## CONCLUSIONS

Simulation is an unparalleled tool for asking questions of the type: “what would happen if…?” It is sensitivity analysis in its most refined and powerful form. Simulation also reduces the degree to which unsupported conjectures drive asset values. By modeling uncertainty in asset or project values as emerging endogenously from the underlying fundamental uncertainties (*e.g.*, variable costs or market prices) rather than being superimposed on the capital structure through assumptions about what constitutes “best case” and “worst case” scenarios, managers, lenders, and other stakeholders gain not only a clearer perspective on how the firm's value changes (both as a whole and within each class), but also gain a platform from which to communicate about such values.

In this paper, we have illustrated how simulation can be used by managers and investors to analyze potential opportunities and structure the firm's capital accordingly. By incorporating the continuum of possible outcomes, as opposed to a select few, managers and investors are given a better perspective with which to make decisions. The ability to tie operational risks (such as fuel prices, maintenance expenses, regulatory compliance costs, *etc*.) directly to impacts on capital structure provides a unifying mechanism for understanding firm value and provides insight into areas in which non-intuitive negative consequences may arise from well-intentioned actions. We have also illustrated how creditors can use simulation to inform decision making regarding the division of firm value among claimants and how the impact of discretion granted to managers by creditors influences the value of claims.

Enormous advances in computing power and the widespread availability of off-the-shelf simulation software that can be used interactively within common spreadsheet packages mean that vast amounts of information can now be obtained quickly and cost-effectively through the use of simulation modeling. Even simple implementations of simulation models can generate significant insight, providing an edge to savvy managers and investors in an environment characterized by ever-narrower margins and ever-greater risks.

## REFERENCES

Amram, M., and N. Kulatilaka. *Real Options* (Boston, MA: Harvard Business School Press, 1999).

Cavus, M. Valuing a Power Plant Under Uncertainty. In S. Howell, A. Stark, D. Newton, D. Paxson, M. Cavus, J. Pereira, and K. Patel, eds., *Real Options: Evaluating Corporate Investment Opportunities in a Dynamic World* (London: Prentice Hall, 2002).

Haug, E. *The Complete Guide to Option Pricing Formulas* (New York, NY: McGraw-Hill, 1997).

Miller, M., and F. Modigliani. "Dividend Policy, Growth, and the Valuation of Shares." *Journal of Business* **34:4** (1961): 411-433.

Modigliani, F., and M. Miller. "The Cost of Capital, Corporation Finance, and the Theory of Investment." *American Economic Review* **48:3** (1958): 261-297.

Rode, D., P. Fischbeck, and S. Dean. "Monte Carlo Methods for Appraisal and Valuation: A Case Study of a Nuclear Power Plant." *Journal of Structured and Project Finance* **7:3** (2001): 38-48.