Measuring Investment Distortions when Risk-Averse Managers Decide Whether to Undertake Risky Projects

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We create a dynamic model in which a self-interested, risk-averse manager makes corporate investment decisions at a levered firm with characteristics typical of public US firms. We examine the magnitude of distortions in those decisions when a new project changes firm risk and find expected changes in the values of future tax shields and bankruptcy costs to be important factors. We evaluate the extent to which these distortions vary with firm leverage, debt duration, project size, managerial risk aversion, managerial non-firm wealth, and the structure of management compensation packages.

The corporate finance literature has extensively modeled the distortions in investment decisions that result from conflicts of interest between claimholders. These models generally imply that firms make suboptimal project choices, either in terms of good projects that are rejected, or bad projects that are accepted. Since it is difficult to observe management forecasts of project net present values, especially for projects that are not ultimately undertaken, it is difficult to assess the importance of these models quantitatively.

One approach to evaluating the importance of investment distortions is to first calibrate a model that uses data from public firms, and then estimate the magnitude of the distortion in investment decisions by examining the characteristics of the projects that the model predicts would be accepted or rejected. Studies such as those by Mello and Parsons (1992), Leland (1998), Parrino and Weisbach (1999), Moyen (2000), and Titman and Tsyplakov (2001) use this approach to estimate the magnitude of the impact of stockholder/debtholder conflicts on investment decisions. However, papers that examine stockholder/debtholder conflicts in this way typically do not consider the conflict of interest between managers and stockholders. Instead, they usually assume that managers seek to maximize the value of the firm's stock.

In this article, we relax this assumption and estimate the magnitude of stockholder/manager conflicts, their interactions with stockholder/debtholder conflicts, and their effect on a firm's investment decisions. We do so by considering a risk-averse manager who makes the investment decisions at a firm, and at the same time seeks to maximize his own utility function. In our model, the manager owns shares in a levered firm (which he cannot hedge), options on the firm's stock, and has other wealth that is independent of the value of the firm. We model the firm by using the

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dynamic approach of Ju (2001), in which the underlying state variable is the unlevered value of the firm, the firm issues new debt when old debt matures, interest payments are fully deductible in computing corporate taxes, and the firm enters bankruptcy if its value hits a prespecified bankruptcy boundary. If the firm defaults on its debt, the stock owned by the manager (and other shareholders) becomes worthless and the debtholders recover a fixed percentage of the remaining levered value of the firm.

We characterize the set of fairly priced projects that a utility-maximizing manager would choose to undertake and that this manager would reject. In doing so, we calculate the impact of potential projects on the value of stockholder and debtholder claims. We account for changes in the expected value of the firm's tax shields and the expected bankruptcy costs attributable to the acceptance of each new project. This approach allows us to quantify the magnitude of wealth transfers between stockholders and debtholders that occur when projects with different characteristics are accepted.

We also quantify the magnitude of stockholder/manager conflicts that result from the manager's risk aversion by computing the net present value (NPV) of the project that makes the manager indifferent between accepting or rejecting it. We call this measure the "indifference NPV." We also compute the incremental cost of equity, relative to that required for a zero NPV project, which makes the manager indifferent to undertaking or rejecting a project. The sensitivities of the indifference NPV and the incremental cost of equity to the risk of the project provide direct measures of how averse a manager is to project risk.

Our analysis includes several innovations. Using the unlevered value of the firm as the underlying state variable distinguishes our model from the important capital structure models of Kane, Marcus, and McDonald (1984, 1985) and Fischer, Heinkel, and Zechner (1989), in which the underlying state variable is the optimally levered value of the firm. By modeling the unlevered value of the firm, we are able to directly analyze the impact of the manager's project choices on tax shields and bankruptcy costs.

Our modeling framework is also more realistic than other recent work in four noteworthy ways. First, unlike the models in Leland (1994) and Leland and Toft (1996), in which capital structure does not respond to varying firm value, our model allows the manager to periodically adjust the level of debt as firm value changes. Second, unlike other models in papers such as Goldstein, Ju, and Leland (2001), in which the firm is liquidated after it goes bankrupt, in our model the new shareholders (old debtholders) optimally lever the firm after bankruptcy. Third, by considering utility-maximizing rather than value-maximizing objectives, we can evaluate the effect of executive compensation plans on the firm's investment distortions.[1] Finally, because we calibrate the model to actual data, we can quantify the magnitudes of several previously unexplored effects, including the effect of changes in project risk on the value of tax shields and expected bankruptcy costs.

We first estimate the magnitude of stockholder/manager conflicts for a hypothetical firm that has characteristics typical of publicly traded firms in the Standard and Poor's Compustat database. Before adopting the project, the firm is financed with ten-year coupon-bearing debt and has a market debt to total capital ratio of 22.62%. We note here that although we calibrate our model with specific capital structures in our analyses, the model can be used to estimate distortions for any capital structure. Given the disagreement in the literature on the

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[1] Recent papers by Lewellen (2004) and Ross (2004) also consider utility-maximizing models. Lewellen examines differences in the impact of changes in volatility from financing decisions on the cost of debt to stockholders and the cost of debt to risk-averse managers who are not diversified. She finds that executive stock options can decrease a manager's willingness to take risks and diminish his or her willingness to use debt. Ross shows that no incentive schedule exists which makes all expected utility maximizers either more or less risk averse. He identifies necessary and sufficient conditions for incentive schemes to increase or decrease managerial risk aversion.

correct model for a firm's capital structure, having estimates of investment distortions that are not dependent on a firm's capital structure being optimal is also a benefit of our approach. Further, in related work, Ju, Parrino, Poteshman, and Weisbach (2005) show that the optimal capital structures predicted by our model are similar to both capital structures observed in practice and to the 22.62% market debt to total capital ratio assumed for the hypothetical firm in our analysis.

We assume that the manager has a constant relative risk aversion (CRRA) utility function with a risk-aversion parameter of two. Further, the manager has 50% of his non-option wealth invested in shares of the firm, with the remainder invested in risk-free assets. We assume that the value of the project's assets (e.g., the value of the cash flows from operations) is 20% of the value of the firm's assets without the project, and that the firm finances the project by issuing new debt and equity in the same proportions as the firm's outstanding debt and equity before it adopted the project.

The limitations of our approach are that it does not allow for re-optimization of the manager's compensation or the financing mix to reflect the impact of the project on the characteristics of the firm. Instead, we assume that as a means of obtaining first-pass estimates of the magnitude of investment distortions arising from agency costs, the firm uses a compensation plan and a capital structure similar to those in typical firms.

We vary the volatility of the value of the assets of the firm with the project, holding other factors constant, to determine the effects of incremental changes in risk. This analysis indicates that in contrast to arguments in the literature, a manager at a typical firm who receives equity-based compensation is likely to favor projects that lower firm risk. In other words, he will want to undertake some projects that lower firm risk even if they have a negative NPV, and to ignore some high-risk projects that have a positive NPV. This behavior occurs even though low risk (risky) projects transfer wealth to (from) debtholders from (to) stockholders.

Many studies argue that managers' incentives to take risks increase substantially with firm leverage, because wealth transfers between stockholders and debtholders increase with leverage (see, e.g., Myers, 1977). In our model, wealth transfers do increase with leverage. However, the values of tax shields and bankruptcy costs are also more sensitive to changes in risk when leverage is higher. The overall relation between leverage and risk-taking behavior appears to be nonlinear. When leverage is low (e.g., at typically observed levels), managers prefer safe projects. However, at high leverage ratios (e.g., above 50% debt/total capital), the wealth transfer effect dominates other effects and managers have incentives to take negative NPV projects that increase firm risk.

We also consider the sensitivity of these results to variations in other firm- and manager-specific parameters. We find that distortions in investment decisions decrease as the duration of the firm's debt increases, because the larger wealth transfers associated with longer maturity debt offset to a greater extent the preference for relatively safe projects. We also find that larger projects exacerbate the distortions attributable to stockholder/manager conflicts.

Our analysis of manager characteristics indicates that the magnitude of the stockholder/manager distortions is particularly sensitive to the choice of the risk-aversion parameter. Investment distortions are also very sensitive to changes in the fraction of the manager's wealth invested in the firm. Investment decisions are less sensitive to changes in share values when the equity in the firm owned by a manager represents a relatively low share of his total wealth.

Finally, the structure of a manager's compensation can also affect risk-taking behavior in important ways. In our model, not surprisingly, options induce better (from the perspective of stockholders) risk-taking behavior than does restricted stock, and options that are issued in-the-money make managers more risk averse than do options issued with exercise prices equal to or greater than the current market price of the firm's stock.

In addition to estimating the magnitudes of investment distortions for a hypothetical firm, we use our model to estimate these distortions at 15 public firms from three industries. These estimates use the actual stock and option holdings of the CEOs and firm-specific characteristics. They show that CEOs with a risk-aversion parameter of two will prefer to reject some positive NPV projects even when the volatilities of the projects' assets are less than twice the volatilities of the existing firm assets. This evidence suggests that managers can have limited incentives to invest in highly risky projects even when they receive relatively large amounts of stock and option-based compensation.

In this article, we focus on conflicts due to differences in risk aversion. Zingales (2000) suggests that these effects are understudied and potentially important considerations in corporate financing decisions. However, although we focus on managerial risk aversion, we do not wish to downplay the importance of other stockholder/manager conflicts. In addition to the risk-related reasons considered here, conflicts between stockholders and managers arise because managers tend to empire-build. Conflicts also arise because of concerns about a manager's human capital both inside and outside of the firm, a tendency to focus on short-term objectives, a propensity to herd and not utilize private information about a project's quality, a preference for an easy job, and finally, overconfidence. Stein (2001) provides an excellent summary of these considerations.

The article is organized as follows: In Section I, we describe our model, and in Section II explain how it is calibrated. In Section III, we discuss implications of the model for investment decisions at a typical firm, and in Section IV the implications for a sample of public firms. In Section V, we summarize the results and discuss the extent to which stockholder/manager problems of the type considered in this article are likely to have an important impact on corporate financial decisions.

I. The Model

We use a model based on Ju (2001) to estimate the magnitudes of the agency conflicts. In this model, the value of the cash flows from a firm's operations follows geometric Brownian motion. The firm issues debt with a maturity of T, which pays a continuous, constant (tax-deductible) coupon. The manager's wealth at time 0 is divided between non-firm wealth and his stake in the firm, which consists of equity shares and standard European call options, which expire at time T_u. The manager cannot sell or hedge his shares or options. We assume that the manager's non-firm wealth grows at the risk-free rate, r, and is therefore uncorrelated with the value of the manager's stake in the firm. Under the assumption that the manager can replace his salary with an equal salary if the firm goes bankrupt, we treat his salary as part of his non-firm wealth. A CRRA utility function defined over his entire wealth gives the manager's utility.

At time 0, the manager has the opportunity to undertake a project. Without the project, the value process of the firm's assets (i.e., the value of the cash flows from operations) follows a geometric Brownian motion. If the manager accepts the project, the value process of the assets still follows a geometric Brownian motion, but with drift and volatility parameters that can differ from those without the project, depending on the characteristics of the project. The manager decides whether to accept the project by maximizing, at time 0, his expected utility at time T_u.

The model is in continuous time with $0 < T_u < T$. At time 0, the value of the firm's assets without the project is $V_{NP}(0)$. (The subscript *NP* refers to quantities when the project is not taken (no project) and the subscript *P* refers to quantities when the project is taken (project).) The firm's capital consists of N_{NP} shares of stock with a total market value of $E_{NP}(0)$ and F_{NP} face value of debt that matures at time *T*. The debt pays a coupon at a constant annualized rate C_{NP} and has a market value of $D_{NP}(0)$. The coupon rate C_{NP} is set so that without the project, the debt is priced at par. When computing its taxes, the firm deducts its coupon payments at an effective rate τ, and the tax benefit of the debt at time 0 has a value $TB_{NP}(0)$.

The debt has a protective covenant that specifies that if at any time during the life of the debt [0, *T*] the firm value decreases to an exponential boundary, the firm is forced into bankruptcy. We implicitly assume here that this covenant acts somewhat like the covenants found in bond indenture agreements. These covenants are designed to enable debtholders to seize assets when they are in danger of being lost. Our assumption models this process explicitly. (See Black and Cox, 1976, and Ju, 2001 for other papers that use this approach.)

When bankruptcy occurs, the stock becomes worthless and the debtholders recover $1 - \alpha_{BC}$ of the levered value of the assets. We assume that the fraction of the value of the assets not recovered by the debtholders is consumed in the bankruptcy process. The bankruptcy boundary is an exponential curve that increases at a rate *g* and is equal to the face value of debt at time *T*. Consequently, without the project, the bankruptcy boundary is described by $F_{NP}e^{g(t-T)}$. The bankruptcy costs for the firm equal the present value of the expected losses in bankruptcy, and are denoted by $BC_{NP}(0)$.

The value of the firm's assets plus the tax benefit of debt equals the total value of the debt and equity, plus the bankruptcy costs:

$$V_{NP}(0)+TB_{NP}(0)=D_{NP}(0)+E_{NP}(0)+BC_{NP}(0). \tag{1}$$

If the firm does not accept the project at time 0, then the value of the firm's assets, $V_{NP}(t)$, follows a geometric Brownian motion described by:

$$\frac{dV_{NP}(t)}{V_{NP}(t)}=(\mu_{NP}-\delta)dt+\sigma_{NP}dZ(t) \tag{2}$$

where μ_{NP} and $\sigma_{NP} > 0$ are constants and $dZ(t)$ is a standard Weiner process.

The firm liquidates assets at a rate of δ of the total value of the firm's assets, so that $dV_{NP}(t)dt$ equals the sum of the after-tax coupon paid to debtholders $[(1-t)C_{NP}dt]$ and a time-varying dividend *DivRate*(*t*)*dt* paid to stockholders over the time interval *dt*:

$$\delta V_{NP}(t)dt=\left[DivRate(t)+(1-\tau)C_{NP}\right]dt. \tag{3}$$

The value of δ is specified exogenously as a model parameter.

At time 0, a project costing $COST_P$ becomes available. If the manager accepts this project, the value of the assets becomes $V_P(0)$. If the project is taken, the value of the assets, $V_P(t)$, follows a geometric Brownian motion described by:

$$\frac{dV_P(t)}{V_P(t)} = (\mu_P - \delta)dt + \sigma_P dZ(t) \tag{4}$$

where μ_P and $\sigma_P > 0$ are constants.

Consequently, if the project is accepted, the net impact on the current and future value of the firm's assets is to change the value of these assets at time 0 from $V_{NP}(0)$ to $V_P(0)$, and to change the parameters of the geometric Brownian motion obeyed by the assets from μ_{NP} to μ_P and σ_{NP} to σ_P. The firm still liquidates assets at a rate δ.

If the manager does not accept the project, the capital structure of the firm does not change. If the project is accepted, it is financed with fairly priced debt and equity. Any new debt that the firm issues has exactly the same characteristics as the old debt (i.e., it has the same priority, pays a coupon that is the same percentage of the face value, and has time T to maturity).

Let N_P be the number of shares outstanding, F_P the face value of debt outstanding, and C_P the constant annualized coupon rate paid after the project is financed. Then:

$$C_P = C_{NP}(F_P/F_{NP}) \tag{5}$$

$$COST_P = \left(\frac{N_P - N_{NP}}{N_P}\right)E_P(0) + \left(\frac{F_P - F_{NP}}{F_P}\right)D_P(0) \tag{6}$$

and the value of the firm's assets becomes:

$$V_P(0) = D_P(0) + E_P(0) + BC_P(0) - TB_P(0) \tag{7}$$

where $D_P(0)$, $E_P(0)$, $BC_P(0)$, and $TB_P(0)$ are the time zero values of debt, equity, bankruptcy costs, and tax benefit to debt respectively, when the manager accepts the project.

To solve the model, we must choose how the project is financed. We specify three alternative financing rules. The first financing rule holds the firm's market debt/total capital ratio fixed, so that:

$$\frac{D_{NP}(0)}{D_{NP}(0) + E_{NP}(0)} = \frac{D_P(0)}{D_P(0) + E_P(0)} \tag{8}$$

Under the second financing rule, the firm is required to finance the project using quantities of new debt and equity so that the market value of each dollar of face value of the debt does not change.

$$\frac{D_P(0)}{F_P} = \frac{D_{NP}(0)}{F_{NP}} \tag{9}$$

The final version of the model requires that the ratio of the market values of the newly issued debt to equity is the same as the ratio of the market values of the debt to equity before the project is adopted:

$$\left(\frac{F_P - F_{NP}}{F_P}\right) D_P(0) \Big/ \left(\frac{N_P - N_{NP}}{N_P}\right) E_P(0) = \frac{D_{NP}(0)}{E_{NP}(0)} \tag{10}$$

The financing rule matters because potential projects will affect the firm's total risk, and therefore will also affect the relative values of its securities.

For example, consider a project that substantially increases a firm's risk. With such a project, if the firms is to obey the financing rule keeping the market debt-to-equity ratio constant (Equation 8), it will have to finance the project with a disproportionately large fraction of debt, since the value of existing debt will decrease with the addition of a risky project. This financing rule is not particularly realistic, since risky projects are typically financed with relatively more equity.

In contrast, Equation (9), which holds the value of the outstanding debt constant, would require the firm to retire some existing debt so that current debtholders would remain whole. This financing rule is not consistent with the way firms usually finance projects either.

The third rule, which constrains the firm to issue new securities in the same proportion as the pre-project relative values of old securities (Equation 10), is probably the most realistic of the three. Therefore, we use this financing rule as our "base case."

At time 0, the manager's stake in the firm consists of $N_{Man}(<N_{NP})$ shares and N_{Calls} European call options with strike price K that expire at time T_u. For purposes of computational tractability, we assume that the firm buys the shares necessary to facilitate exercise of the manager's calls from a third party. Hence, if the manager exercises the calls at time T_u, he effectively buys N_{Calls} shares from the third party at a price of $N_{Calls}K$ dollars.[2] We assume that the manager cannot sell or hedge either his shares or his options. In addition, at time 0 the manager has $NFW(0)$ dollars of non-firm wealth. We asume that this wealth grows at the risk-free rate. The manager decides whether to accept the project at time 0 by maximizing his expected utility at time T_u, which is described by:

$$U\left(Wealth_{T_u}\right) = \frac{\left(Wealth_{T_u}\right)^{1-\gamma} - 1}{1-\gamma} \tag{11}$$

where γ is a risk-aversion parameter and $Wealth_{Tu}$ is the manager's total wealth at time T_u.[3]

Our model contains a dynamic reissuance of debt at fixed intervals. At time 0, the firm has

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[2] We have also formulated and solved the model for the situation in which the manager's options are issued directly by the firm. In this case, if the manager exercises his options, the firm issues N_{Calls} new shares of stock, which are given to the manager, and the manager pays $N_{Calls}K$ to the firm, which is invested in a scaling project. It took approximately 10,000 times longer to compute solutions to this version of the model. Consequently, it would not be feasible to provide the analysis presented below with these types of options. However, we believe that the results would be similar for the model with this alternative type of managerial options.

[3] Below we document how our conclusions vary with the choice of the manager's risk-aversion parameter. An alternative to specifying a utility function would be to use an approach such as that chosen by Meulbroek (2001). She avoids having to specify a utility function, and therefore choose a risk-aversion parameter, by assuming that managers maximize the private value of their wealth, which accounts for the non-systematic risk that they bear.

debt outstanding with T years to maturity and the manager decides whether to accept a project. If the firm has not gone bankrupt at the end of T years, the firm issues new T-year debt at time T. The new debt pays a coupon of either $C_{NP}V_{NP}(T)/V_{NP}(0)$ or $C_PV_P(\mathrm{T})/V_P(0)$, respectively, depending on whether the firm has forgone or accepted the project at time 0. Similarly, as shown in Ju et al. (2005), all other securities can be scaled by a factor of $V_{NP}(T)/V_{NP}(0)$ or $V_P(\mathrm{T})/V_P(0)$, because at time T the firm is identical to itself at time 0 except that it is $V(\mathrm{T})/V(0)$ as large. The process of issuing new T-year debt each time existing debt matures continues indefinitely until the firm goes bankrupt. The Appendix discusses the technical details for solving the model.

II. Calibrating the Model

We normalize the total value of the firm's assets without the project to \$100 at time T_0. We divide this value (plus the tax benefit of debt) between debtholders who own debt with a maturity of ten years, stockholders who own a total of 100 shares, and bankruptcy costs. We assume that the manager of the firm owns a 0.32 share of stock and a ten-year exchange traded European call option on an additional 0.38 share. The manager's stock and option holdings represent the median values for managers at 1,405 firms for which sufficient data to estimate these figures are available for 1999 on the ExecuComp database. We set the strike price for the call option equal to the time zero value of a share of equity of the firm without the project.

For the base-case, we assume that the manager's non-firm wealth equals the time-0 value of the shares that the manager owns without the project. Consistent with the literature, we assume the manager's risk-aversion parameter γ equals two (see Ljungqvist and Sargent, 2000 for a discussion of the interpretation of this value and other values of γ used in the sensitivity analysis). The manager makes investment decisions in such a way as to maximize his expected utility in one year ($T_u = 1$).

We also assume that the value of the cash flows from operations of the project is sufficient to ensure that the total value of the firm's assets with the project equals \$120 at time T_0.

Given these assumptions, calibration of the model requires estimates of: 1) the risk-free rate, r; 2) the effective tax rate, τ; 3) the level of dividends, *DivRate*, paid by the firm; 4) the face value of the debt with no project, F_{NP}; 5) the volatility of the total value of the firm with no project, σ_{NP}; 6) the debtholder bankruptcy recovery rate, $(1 - \alpha_{BC})$; 7) the bankruptcy boundary's exponential growth rate, g; 8) the volatility of the total value of the firm with the project, σ_P; and 9) the drift parameter for the total value of the firm, μ. Where possible, we estimate these parameters using data from the end of January 2001, so that the model's implications are realistic and reasonably current.

As our estimate of the risk-free rate, we use the 5.22% rate on ten-year Treasury bonds as of January 30, 2001 reported in the February 7, 2001 edition of Standard & Poor's *The Outlook*. We estimate the tax rate used to calculate the tax shields from the debt using data on estimated marginal tax rates (before interest expense) provided by John Graham. These estimated marginal tax rates were obtained using the approach described in Graham (1996). For the base case, we assume that the tax rate equals the median marginal tax rate of 34% for the 5,519 firms for which 1999 estimates are available.

In the base case we set the dividend rate, *DivRate*, equal to 1.5%. Because we express this rate as a percentage of the unlevered value of the firm, we use a number that is on the lower end of the 1.5% to 2% dividend yield paid by public firms at the beginning of 2001.

We base our choice of the face value of the debt at the firm with no project on the distribution of the ratio of the book value of debt to the book value of debt plus the market value of the equity. We estimate this ratio for all 2,609 firms for which there are sufficient data in the Compustat database in 2000. This distribution, which we show in Table I, illustrates the wide variation in capital structures that we observe in public US firms. We select the face value of the debt with no project, F_{NP} = \$23.72, so that its market value, as a percentage of total capital, equals the median value of this distribution (22.62%) at time 0. Because of the importance of this parameter, we also present results for alternative capital structures.

We select the volatility of the total value of the firm's assets with no project, σ_{NP}, the debtholder bankruptcy recovery rate, $(1 - \alpha_{BC})$, and the exponential growth rate for the bankruptcy boundary, g, to yield an expected recovery rate of 45% and a spread over the ten-year Treasury bond rate for the firm's debt equal to 1.9%. The 45% recovery rate is consistent with recovery rates published by Hamilton, Gupton, and Berhault (2001). For the 1981 to 2000 period, Hamilton et al. (2001) estimate the mean default recovery rates for senior secured bonds, senior unsecured bonds, and subordinated bonds of all ratings to equal 53.9%, 47.4%, and 32.3%, respectively. The 1.9% spread over the Treasury bond rate equals the spread for ten-year A-rated corporate debt as of January 30, 2001, as reported in the February 7, 2001 edition of Standard & Poor's *The Outlook*. The resulting estimate of the volatility of the total value of the firm's assets with no project, σ_{NP}, is 0.3802. This value implies a volatility of the value of the typical firm's equity of 0.4809. The bankruptcy recovery and bankruptcy boundary growth rates for our base case are estimated as 0.509 ($\alpha_{BC} = 0.491$) and 3.69%, respectively.

Using the standard portfolio formula, we compute the volatility of the value of the firm's assets with the project, σ_P, based on the volatility of the value of the firm's assets with no project (0.3802), the volatility of the value of the assets of the project (set equal to the volatility of the value of the firm's assets with no project), a correlation between total firm (with no project) and project asset value volatilities of 0.5, and a project with an asset value equal to 20% of the value of the firm's assets. This process yields a value of 0.3528 for the base case volatility of the firm's assets with the project. The parameter σ_P ranges from 0.3168 to 0.492 in the base-case sensitivity analyses below. This range is consistent with project volatilities varying from zero to approximately four times the volatility of the firm without the project. For a risk free rate of 5.22%, and assuming an equity risk premium of 6%, we show in the Appendix that Ito's Lemma implies that the drift of the Brownian motion, μ, equals 10.63%.

Panel A of Table II summarizes our parameter choices. We use these choices to derive the set of parameters that we present in Panel B of Table II.

III. Implications of the Model for Investment Decisions

We use our model to estimate the magnitude of potential distortions in investment decisions for a hypothetical "typical firm". We first summarize the implications of the model using the base case parameters presented in Panel A of Table II. We then perform sensitivity analyses where we consider how the results change with alternative parameters choices.

A. Base-Case Results

Table III presents statistics describing the impact of zero NPV projects of varying risk (volatility of asset value) on firm leverage, the expected values of tax shields and bankruptcy costs, and the values of the original debt and equity claims. Throughout this table, adopting

Table I. Capital Structure Distribution for Public Firms in 2000

Distribution is for 2,609 public firms for which sufficient data are available on Compustat in 2000.

Percentile	**Equity/Total Capital**	**Debt/Total Capital**
0%	0.00%	100.00%
10%	26.30%	73.70%
20%	42.69%	57.31%
30%	55.44%	44.56%
40%	65.95%	34.05%
50%	77.38%	22.62%
60%	85.78%	14.22%
70%	92.56%	7.44%
80%	97.46%	2.54%
90%	99.72%	0.28%
100%	100.00%	0.00%

the project increases the unlevered value of the firm's assets by 20%.

Table III summarizes the most important statistics for the case. We use the financing rule under which the market debt to total capital ratio for the project financing equals the market debt to total capital ratio of the firm without the project (Equation 10). We focus on this case because, as noted in Section I, we believe it is the most reasonable of the financing rules we consider.[4]

The results in Table III are based on the parameter values listed in Table II, except that we vary the volatility of the value of the assets of the project between zero and four times the volatility of the value of the assets of the firm without the project. Doing so causes the volatility of the value of the assets of the firm with the project to vary from 31.68% to 49.2%.

The third row in Table III reports the value of the project to the firm. This value is the sum of the value of the underlying assets of the project, \$20, and the net impact of the project on the firm's tax shields and bankruptcy costs. To see this, consider the first column in Table III. Row 3 shows that the value of the project equals \$26.17. This number is precisely equal to the \$20 value of the project's underlying assets, plus the \$4.68 increase in the value of the interest tax shields (Row 5) and the \$1.49 reduction in bankruptcy costs (Row 6) that are realized from the project. If the firm pays this price for the project, it is a zero NPV project.

The value of the project decreases as its risk increases. This decrease occurs because the expected value of the debt tax shields declines and the expected bankruptcy costs increase as firm risk increases. The expected value of the tax shields declines, because greater risk reduces the probability that a firm will be able to utilize those shields in any given period. The expected bankruptcy costs increase, because the probability of default rises when a project increases firm risk. These effects are reversed if a project reduces firm risk.

Table III also illustrates that leverage with the project (Row 4) is slightly higher than leverage without the project (Row 2) for projects that lower firm risk, and that leverage

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[4] For brevity, we do not report estimates obtained using the other two financing rules. However, these results are available from the authors on request.

Table II. Model Parameters

Panel A. Chosen Parameters

Variable	Calibrated Value	Variable Description
$V_{NP}(0)$	\$100	Initial value of assets of firm with no project
T	10	Time at which debt matures
N_{NP}	100	Total shares outstanding with no project
N_{Man} ($< N_{NP}$)	0.32	Number of shares owned by manager
N_{Calls}	0.38	Number of exchange traded European calls owned by manager
K	\$0.8116	Strike price of calls
$NFW(0)$	\$0.2597	Manager's non-firm wealth in dollars at time 0
γ	2	Manager's risk-aversion parameter
T_u	1	Time at which manager evaluates utility
$V_P(0)$	\$120	Initial value of assets of firm with project
r	5.22%	Annualized risk-free rate
τ	34.0%	Effective tax rate for debt tax shield
$DivRate$	1.5%	Dividend payout rate to stockholders as a percentage of the unlevered value of the firm.
F_{NP}	\$23.72	Face value of debt with no project (yields market debt/capital ratio of 22.62% at T_0)
σ_{NP}	0.3802	Volatility of value of assets of firm with no project
α_{BC}	0.4910	1 - Debtholder bankruptcy recovery rate
g	3.69%	Bankruptcy boundary exponential growth rate
σ_P	0.3528	Volatility of value of assets of firm with project (with $\rho = 0.5$)
μ_{NP}	10.63%	Drift of value of assets of firm with no project
μ_P	10.63%	Drift of value of assets of firm with project

declines moderately as firm volatility increases (Row 4). This relation is due to the impact of the project on the value of the original debt.

1. Changes in the Values of Equity and Debt Claims

Fama and Miller (1972), Jensen and Meckling (1976), and Myers (1977) suggest that

Table II. Model Parameters (*Continued*)

Panel B. Derived Variables

Variable	**Variable Description**
F_P	Face value of debt with project
N_P	Total shares outstanding with project
$E_{NP}(0)$	Initial total value of equity with no project
$E_P(0)$	Initial total value of equity with project
$D_{NP}(0)$	Initial total value of debt with no project
$D_P(0)$	Initial total value of debt with project
$BC_{NP}(0)$	Initial total value of bankruptcy costs with no project
$BC_P(0)$	Initial total value of bankruptcy costs with project
$TB_{NP}(0)$	Initial total value of tax benefits of debt with no project
$TB_P(0)$	Initial total value of tax benefits of debt with project
$NFW(T_u)$	Value of manager's non-firm wealth at time T_u
$C_{NP}(0)$	Constant annualized coupon rate paid by the debt when there is no project. This rate is set to price the debt without the project at par.
C_P	Constant annualized coupon rate paid by the debt when the project is accepted
$Utility_{NP}(0)$	Expected future value of manager's utility with no project
$Utility_P(0)$	Expected future value of manager's utility with project
$COST_P^{Indiff}$	The cost of the project at which the manager is indifferent to taking it
ϕ_{NP}	Discounted risk-neutral expected value of the quantity $V_{NP}(T)/V_{NP}(0)$
ϕ_P	Discounted risk-neutral expected value of the quantity $V_P(T)/V_P(0)$
δ	After tax cash payout rate to both debtholders and stockholders as a percentage of the unlevered value of the firm

Table III. Impact of Zero NPV Project on Firm Leverage and Values of Original Debt and Equity

This table shows model output for projects with different volatilities. The ratio of the market value of debt to the market value of equity for the project financing equals the corresponding ratio for the firm without the project. Reported values are for a firm with an initial value of $100 without the project, a project with an asset value of $20, and drift parameters for the value of the firm and the project of 10.63%.

		Volatility of Firm Asset Value With Project										
Row		**0.3168**	**0.3300**	**0.3446**	**0.3602**	**0.3769**	**0.3945**	**0.4128**	**0.4318**	**0.4514**	**0.4715**	**0.4920**
1	Volatility of firm value without project	0.3802	0.3802	0.3802	0.3802	0.3802	0.3802	0.3802	0.3802	0.3802	0.3802	0.3802
2	Leverage without project	22.62%	22.62%	22.62%	22.62%	22.62%	22.62%	22.62%	22.62%	22.62%	22.62%	22.62%
3	Value of/Price paid for project	$26.17	$25.04	$23.82	$22.54	$21.23	$19.91	$18.60	$17.31	$16.06	$14.86	$13.72
4	Leverage with project	23.73%	23.52%	23.27%	22.99%	22.68%	22.34%	21.98%	21.60%	21.20%	20.79%	20.37%
5	Change in value of tax shields	$4.68	$4.22	$3.71	$3.18	$2.63	$2.07	$1.51	$0.95	$0.39	-$0.14	-$0.67
6	Change in bankruptcy costs	-$1.49	-$0.82	-$0.10	$0.64	$1.40	$2.16	$2.91	$3.63	$4.33	$4.99	$5.62
7	*Δ Value of original debt*	$1.46	$1.17	$0.84	$0.47	$0.08	-$0.34	-$0.79	-$1.25	-$1.72	-$2.19	-$2.67
8	*Δ Value of original debt: Tax rate = 0*	$1.54	$1.24	$0.89	$0.50	$0.08	-$0.36	-$0.83	-$1.32	-$1.82	-$2.32	-$2.83
9	*Δ Value of original debt: BC = 0*	$0.34	$0.28	$0.21	$0.12	$0.02	-$0.09	-$0.22	-$0.35	-$0.49	-$0.65	-$0.80
10	*Δ Value of original debt: Tax rate & BC = 0*	$0.42	$0.34	$0.25	$0.14	$0.02	-$0.11	-$0.25	-$0.41	-$0.58	-$0.75	-$0.92
11	*Δ Value of original equity*	-$1.46	-$1.17	-$0.84	-$0.47	-$0.08	$0.34	$0.79	$1.25	$1.72	$2.19	$2.67
12	*Δ Value of original equity: Tax rate = 0*	-$1.54	-$1.24	-$0.89	-$0.50	-$0.08	$0.36	$0.83	$1.32	$1.82	$2.32	$2.83
13	*Δ Value of original equity: BC = 0*	-$0.34	-$0.28	-$0.21	-$0.12	-$0.02	$0.09	$0.22	$0.35	$0.49	$0.65	$0.80
14	*Δ Value of original equity: Tax rate & BC = 0*	-$0.42	-$0.34	-$0.25	-$0.14	-$0.02	$0.11	$0.25	$0.41	$0.58	$0.75	$0.92

undertaking a project that causes firm volatility to change will generally transfer wealth between stockholders and debtholders. This effect is clearly illustrated in Table III. The value of the original debt increases (decreases) when firms adopt projects that decrease (increase) the overall risk of the firm (Row 7). The impact on the value of the original equity is equal, but opposite, when the project has a zero NPV (Row 11). Consequently, the change in the value of the debt reflects a wealth transfer between debtholders and stockholders.

The magnitude of the wealth transfer reflects the net impact of the project on the present value of the expected tax shields and bankruptcy costs, as well as a pure wealth transfer. Rows 8–10 and 12–14 in Table III illustrate the impact of taxes and bankruptcy costs on the magnitude of the wealth transfers. For instance, with no taxes, the wealth transfer between the debtholders and stockholders equals $1.54 in the first column (Rows 8 and 12). This quantity is higher than the wealth transfer with taxes, because the stockholders disproportionately benefit from tax shields associated with the project's debt when the firm adopts a low risk project. Similarly, the smaller wealth transfer with no bankruptcy costs ($0.34 in the first column in Rows 9 and 13) indicates that the bankruptcy costs disproportionately harm stockholders with low risk projects. In the absence of bankruptcy costs, the wealth transfer from stockholders is smaller.

Wealth transfers to debtholders decrease and eventually become negative as project risk increases, indicating that wealth is transferred away from debtholders to stockholders for projects that increase overall firm risk. This effect can be seen by examining Rows 7–10, in which wealth transfers to debtholders decrease as project and firm volatility increase (moving across columns to the right). This finding is the asset substitution effect described by Jensen and Meckling (1976) through which an increase in risk, holding all other factors constant, lowers the value of existing debt by transferring wealth to stockholders. When a project is financed with fairly priced debt, the wealth transfers between claimholders, as well as the changes in the values of the tax shields and bankruptcy costs (for non-zero NPV projects), determine the net changes in the values of the original debt and equity claims.

Comparing the relative magnitudes of these effects provides useful insights. The effect of changing firm risk on the value of tax shields is large relative to the wealth transfer effect for the typical firm. For example, given the assumptions underlying the estimates in Table III, a low-risk project that decreases firm volatility to 0.3168 transfers $0.42 from stockholders to debtholders (see Rows 10 and 14). Many studies (e.g., Myers, 1977) argue that this risk shifting is one reason why stockholders might avoid low-risk projects. However, undertaking this project adds $4.68 to the value of the tax shields, more than ten times as much value as is transferred from stockholders to debtholders with the same project. When the change in bankruptcy costs is taken into account, the total gains are $6.17.

We assume that the low-risk project illustrated in Table III is a zero NPV project, in the sense that it requires an investment that exactly equals the $20 value of its underlying assets plus the $6.17 value from changes in tax and bankruptcy costs. We note that when we re-estimate the model by assuming that the project can be undertaken at a cost of $20, the value of existing debt increases by $1.62 and the value of existing equity increases by $4.68. There is no conflict between stockholders and debtholders in this case. Stockholders and debtholders both split the gains that result from the extra tax shields and the lowering of expected bankruptcy costs.

This last example suggests that, at least for firms with moderate leverage, the usual intuition derived from agency theory is reversed. In contrast to the intuition from Jensen and Meckling (1976) and Myers (1977), there is little disagreement between debtholders and stockholders over project choice. All else equal, both debtholders and stockholders prefer safe projects to risky ones. Wealth is in fact transferred, but the wealth transfer is more than offset by the changes in tax shields and bankruptcy costs.

Our perspective on tax and bankruptcy effects differs from what we often find in corporate finance textbooks. Taxes and bankruptcy costs are usually discussed in the context of the "trade-off" theory of capital structure, in which, *ex ante*, firm managers trade off the relative benefits and costs in choosing a capital structure. The results in Table III suggest that once a firm chooses a capital structure, taxes and bankruptcy costs have values that are affected by managers' investment decisions. Therefore, *ex post*, once the firm chooses the capital structure, tax and bankruptcy costs create investment distortions that the literature does not emphasize.

2. Changes in the Manager's Utility

In Table IV, we evaluate the impact of projects that alter firm risk from the manager's perspective. We use the same projects that we consider in Table III. In Table IV, we characterize the distortion in investment decisions by estimating the project cost necessary to make the manager indifferent as to whether or not the project is accepted. To do this, we solve for the project cost for which the manager's utility with the project is unchanged from his utility without the project. This cost will generally be different from the cost at which the project has a zero NPV. For projects that reduce firm volatility, this cost will typically be higher, and for projects that increase firm volatility, it will typically be lower. Each of these cost estimates implies the indifference NPV, the amount of additional value (positive or negative) necessary to make the manager indifferent between accepting and rejecting a project with a specified volatility.

To evaluate the importance of these distortions, we express them in terms of incremental rates of return on equity (Rows 10–14 in Table IV). Since we base our model on a value process that does not explicitly model cash flows, we must first calculate the implied level of cash flows from operations for the project. We compute the implied initial cash flow from operations for the project as $CF = \Delta V(WACC - g_{CF})$, where ΔV is the change in the total incremental value of the cash flows from the project, if the project is adopted, $WACC$ is the weighted-average cost of capital of the firm at time zero (set equal to μ_{NP}, the drift parameter of 0.1063), and g_{CF} (the growth rate of cash flows) is assumed to equal 0.0663. We estimate the value of g_{CF} using the formula $g_{CF} = WACC - CF/\Delta V$ where $WACC = 0.1063$ and $\Delta V/CF$ is assumed to equal 25. These calculations model the cash flows from operations of the project as a growing perpetuity.

We next assume that the cost of the project equals the cost that makes the manager indifferent (Row 3 in Table IV). We solve for the cost of equity implied by our estimate of the level of the initial operating cash flows from the project, again modeling the cash flows from operations for the project as a growing perpetuity with a growth rate equal to 0.0663. Finally, we compute the incremental cost of equity where the manager is indifferent as the difference between the cost of equity estimated in this way and the cost of equity that is consistent with a WACC of 0.1063. This incremental cost of equity has a natural interpretation as the extra cost, in rate-of-return terms, of the net agency conflict between stockholders, debtholders, and managers.

Row 3 in Table IV shows the price that the manager would be willing to pay for each project. For the base case, Row 5 reports the manager's indifference NPVs. We convert them to incremental costs of equity in Row 10.

Both the indifference NPVs and the incremental costs of equity are increasing in project risk, indicating that the manager prefers lower-risk projects. A combination of factors determines these relations. Two factors, the wealth transfer between debtholders and stockholders and the impact of risk on the value of stock options, work to make riskier

Table IV. Impact of Zero NPV Project on Manager's Utility, Indifference NPV, and Incremental Cost of Equity Where Manager is Indifferent

This table shows model output for projects with different volatilities. The ratio of the market value of debt to the market value of equity for the project financing equals the corresponding ratio for the firm without the project. Reported values are for a firm with an initial value of $100 without the project, a project with an asset value of $20, and drift parameters for the values of the firm and the project of 10.63%. The manager has constant relative risk aversion with a risk-aversion parameter of 2.

		Volatility of Firm Asset Value With Project										
Row		**0.3168**	**0.3300**	**0.3446**	**0.3602**	**0.3769**	**0.3945**	**0.4128**	**0.4318**	**0.4514**	**0.4715**	**0.4920**
1	Change in manager's utility	0.0234	0.0191	0.0140	0.0081	0.0014	-0.0062	-0.0145	-0.0237	-0.0337	-0.0444	-0.0559
2	Change in manager's utility with no options	0.0275	0.0221	0.0160	0.0091	0.0015	-0.0068	-0.0158	-0.0255	-0.0358	-0.0468	-0.0584
3	Project cost where manager is indifferent	$27.77	$26.37	$24.81	$23.12	$21.33	$19.44	$17.47	$15.44	$13.33	$11.17	$8.94
4	Value of project (from Row 3 in Table III)	$26.17	$25.04	$23.82	$22.54	$21.23	$19.91	$18.60	$17.31	$16.06	$14.86	$13.72
NPV where manager is indifferent (Row 4 less Row 3):												
5	Base case	-$1.61	-$1.33	-$0.99	-$0.59	-$0.10	$0.47	$1.12	$1.87	$2.73	$3.70	$4.78
6	Tax rate =0	-$1.55	-$1.28	-$0.95	-$0.56	-$0.10	$0.45	$1.07	$1.79	$2.61	$3.54	$4.58
7	BC =0	-$3.96	-$3.24	-$2.38	-$1.38	-$0.24	$1.07	$2.53	$4.17	$5.99	$8.00	$10.22
8	BC & tax rate = 0	-$4.02	-$3.29	-$2.42	-$1.41	-$0.24	$1.09	$2.59	$4.27	$6.15	$8.23	$10.54
9	Risk neutral manager, BC & tax rate = 0	$0.34	$0.27	$0.19	$0.11	$0.02	-$0.09	-$0.21	-$0.35	-$0.51	-$0.70	-$0.92
Incremental cost of equity where manager is indifferent:												
10	Base case	-0.30%	-0.26%	-0.21%	-0.13%	-0.02%	0.12%	0.33%	0.62%	1.04%	1.67%	2.69%
11	Tax rate =0	-0.37%	-0.31%	-0.25%	-0.15%	-0.03%	0.14%	0.36%	0.66%	1.07%	1.66%	2.53%
12	BC =0	-0.74%	-0.63%	-0.48%	-0.30%	-0.05%	0.26%	0.69%	1.27%	2.11%	3.38%	5.51%
13	BC & tax rate = 0	-0.88%	-0.74%	-0.57%	-0.35%	-0.06%	0.30%	0.78%	1.42%	2.31%	3.64%	5.79%
14	Risk neutral manager, BC & tax rate = 0	0.09%	0.07%	0.05%	0.03%	0.00%	-0.02%	-0.05%	-0.09%	-0.13%	-0.18%	-0.23%

projects more desirable through their impact on the values of the manager's shares and options.[5] Working against these factors are the manager's risk aversion and the changes in the value of debt tax shields and bankruptcy costs.

To better understand these various effects, we decompose the indifference NPVs and incremental costs of equity by factor in Rows 6–9 and Rows 11–14 of Table IV. Rows 9 and 14 present the indifference NPVs and incremental costs of equity for the case of a risk-neutral manager without taxes or bankruptcy costs. Since these results assume that managers are not risk averse and that there are no taxes or bankruptcy costs, we would expect managers to prefer riskier projects. Not surprisingly, the manager's indifference NPV and the incremental cost of equity decrease as project risk increases.

Rows 8 and 13 present the same variables, except for a risk-averse manager. Once we add risk aversion to the model, the relations between the indifference NPV and incremental cost of equity and project risk change sign, and the indifference NPV and incremental cost of equity increase as project risk increases. This result suggests that with a moderately risk-averse manager ($\gamma = 2$), risk aversion is a more important factor than are wealth transfers between stockholders and debtholders.

We add tax effects and bankruptcy effects individually, in Rows 6, 7, 11, and 12, by separately considering the cases in which the tax rate and bankruptcy costs both equal zero. In each of these two cases, the relation between project risk and indifference NPVs or incremental costs of equity are less steeply sloped than for case with no taxes or bankruptcy costs (Rows 8 and 13).

B. Stockholder/Manager Conflicts and Variation in Underlying Parameters

Our base-case analysis shows how the values of equity and debt change when a firm adopts a project that changes firm-wide risk. Our analysis also illustrates the extent to which stockholder/manager conflicts can affect the decision to accept or reject projects. Our results so far are for a model that we calibrate to resemble a typical large, publicly traded firm. Here, we vary a number of the underlying model parameters and examine the sensitivity of the magnitude of the impact of stockholder/manager conflicts on investment decisions to our choice of model parameters.

1. Variation in Firm Characteristic Parameters

Figure 1 illustrates the magnitude of the impact of project risk on investment decisions for firms with differing degrees of initial leverage. The lines for 0.01% leverage, 22.62% leverage (the base-case leverage we use for Tables III and IV), and 50% leverage slope upward, indicating that as projects get riskier, they become less desirable to managers. Comparing these three lines, the line for 22.62% leverage slopes upward more steeply than do the other two lines. In contrast, when the leverage ratio equals 60%, the line slopes downward, and when it is 75% leverage, the downward slope becomes steep.

To understand the patterns of these relations, we consider the various means through which leverage can affect the impact of risk changes on a manager's utility. First, the magnitude of wealth transfer between stockholders and debtholders increases with leverage. This wealth transfer leads managers to prefer risky projects, since they hold shares and options on the firm's shares. The remaining factors work in the opposite direction as leverage increases,

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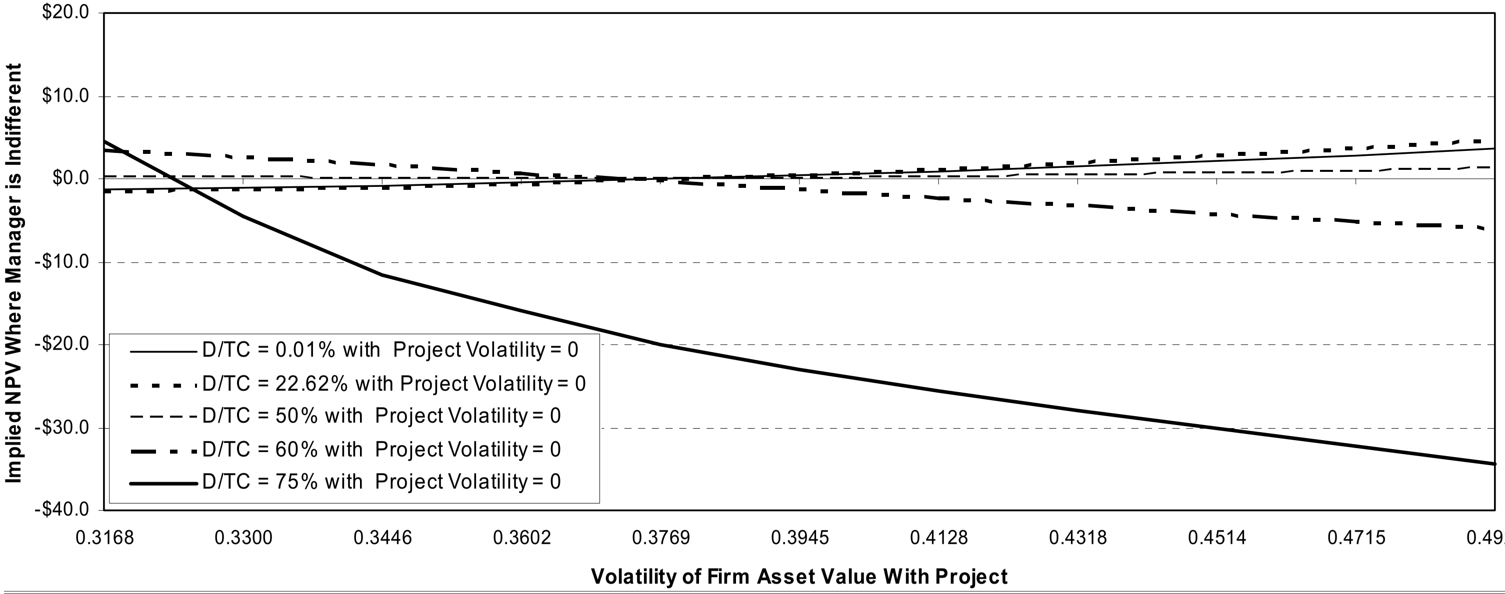
[5] Carpenter (2000) emphasizes that stock options do not necessarily increase in value with firm risk when held by an undiversified executive. However, given the parameters used here, the "option" effect dominates the risk effect, so that the options are increasing in value to the manager when firm risk increases.

Figure 1. Indifference NPV for Different Capital Structures

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio (D/TC) for the project financing equals the firm's market debt/total capital ratio before the project.



causing managers of more-levered firms to prefer less risky projects. Increasing firm risk by adopting a risky project increases expected bankruptcy costs more when a firm has greater leverage. In addition, risk-induced changes in the value of debt tax shields are sensitive to leverage. Since the value of debt tax shields, conditional on the firm being able to use them, increases with leverage, the impact of a change in risk on the value of debt tax shields is magnified when a firm has more leverage. The greater a firm's leverage, the greater the potential decline in the value of the tax shields that will ultimately be realized from the existing debt.

Figure 1 indicates that the various factors affecting stock and debt prices have a nonlinear relation to leverage. At low levels of leverage, the fact that an increase in leverage (e.g., from 0.01% to 22.62%) increases the slopes of the lines in Figure 1 suggests that the combined effects of risk aversion, tax, and bankruptcy cost are larger than the wealth-transfer effect. On the other hand, as firms become more highly levered, the wealth-transfer effect dominates, so that managers of highly levered firms have incentives to invest in projects that increase firm risk.

Our base-case model assumes that the firm is financed with ten-year debt. We select a debt maturity of ten years because the duration of this debt is similar to the weighted-average duration of debt issued by large corporations. However, the data suggest that there is substantial cross-sectional variation in debt maturity (see Barclay and Smith, 1995). Therefore, we evaluate the effect of different maturities on the stockholder/manager conflicts considered in this article.

Figure 2 presents results from our model for debt having five-, ten-, and 15-year maturities. The results in Figure 2 indicate that the longer the duration of the debt, the smaller the distortions in investment. The intuition for these results follows from the fact that the tax shield, bankruptcy cost, and risk aversion effects are likely to be relatively independent of debt duration. These effects are mainly driven by the size of the debt.

However, the effect of duration on the magnitude of the wealth transfer from either risky or safe projects can be substantial, and the magnitude of these transfers is positively related to the maturity of the debt. Wealth transfers mitigate the effects of a change in firm volatility on the manager and on the value of debt tax shields and bankruptcy costs to a greater extent with longer-term debt than with shorter-term debt. As a result, the lines in Figure 2 are flatter for longer-term debt.

In the base-case analysis, we assume that the value of the assets of the project equals 20% of the value of the assets of the firm without the project. We vary this value from 10% to 50% in Figure 3. This figure indicates that the indifference NPV slopes upward more steeply with larger projects than with smaller ones. Although this result might appear to be counterintuitive, since the rates of return on the projects are similar, the greater impact of the larger projects on the indifference NPV reflects the greater impact that these projects have on the volatility of the firm. For example, the volatility of the assets of the firm with the project ranges from 31.68% to 49.2% for a project that is 20% as large as the firm, but the corresponding range is from 25.35% to 66.41% for a project that is 50% as large as the firm. These findings indicate that a larger high-risk project has a disproportionately large impact on the distortion of the investment decision when the manager is risk averse.

2. Variation in Manager Characteristic Parameters

The choice of the risk aversion coefficient (γ) is critical to our analysis. Managerial risk aversion is fundamentally unobservable, yet it is one of the most important underlying variables in all of economics. Therefore, it is understandable that the appropriate coefficient of risk

Figure 2. Indifference NPV for Different Debt Maturity Structures

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio for the project financing equals the firm's market debt/total capital ratio before the project.

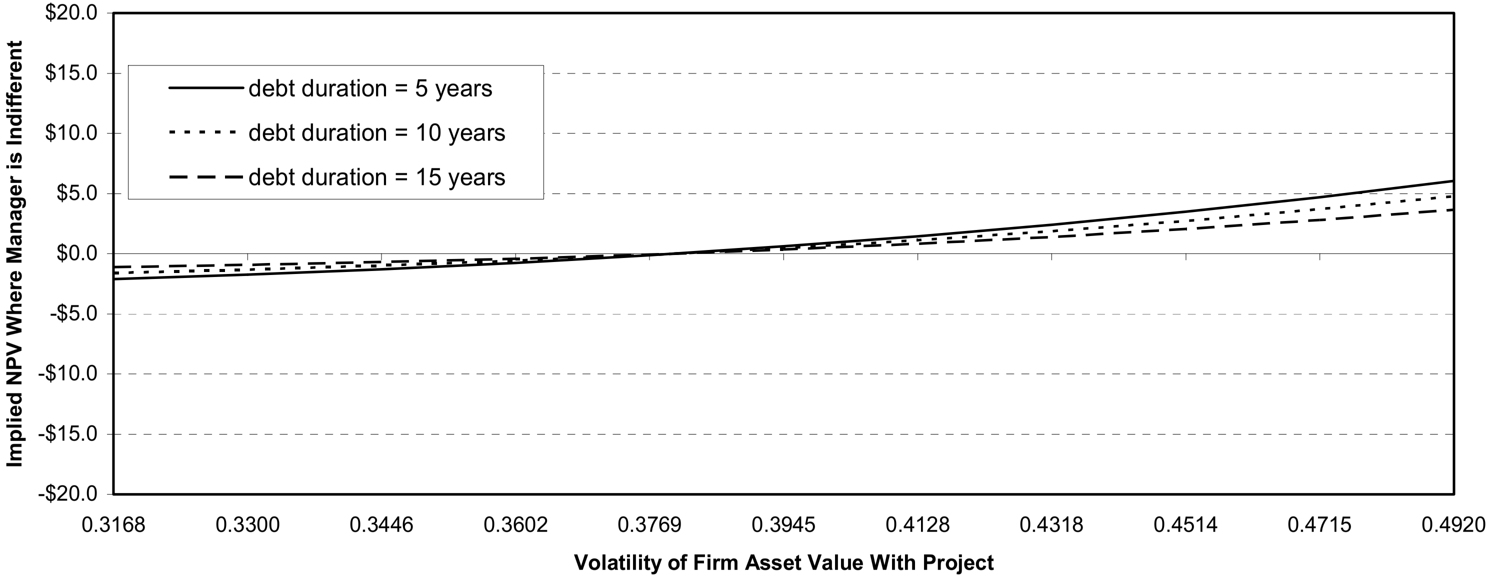
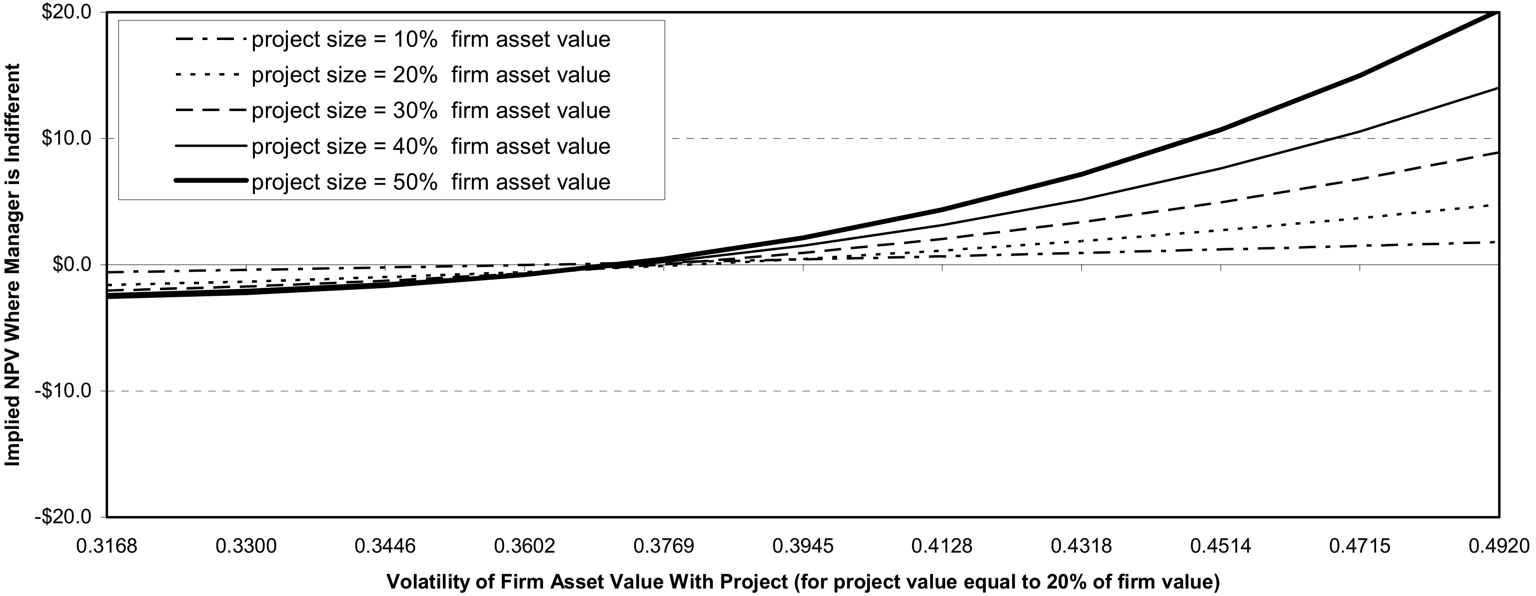


Figure 3. Indifference NPV for Different Project Sizes

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio for the project financing equals the firm's market debt/total capital ratio before the project.



aversion has been a subject of much debate. Given our goal of examining the implications of managerial risk aversion on project choice, our approach is to first examine the implications of our model, using a reasonable parameter value that has been suggested by others, and to then examine the sensitivity of the results to this parameter value. In our analysis so far, we have used a value of two for γ, based on the discussion in Ljungqvist and Sargent (2000). We now evaluate the sensitivity of the estimates from our model to this choice.

Figure 4 presents graphs of the indifference NPV for our base-case firm with risk-aversion parameter estimates of zero (the risk-neutral case), two, and five. The graphs in Figure 4 indicate that the distortion due to stockholder/manager conflicts is extremely sensitive to γ. The risk-neutral line slopes downward, because risky projects increase the value of the manager's stock and options with zero NPV projects (see Table III). The slopes of the curves in Figure 4 increase with γ, because as the manager becomes more risk averse, risk-reducing projects become more attractive and risk-increasing projects become less attractive.

Our base-case scenario assumes that the manager's non-firm wealth equals the value of his stock holdings (excluding options). Since we do not know of any reliable data on the outside wealth of corporate managers relative to the value of the shares they hold, this assumption seems to be a reasonable starting point. However, given the uncertainty about the outside wealth of a typical manager, as well as the substantial cross-sectional variation in non-firm wealth that undoubtedly exists, we believe it is important to understand the impact of this assumption on the distortion in investment behavior due to stockholder/manager conflicts. Therefore, in Figure 5 we present estimates of the indifference NPV for three values of outside wealth: 10%, 100%, and 1000% of the value of the manager's stockholdings.

Figure 5 shows that the level of outside wealth has a dramatic effect on investment incentives. When the manager has a high level of non-firm wealth, the line is slightly downward sloping. The high level of non-firm wealth in this case reduces the impact of the manager's investment decision on his total wealth, which reduces its impact on his utility. This smaller impact effectively reduces his risk aversion in investment decisions almost to the level illustrated in Figure 4 for a risk neutral manager. When the manager has a lot of non-firm wealth, he is relatively diversified. He is also more concerned about value than risk when making the firm's investment decisions.

In contrast, when the manager has a low level of non-firm wealth, the lines in Figure 5 slope upward. In such cases, the firm's stock represents a high proportion of the manager's total wealth and he is very reluctant to undertake a project that makes the stock value more volatile. Therefore, the manager will only accept risky projects that have very large values.

Much discussion in the compensation and corporate finance literature concerns the incentives that stock options provide and how option grants can best be structured.[6] This analysis is often presented in the context of formal models of stylized firms. Our model provides a way to examine the effect of stock options on management incentives to take risks in the context of a model calibrated to realistically reflect a number of factors not usually considered.

We first examine the differences between option and stock ownership. Firms often grant executives call options on the firms' shares as part of their compensation packages. However, some firms choose to grant restricted stock instead of options. Unlike options, restricted stocks require managers to bear both upside and downside risks.

In our base case, we set the percentage of the firm's shares on which the manager holds

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[6] See, for example, Hall and Murphy (2002), Meulbroek (2001) and Nohel and Todd (2001, 2002).

Figure 4. Indifference NPV for Different Risk-Aversion Parameters

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio for the project financing equals the firm's market debt/total capital ratio before the project.

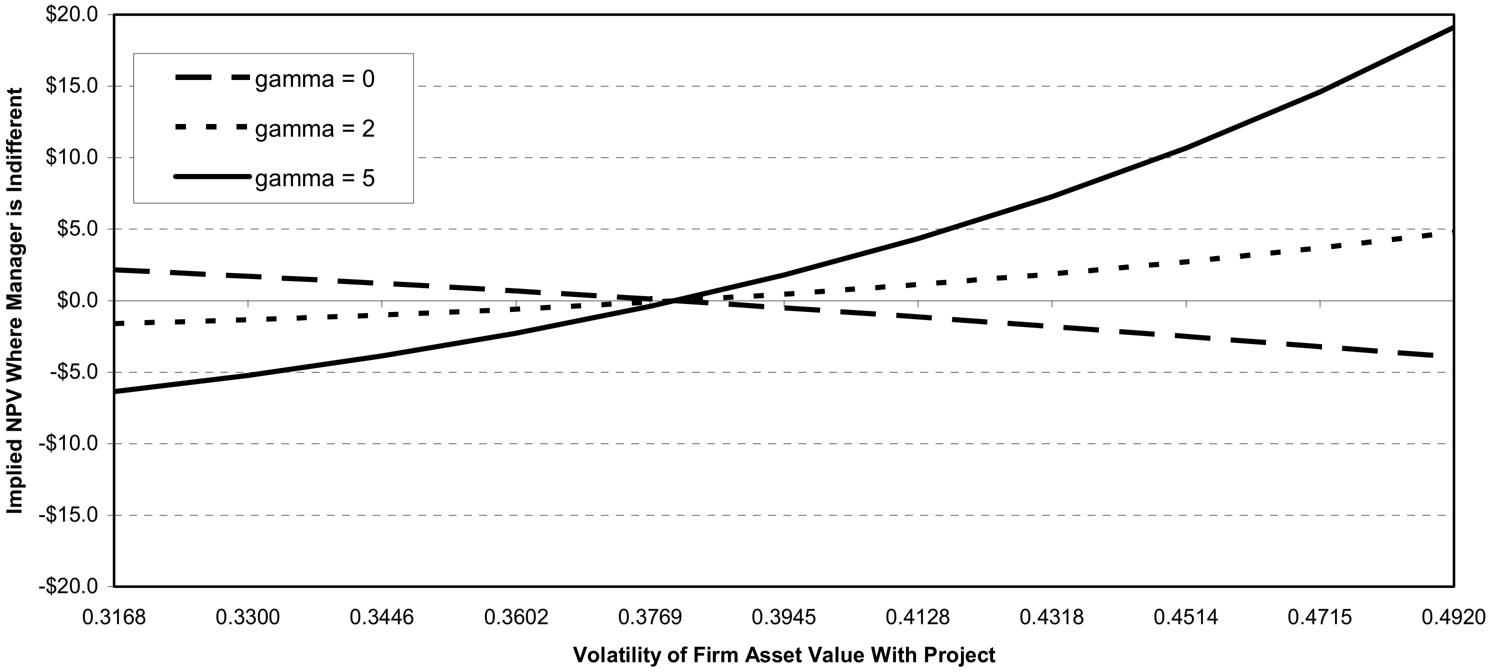
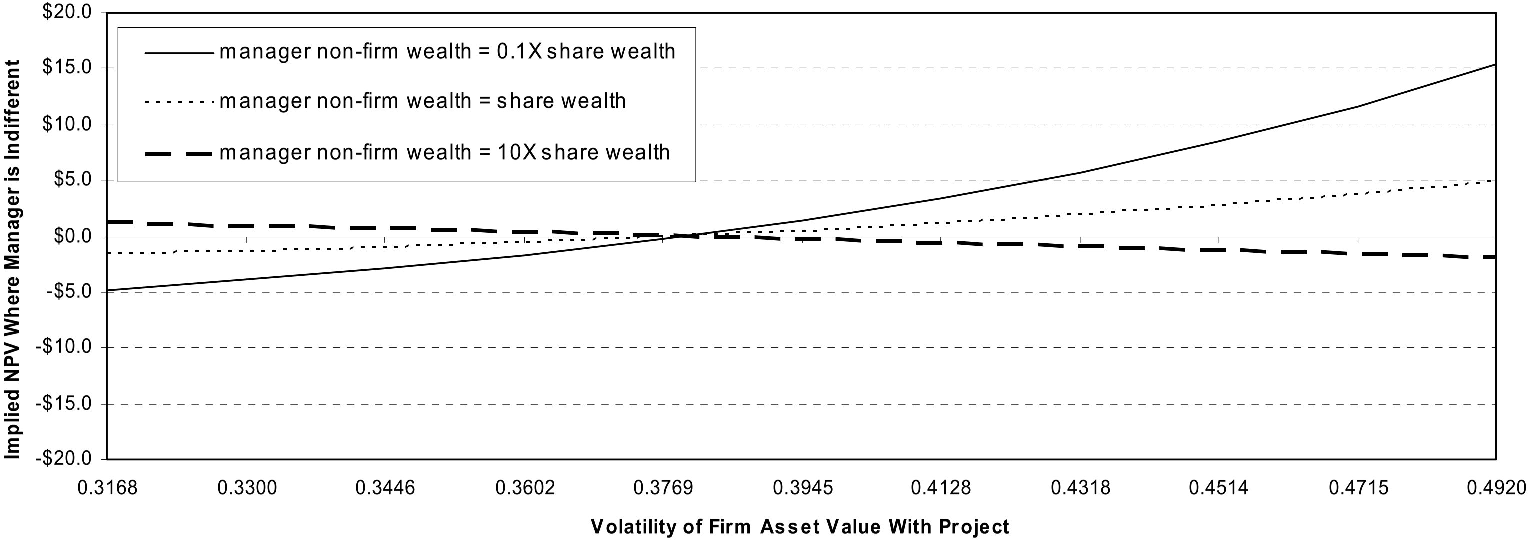


Figure 5. Indifference NPV for Different Levels of Manager Non-Firm Wealth

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio for the project financing equals the firm's market debt/total capital ratio before the project.



options equal to 0.38% and the percentage of shares the manager owns equal to 0.32%.[7] To consider the effects of option and stock holdings on risk-taking, in Figure 6 we compare the base case to cases in which the same overall fractional ownership, 0.7%, is represented entirely by option holdings or by stock holdings.

Figure 6 tells a straightforward story. The plot for the case in which the manager holds only options slopes downward. As before, the base-case plot slopes upward, and the plot for the case in which the manager holds only stock slopes upward more steeply than it does in the base case. These results reflect the fact that the value of the options increases with risk. This increase in option value that is attributable to greater volatility more than offsets the tax shield and bankruptcy cost effects and the effect of manager's risk aversion with high-risk projects when the manager holds only options. In contrast, when the manager holds only stock, the indifference NPV and incremental cost of equity increase with the risk of the project. These results suggest that the mix of options and restricted stock held by managers has a substantial impact on their risk-taking incentives.

Another question we examine is what exercise price firms should set for options granted to employees. The exercise price is often set equal to the stock price at the time of the option award. Figure 7 presents estimates from our model that allow us to compare three cases: the base case, in which options held by the manager have an exercise price equal to the value of the shares of the firm without the project; and cases in which the option exercise prices equal 50% and 150% of that value.

Figure 7 shows that setting the exercise price equal to 100% and 150% of the stock value leads to virtually identical risk-taking behavior. However, for options with the exercise price set equal to 50% of the market price, distortions from risk-taking are substantially larger. This result makes sense, since in-the-money options are more like stock than at-the-money or out-of-the-money options. With in-the-money options, management is more averse to downside movements in stock value, and thus requires a higher rate of return to undertake risky projects.

IV. Implications of the Model for a Sample of Public Firms

We also use our model to estimate the magnitude of potential distortions in investment decisions at 15 public firms, five each from the paper industry and allied products manufacturing, beer and wine manufacturing, and electrical goods distribution industries. These estimates provide additional insights on the willingness of risk-averse managers at levered firms to invest in projects with various levels of risk.

The firms we select within each industry exhibit considerable variation in leverage, the duration of their debt, their marginal tax rate, and/or the stock and options held by the CEO. Across the 15 firms, leverage varies from 6.24% (Kimberly-Clark) to 48.19% (Boise Cascade), The duration of outstanding debt varies from 1.5 years (Audiovox and Grainger (W. W.)) to 23 years (Mead), the marginal tax rate varies from 12.2% (Boise Cascade) to 35.4% (Audiovox), CEO stock ownership varies from 0.02% (Boise Cascade) to 22.16% (Willamette Valley Vineyards) of total shares, and CEO option holdings vary from 0.29% (Kimberly-Clark) to 10.66% (Golden State Vintners) of total shares. We use the actual values for each of these variables in estimating the investment distortions for each firm.

---

[7] We note that the stock in the model is effectively restricted stock, since the manager is not permitted to sell it. We also do not allow the manager to hedge equity risk even though, in practice, managers are increasingly able to hedge their personal positions by using derivatives (see Bettis, Bizjak, and Lemmon, 2001).

Figure 6. Indifference NPV for Different Levels of Stock and Option Ownership

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio for the project financing equals the firm's market debt/total capital ratio before the project.

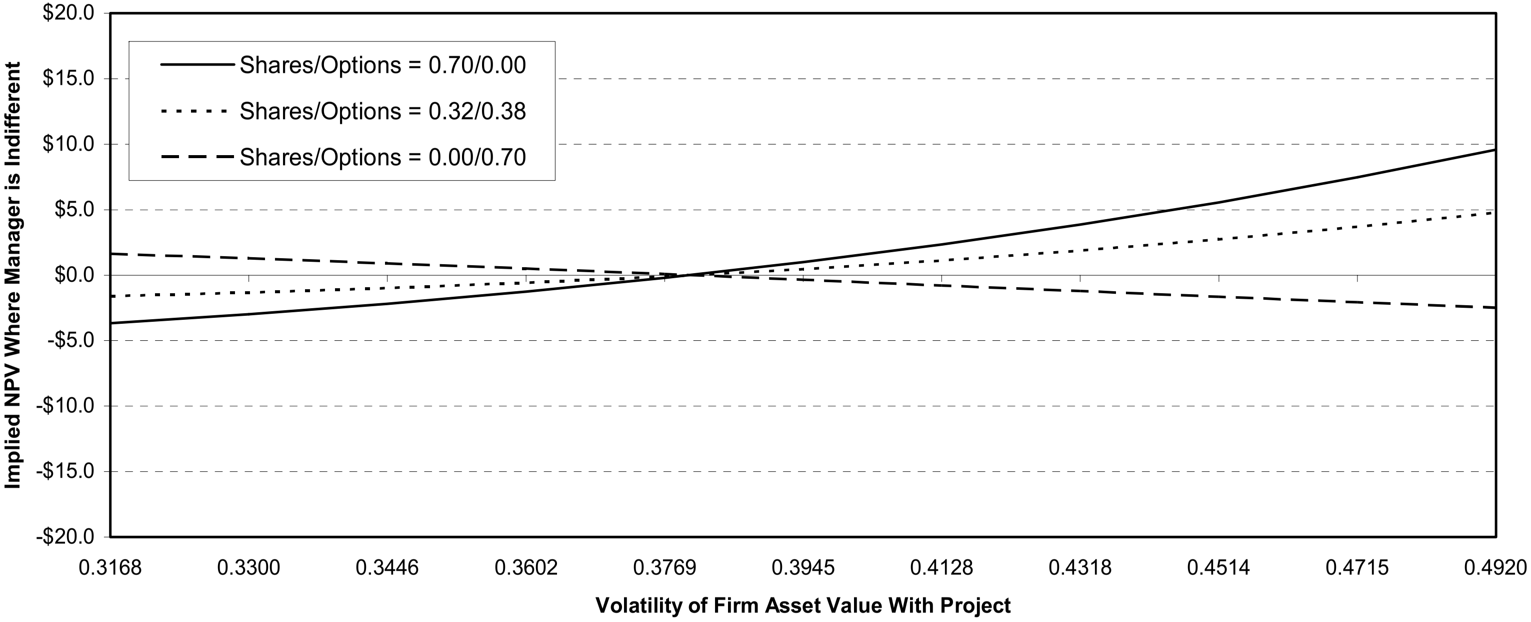
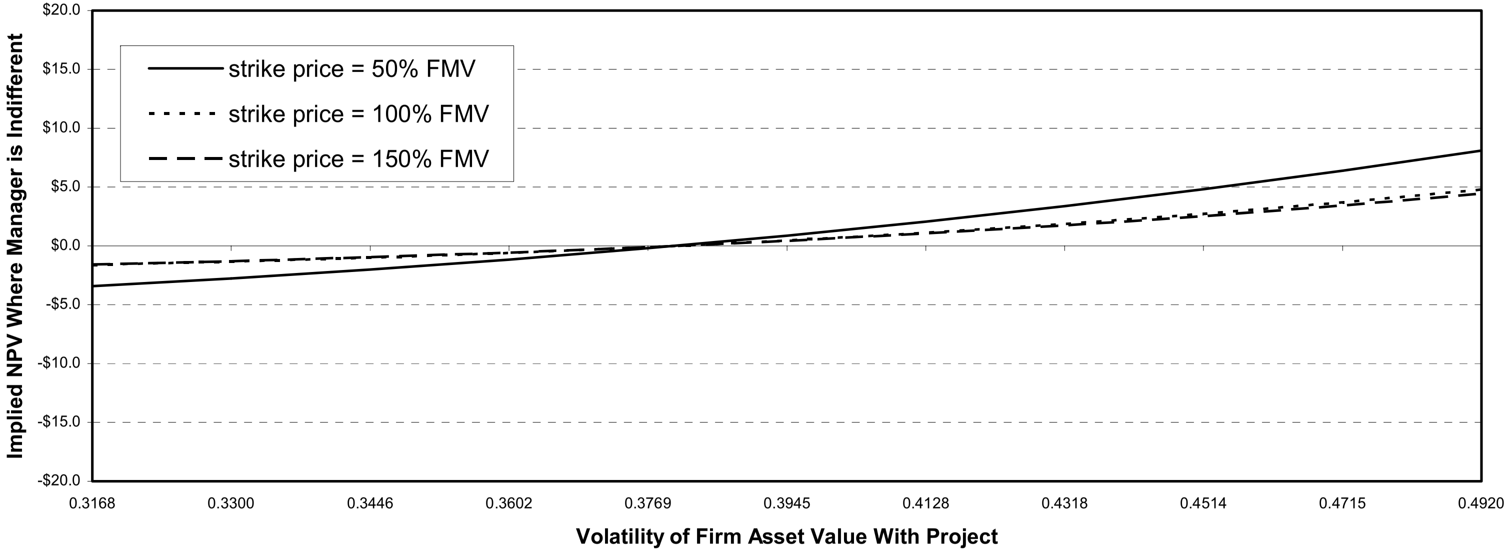


Figure 7. Indifference NPV for Different Option Strike Prices

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio for the project financing equals the firm's market debt/total capital ratio before the project.



For all firms, we assume that the manager has a risk aversion parameter of two, that the manager's non-firm wealth equals the value of the stock that he owns, and that the drift of the firm and project asset values is 10.63%. We select the debtholder bankruptcy recovery rate and the exponential growth rate for the bankruptcy boundary to yield an expected recovery rate of 45% in all cases. We choose the volatility of each firm's asset value and the bankruptcy recovery and boundary growth rates so that the spread between the cost of debt and risk free rate is consistent with the firm's credit risk. As with our base-case estimates, we assume the project's asset value equals 20% of the firm's asset value.

Figure 8 summarizes the results from these estimates. We note that instead of the post-project volatility reported in previous figures, in each plot in Figure 8 we report the ratio of the volatility of the project asset value to the volatility of the firm asset on the horizontal axis. We do this because without the project, the asset volatilities differ across firms. This ratio facilitates a more meaningful comparison of the results.

The most striking feature of the plots in Figure 8 is that, in all cases, the indifference NPVs are positive for projects with volatilities greater than 1.75 times the respective firm volatilities. This evidence suggests that managers can have relatively little incentive to invest in highly risky projects even when they receive relatively large amounts of option-based compensation.

Figure 8 also illustrates the considerable variation in investment incentives among CEOs within and across industries, even when we assume that their risk-aversion parameters are constant.

V. Conclusion

Since the Jensen and Meckling (1976) and Myers (1977) studies, researchers have often argued that the managers of a levered firm, who usually have a stake in the firm's equity but not the firm's debt, have incentives to accept projects that are too risky. Managers are especially likely to accept some relatively risky, value-reducing projects, and reject some relatively safe, value-increasing projects.

These arguments have generally ignored or downplayed the importance of managerial risk aversion, which is an important source of conflict between stockholders and managers and, as Prendergast (1999) notes, a central consideration in the design of incentive systems. In addition, risk changes can have important implications for the magnitude of other components of firm value, such as expected bankruptcy costs and tax shields. We know relatively little about the various mechanisms through which changes in a firm's risk affect a manager's utility, and consequently, the extent to which these changes distort investment decisions.

In this article, we assess the quantitative importance of the distortion in investment decisions that result from a number of factors. Our goal is to assess the relative importance of these factors. We present a dynamic model in which a manager of a levered firm, who owns a fraction of the equity and holds options on this equity, decides whether to undertake a risky project based on his own utility function. In the model, which we calibrate by using current market data and typical firm and manager characteristics, we use contingent-claims methods to estimate the values of the firm's equity, debt, debt tax shields, expected bankruptcy costs, and the extent to which all of these values change when the firm adopts a project. We calculate both the magnitude of the distortion in the investment decision and the importance of factors that affect the magnitude of this distortion. In contrast to most empirical studies in corporate finance, which examine the qualitative predictions of various models, we derive quantitative predictions from a model that we calibrate to reflect real-world data.

Figure 8. Indifference NPV for Individual Firms

This figure shows the implied NPV where the manager is indifferent for different values of firm asset value volatility with the project, and where the market debt/total capital ratio for the project financing equals the firm's market debt/total capital ratio before the project.

Panel A. Paper and Allied Products Manufacturing Firms

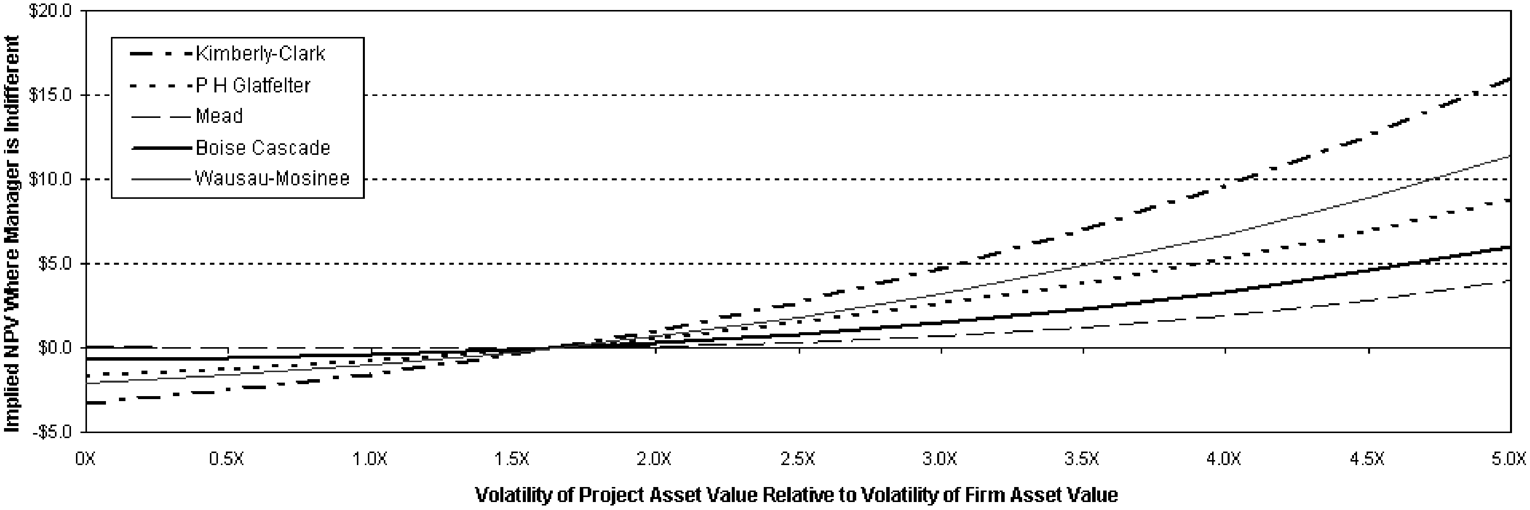


Figure 8. Indifference NPV for Individual Firms (*Continued*)

Panel B. Beer and Wine Manufacturing Firms

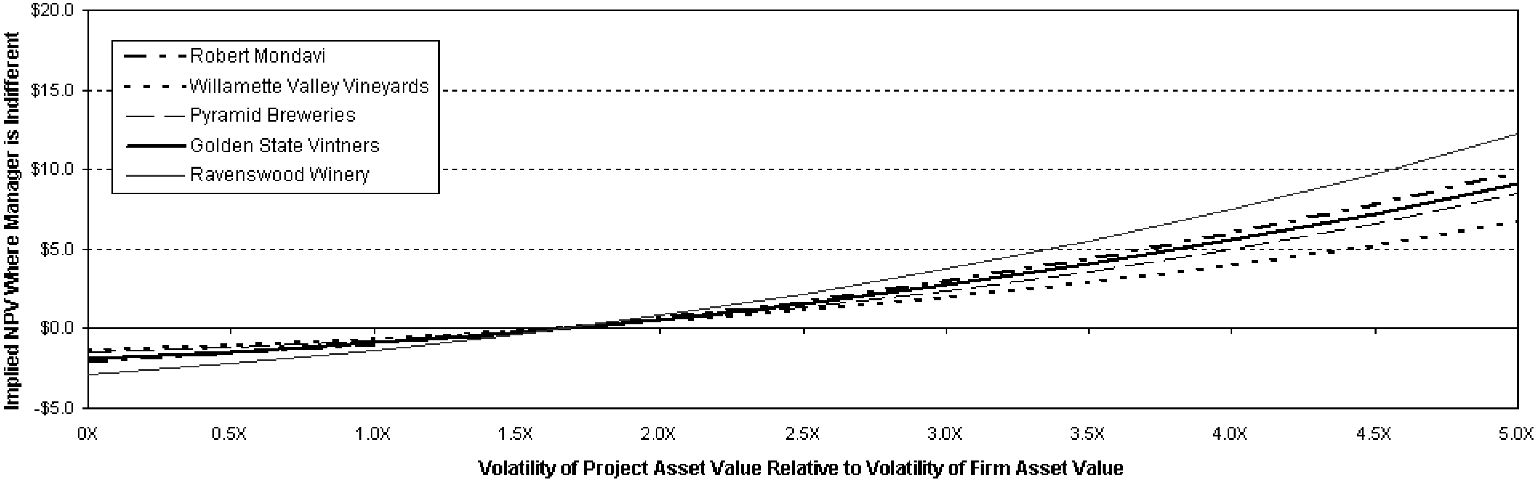
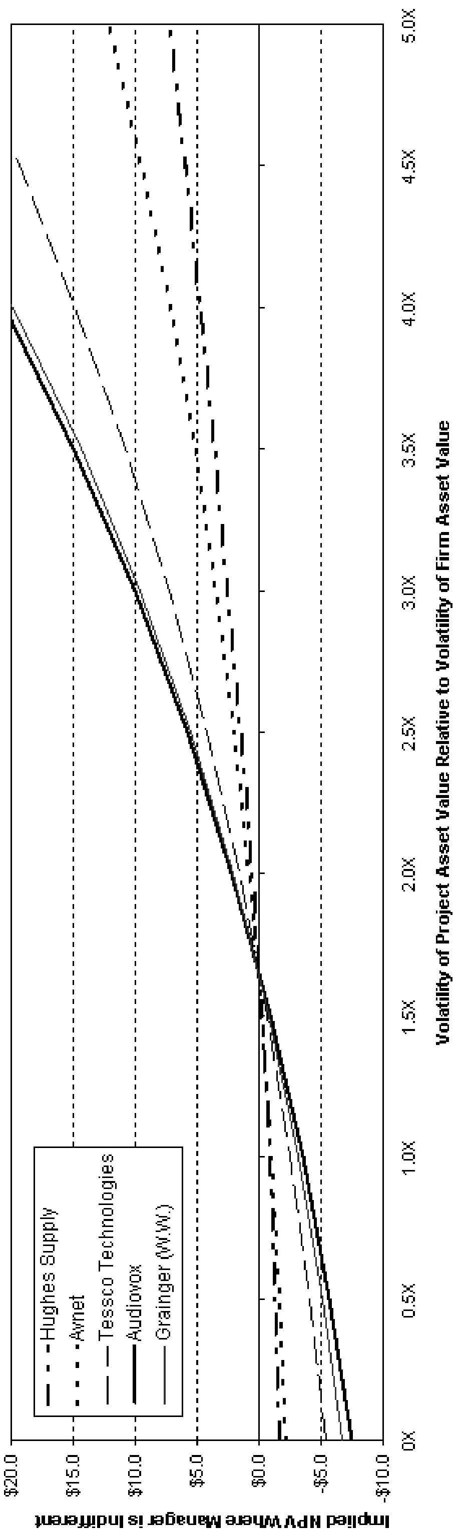


Figure 8. Indifference NPV for Individual Firms (*Continued*)

Panel C. Electrical Goods Distribution Companies



Our results suggest that the distortion in investment decisions that results from managerial risk aversion is significant. In our base-case scenario it is more important than the distortion due to stockholder/debtholder conflicts. A manager's reluctance to undertake a project generally increases with the project's risk, despite the fact that the magnitude of the wealth transfer from debtholders to stockholders also increases with project risk. Thus, our results are consistent with the growing literature suggesting that total firm risk, in addition to systematic risk, is an important factor in the decision-making process. (see, for example, Graham and Smith, 1999; Goyal and Santa-Clara, 2001; and Meulbroek, 2001). Our analysis is based on the assumption that the firm's compensation scheme and its capital structure are similar to those we observe in public firms. An interesting extension of our analysis would be to derive the magnitudes of the investment distortions using a model that allows the firm to optimize its compensation scheme and its capital structure to reflect the project characteristics and their interactions with other key assumptions.

We also find that debt tax shields and bankruptcy costs are important factors in the decision to adopt a project that changes a firm's risk. While tax shields and bankruptcy costs are often emphasized in the trade-off theory of optimal capital structure, we show that they have other important implications that the literature does not examine. In particular, once a firm's capital structure is in place, risk changes cause the values of both the firm's expected debt tax shields and expected bankruptcy costs to change. These changes result in distortions in investment decisions, ex post, in a manner similar to that posited by Jensen and Meckling (1976) and Myers (1977) for wealth transfers between stockholders and debtholders. However, the debt tax shield and bankruptcy cost effects move in the opposite direction from the wealth transfer effect, providing incentives for managers at levered firms to adopt projects that are overly safe, rather than excessively risky.

Our model suggests that once we consider these factors, then a manager who holds stock and options in proportion to the median ownership of CEOs at large publicly traded corporations is likely to behave in an overly risk-averse manner in selecting projects. The manager will accept some safe, value-reducing projects, and reject some risky, value-increasing projects. We find that three factors—the manager's risk aversion, the changes in the value of expected tax shields, and changes in the value of expected future bankruptcy costs — each work towards making relatively safe projects more desirable and relatively risky projects less desirable. These three factors provide incentives for managers to avoid additional firm risk, even at the cost of firm value.

We also find that the magnitude of the distortion is sensitive to model parameters and that the choice of the risk-aversion parameter has a large impact. Similarly, the fraction of the manager's wealth outside the firm is an important determinant of the distortion due to managerial risk aversion, as are the project size and debt maturity.

We contribute to the literature on executive compensation by documenting the benefits of options relative to stock grants as a means of providing risk-averse managers with incentives to accept risky projects, and we show how granting in-the-money options can provide managers with incentives to become excessively cautious.

Much work in corporate finance focuses on the existence of distortions in investment that result from contracting problems. Yet, evaluating the circumstances under which various distortions are or are not important is difficult. In this paper we apply a quantitative approach to estimating the magnitude of these distortions. Using this approach allows us to identify and evaluate the importance of these effects. Once a capital structure is in place, risk changes can have a major impact on the value of existing components of firm value, especially debt tax shields and bankruptcy costs.■

Appendix

This Appendix presents the solution to the model defined in the main body of the paper and describes how we use Ito's Lemma to extract the drift of the value of the unlevered assets of the firm from the risk-free rate and the equity premium.

A. Model Solution

The value of the debt, the bankruptcy costs, and the tax benefit of debt are computed from the probability density function for first hitting the exponential bankruptcy boundary. Let $f(t^*; V(0), A, g, r, \delta, \sigma)$ be the probability density for first hitting a boundary described by Ae^{gt} at a time t^*, where A is a constant, if the variable V initially has a value $V(0) > A$ and follows a geometric Brownian motion with drift $r - \delta$ and volatility σ. In our model, A is the value of the bankruptcy boundary at time zero, so that A is equal to $F_{NP}e^{-gT}$ if the project is forgone and is equal to $F_P e^{-gT}$ if the project is accepted. An explicit expression for $f(t^*; V(0), A, g, r, \delta, \sigma)$ is provided in Ju et al. (2005). We next define:

$$G\left(T, V(0), A, g, r, \delta, \sigma\right) \equiv \int_0^T f\left(t^*; V(0), A, g, r, \delta, \sigma\right) dt^* \tag{A.1}$$

$$H\left(T, V(0), A, g, r, \delta, \sigma\right) \equiv \int_0^T e^{-rt} f\left(t; V(0), A, g, r, \delta, \sigma\right) dt \tag{A.2}$$

and

$$I\left(T, V(0), A, g, r, \delta, \sigma\right) \equiv \int_0^T e^{-(r-g)} f\left(t^*; V(0), A, g, r, \delta, \sigma\right) dt^*. \tag{A.3}$$

The following closed form solutions for these expressions are derived in Ju et al. (2005):

$$\begin{aligned} G\left(T, V(0), A, g, r, \delta, \sigma\right) = {} & N\left[h_1\left(T, V(0), A, g, r, \delta, \sigma\right)\right] \\ & + \left(\frac{V(0)}{A}\right)^{-2a(r,\delta,g,\sigma)} N\left[h_2\left(T, V(0), A, g, r, \delta, \sigma\right)\right] \end{aligned} \tag{A.4}$$

$$\begin{aligned} H\left(T, V(0), A, g, r, \delta, \sigma\right) = {} & \left(\frac{V(0)}{A}\right)^{-a(r,\delta,g,\sigma)+z(r,\delta,g,\sigma)} N\left[q_1\left(T, V(0), A, r, \delta, g, \sigma\right)\right] \\ & + \left(\frac{V(0)}{A}\right)^{-a(r,\delta,g,\sigma)-z(r,\delta,g,\sigma)} N\left[q_2\left(T, V(0), A, r, \delta, g, \sigma\right)\right] \end{aligned} \tag{A.5}$$

$$I\left(T,V(0),A,g,r,\delta,\sigma\right)=\left(\frac{V(0)}{A}\right)^{-a(r,\delta,g,\sigma)+\bar{z}(r,\delta,g,\sigma)}N\left[\bar{q}_1\left(T,V(0),A,r,\delta,g,\sigma\right)\right]$$
$$+\left(\frac{V(0)}{A}\right)^{-a(r,\delta,g,\sigma)-\bar{z}(r,\delta,g,\sigma)}N\left[\bar{q}_2\left(T,V(0),A,r,\delta,g,\sigma\right)\right] \tag{A.6}$$

where

$$x_0\left(V(0),A\right)=\log\left(\frac{V(0)}{A}\right)$$

$$h_1\left(T,V(0),A,g,r,\delta,\sigma\right)=\frac{-x_0\left(V(0),A\right)-a(r,\delta,g,\sigma)\sigma^2T}{\sigma\sqrt{T}}$$

$$h_2\left(T,V(0),A,g,r,\delta,\sigma\right)=\frac{-x_0\left(V(0),A\right)+a(r,\delta,g,\sigma)\sigma^2T}{\sigma\sqrt{T}}$$

$$q_1\left(T,V(0),A,r,\delta,g,\sigma\right)=\frac{-x_0\left(V(0),A\right)-z(r,\delta,g,\sigma)\sigma^2T}{\sigma\sqrt{T}}$$

$$q_2\left(T,V(0),A,r,\delta,g,\sigma\right)=\frac{-x_0\left(V(0),A\right)+z(r,\delta,g,\sigma)\sigma^2T}{\sigma\sqrt{T}}$$

$$\bar{q}_1\left(T,V(0),A,r,\delta,g,\sigma\right)=\frac{-x_0\left(V(0),A\right)-\bar{z}(r,\delta,g,\sigma)\sigma^2T}{\sigma\sqrt{T}}$$

$$\bar{q}_2\left(T,V(0),A,r,\delta,g,\sigma\right)=\frac{-x_0\left(V(0),A\right)+\bar{z}(r,\delta,g,\sigma)\sigma^2T}{\sigma\sqrt{T}}$$

$$a(r,\delta,g,\sigma)=\frac{\left(r-\delta-g-\sigma^2/2\right)}{\sigma^2}$$

$$z(r,\delta,g,\sigma)=\frac{\left[\left(a(r,\delta,g,\sigma)\sigma^2\right)^2+2r\sigma^2\right]^{1/2}}{\sigma^2}$$

$$\bar{z}(r,\delta,g,\sigma)=\frac{\left[\left(a(r,\delta,g,\sigma)\sigma^2\right)^2+2(r-g)\sigma^2\right]^{1/2}}{\sigma^2}$$

and $N(\bullet)$ is the cumulative standard normal distribution function.

Following Leland and Toft (1996) and Ju (2001), the value of the debt at time zero is the sum of a contribution from the coupon, a contribution from the payment to debtholders if bankruptcy occurs, and the repayment of the face value at time T if bankruptcy does not occur:

$$
\begin{aligned}
D_i(0) &= C_i \int_0^T e^{-rt^*}\left(1-G\left(t^*,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right)\right)dt^* \\
&+ \int_0^T e^{-rt^*}\left(1-\alpha_{BC}\right)\frac{\left(V_i(0)+TB_i(0)+BC_i(0)\right)}{V_i(0)}F_ie^{-g\left(T-t^*\right)}f\left(t^*,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right)dt^* \\
&+ F_i\left(1-G\left(T,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right)\right)e^{-rT}, \quad i\in\{NP,P\}
\end{aligned}
\tag{A.7}
$$

or

$$
\begin{aligned}
D_i(0) &= \frac{C_i}{r}\left(1-\left(1-G\left(T,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right)\right)e^{-rT} - H\left(T,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right)\right) \\
&+ \left(1-\alpha_{BC}\right)\frac{\left(V_i(0)+TB_i(0)+BC_i(0)\right)}{V_i(0)}F_ie^{-gT}I\left(T,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right) \\
&+ F_i\left(1-G\left(T,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right)\right)e^{-rT}, \quad i\in\{NP,P\}
\end{aligned}
\tag{A.8}
$$

The second term of Equations (A.7) and (A.8) contain a factor (i.e., $(V + TB + BC)/V$) which implements our modeling decision that upon bankruptcy the debtholders receive $(1 - \alpha_{BC})$ of the *levered* value to a healthy firm of the remaining assets. Explicit expressions for $TB_i(0)$ and $BC_i(0)$ are provided below.

When deciding how to model the firm, we must also choose whether the firm should refinance maturing debt. Ju (2001) presents two alternative models. The first is a "static" model, in which the firm does not refinance debt, and becomes an all-equity firm subsequent to the time the debt matures. The second is a "dynamic" model in which new debt is reissued at the time of maturity. Since the dynamic framework seems *a priori* more appealing to us, and in fact Ju shows that the refinancing assumption can affect corporate financing decisions *ex ante*, we analyze stockholder/manager conflict using the dynamic model. Nonetheless, it is convenient to present the solution of the dynamic model in terms of that for the static model that we develop now.

In the static model, when the firm is forced into bankruptcy at time t^*, the bankruptcy costs are $\alpha_{BC}V(t^*)$. Hence, at time zero the value of the bankruptcy costs are

$$
BC_i(0) = \int_0^T \alpha_{BC}F_ie^{g\left(t^*-T\right)}e^{-rt^*}f\left(t^*;V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right)dt^*, \quad i\in\{NP,P\} \tag{A.9}
$$

or

$$
BC_i(0) = \alpha_{BC}F_ie^{-gT}I\left(T,V_i(0),F_ie^{-gT},g,r,\delta,\sigma_i\right), \quad i\in\{NP,P\}. \tag{A.10}
$$

The tax benefits of debt accrue to the firm as long as it has not gone bankrupt. Consequently, the tax benefits of debt in the static model can be computed by:

$$TB_i(0)=\int_0^T \tau C_i e^{-rt^*}\left(1-G\left(t^*,V_i(0),F_i e^{-gT},g,r,\delta,\sigma_i\right)\right)dt^*,\qquad i\in\{NP,P\} \tag{A.11}$$

or

$$\begin{aligned}TB_i(0)=\frac{\tau C_i}{r}\Big(1-&\left(1-G\left(T,V_i(0),F_i e^{-gT},g,r,\delta,\sigma_i\right)\right)e^{-rT}\\ &-H\left(T,V_i(0),F_i e^{-gT},g,r,\delta,\sigma_i\right)\Big),\qquad i\in\{NP,P\}.\end{aligned} \tag{A.12}$$

The value of the equity is equal to the value of the assets plus the tax benefits of debt minus the bankruptcy costs minus the value of the debt:

$$E_i(0)=V_i(0)+TB_i(0)-BC_i(0)-D_i(0),\qquad i\in\{NP,P\} \tag{A.13}$$

In order to compute the manager's time zero expectation of his utility at time T_u, we let $V^K(T_u)$ be the value of the firm's assets at time T_u that makes a share of stock worth K at time T_u. Then the manager's time zero expectation of his utility at time T_u can be computed as the sum of three components. The first component is a function of the probability density for the value of the firm's assets being at various levels above $V^K(T_u)$ at time T_u without having touched the bankruptcy boundary between time zero and time T_u. The second component is a function of the probability density for the value of the firm's assets being at various levels below $V^K(T_u)$ at time T_u without having touched the bankruptcy boundary between time zero and time T_u. The third component is the utility derived from the manager's non-firm wealth if the bankruptcy boundary is hit. Let $g(V(0), V(T), T, A, g, \mu,\delta,\sigma)$ be the density function for starting at a value $V(0) > A$ and being at $V(T) > Ae^{gT}$ at time $T > 0$ without ever hitting the boundary Ae^{gT} in the interval $t\in[0,T]$ when the V process follows geometric Brownian motion with drift $\mu - \delta$ and volatility σ. An explicit expression for $g(V(0), V(T), T, A, g, \mu,\delta,\sigma)$ is presented in Ju et al. (2005). Then at time zero, the manager's expectation of his utility at time T_u without and with the project is given by:

$$\begin{aligned}Utility_i(0)=&\int_{V_i^K(T_u)}^{\infty} U\left\{NFW(T_u)+\frac{N_{Man}+N_{Calls}}{N_i}\left[V_i(T_u)+TB_i(T_u)-BC_i(T_u)-D_i(T_u)\right]-N_{Calls}K+Div_i\right\}\\ &\times g\left(V_i(0),V_i(T_u),T_u,F_i e^{-gT},g,\mu,\delta,\sigma_i\right)dV_i(T_u)\\ &+\int_{F_i}^{V_i^K(T_u)} U\left\{NFW(T_u)+\frac{N_{Man}}{N_i}\left[V_i(T_u)+TB_i(T_u)-BC_i(T_u)-D_i(T_u)\right]+Div_i\right\}\\ &\times g\left(V_i(0),V_i(T_u),T_u,F_i e^{-gT},g,\mu,\delta,\sigma_i\right)dV_i(T_u)\\ &+U\left(NFW(T_u)+Div_i\right)\int_0^{T_u} f\left(t;V_i(0),F_i e^{-gT},g,\mu,\delta,\sigma_i\right)dt,\quad i\in\{NP,P\}\end{aligned} \tag{A.14}$$

where:

$$Div_i \equiv \frac{N_{Man}}{N_i} \int_0^{T_u} e^{r(T_u - t)} \int_{Fe^{-g(T-t)}}^{\infty} \left[\delta V_i(t) - (1-\tau) C_i \right] g\left(V_i(0), V_i(t), t, F_i e^{-gT}, g, \mu, \delta, \sigma_i\right) dV_i(T_u) dt, \quad i \in \{NP, P\} \tag{A.15}$$

and $V_i^K(T_u)$ satisfies the equation:

$$K = \frac{V_i^K(T_u) + TB_i(T_u) - BC_i(T_u) - D_i(T_u)}{N_i}, \quad i \in \{NP, P\}. \tag{A.16}$$

Equation (A.15) defines *Div* as the amount of money the manager expects to have at time T_u from dividend payments provided that any dividend payments received before time T_u are re-invested at the risk-free rate until time T_u. Equations (A.14) and (A.15) make an approximation by passing an expectation inside the argument of the utility function. We make this approximation in the interest of numerical tractability, because the joint distribution of $V(T_u)$ and the accumulated dividends until time T_u is not available in closed-form. We are confident that none of the main features of our results are driven by this approximation, because setting *Div* to zero does not alter the conclusions of the paper. All terms in the numerator of the right hand side of Equation (A.16) are a function of $V_i^K(T_u)$.

Next we extend the model to a more realistic dynamic setting. As in the static case, at time zero the firm has debt outstanding with T years to maturity and the manager decides whether to accept a project. Now, however, if the firm has not gone bankrupt at the end of T years, the firm issues new T-year debt at time T. The new debt pays a coupon of either $C_{NP}V_{NP}(T)/V_{NP}(0)$ or $C_P V_P(T)/V_P(0)$, respectively, depending upon whether the firm has foregone or accepted the project at time zero. Similarly, as shown in Ju et al. (2005), all other securities will be scaled by a factor of $V_{NP}(T)/V_{NP}(0)$ or $V_P(T)/V_P(0)$, because at time T the firm is identical to itself at time zero except that it is $V(T)/V(0)$ as large. The process of issuing new T-year debt each time existing debt matures continues indefinitely until the firm goes bankrupt.

In this dynamic setting, the price of the debt is still given by Equation (A.8). The firm value, however, will reflect the costs and benefits of the debt issued in the future until the firm goes bankrupt. In order to determine the total tax benefit and total bankruptcy cost of the current and potential future issues of debt, the following quantity will be useful:

$$\phi_i \equiv e^{-rT} E^Q \left[\mathbf{1}_{\{\text{Firm does not go bankrupt over } [0,\text{T}]\}} \frac{V_i(T)}{V_i(0)} \right] \qquad i \in \{NP, P\} \tag{A.17}$$

The indicator function $\mathbf{1}_{\{\text{Firm does not go bankrupt over } [0,\text{T}]\}}$ is equal to one if the firm does not go bankrupt over the interval $[0, T]$ and zero otherwise. The expectation is taken over the risk-neutral Q measure. Ju et al. (2005) show that ϕ is given by the following expression:

$$\phi_i = e^{-\delta_i T}\left[N\left(d_i^1\right) - \left(\frac{F_i e^{-gT}}{V_i(0)}\right)^{2\left(1+\left(r-\delta-g-\sigma_i^2/2\right)/\sigma_i^2\right)} N\left(d_i^2\right)\right], \qquad i \in \{NP, P\} \tag{A.18}$$

where:

$$d_i^1 = \frac{-\log\left(F_i e^{-gT}/V_i(0)\right) + \left(r-\delta-g+\sigma_i^2/2\right)T}{\sigma_i\sqrt{T}}, \qquad i \in \{NP, P\} \tag{A.19}$$

and

$$d_i^2 = \frac{\log\left(F_i e^{-gT}/V_i(0)\right) + \left(r-\delta-g+\sigma_i^2/2\right)T}{\sigma_i\sqrt{T}}, \qquad i \in \{NP, P\}. \tag{A.20}$$

It is also shown in Ju et al. (2005) that the total tax benefit of debt and the total bankruptcy costs are given by:

$$TB_i^{Dynamic}(0) = \frac{TB_i(0)}{1-\phi_i}, \qquad i \in \{NP, P\} \tag{A.21}$$

and

$$BC_i^{Dynamic}(0) = \frac{BC_i(0)}{1-\phi_i}, \qquad i \in \{NP, P\}. \tag{A.22}$$

As in Equation (A.13), the value of the equity is equal to the value of the assets plus the tax benefits of debt minus the bankruptcy costs minus the value of the debt:

$$E_i^{Dynamic}(0) = V_i(0) + TB_i^{Dynamic}(0) - BC_i^{Dynamic}(0) - D_i(0), \qquad i \in \{NP, P\}. \tag{A.23}$$

B. Drift of Value of Unlevered Assets of the Firm

We select a value for the drift parameter of the firm, μ, by implementing an argument like one used in Merton (1974). We begin by formally writing the dynamics of the equity's value without the project as:

$$dE_{NP} = \left(\mu_{E_{NP}} - \delta_{E_{NP}}\right)E_{NP}\,dt + \sigma_{E_{NP}} E_{NP}\,dZ_{E_{NP}}. \tag{A.24}$$

By Ito's lemma and the dynamics of the firm under the physical measure given in Equation (2), we can also write the dynamics for E_{NP} as:

$$dE_{NP} = \left[\frac{1}{2} \sigma_{NP}^2 V_{NP}^2 \frac{\partial^2 E_{NP}}{\partial V_{NP}^2} + (\mu - \delta) V_{NP} \frac{\partial E_{NP}}{\partial V_{NP}} + \frac{\partial E_{NP}}{\partial t} \right] dt + \sigma_{NP} V_{NP} \frac{\partial E_{NP}}{\partial V_{NP}} dZ. \quad \text{(A.25)}$$

Matching the coefficients on the drift components of Equations (A.24) and (A.25) yields:

$$\mu = \frac{\left(\mu_{E_{NP}} - \delta_{E_{NP}}\right) E_{NP} - \frac{1}{2} \sigma_{NP}^2 V_{NP}^2 \frac{\partial^2 E_{NP}}{\partial V_{NP}^2} - \frac{\partial E_{NP}}{\partial t}}{V_{NP} \frac{\partial E_{NP}}{\partial V_{NP}}} + \delta. \quad \text{(A.26)}$$

We set $\mu_{E_{NP}}$ equal to 0.1122 by assuming an equity risk premium of 6% over our risk free rate of 5.22%. When the rest of the quantities on the right hand side of Equation (A.26) are computed from the calibrated values for our standardized firm, the equation yields our base case value for μ of 10.63%.

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