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Agency Conflicts and Risk Management*

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Abstract. This paper analyzes the relation between agency conflicts and risk management. In contrast to previous contributions, our analysis incorporates not only stockholder-debtholder conflicts but also manager–stockholder conflicts. We show that the costs of both underinvestment and overinvestment are essential in determining the firm's hedging policy. In particular, firms that derive more of their value from assets in place (lower market-to-book ratios), although having lower costs of underinvestment, generally display larger costs of overinvestment. Thus, they may be more likely to hedge to control these overinvestment incentives. Our analysis explains why large profitable firms with fewer growth opportunities tend to hedge more (Bartram et al., 2004). It also provides a number of new predictions relating the benefits associated with risk management to various dimensions of the firm's economic environment.

JEL Classification: G13, G31, G32

1. Introduction

Much of the understanding of corporate risk management is based on static models that describe how various capital market imperfections shape firms' hedging policies. While existing models provide a rich intuition as to why firms should engage in risk management activities, they have not been entirely successful at explaining the empirical evidence on corporate risk management. For example, in a recent study using a sample of 7,319 firms from 50 countries, Bartram et al. (2004) "find evidence clearly counter to the most widely-cited theories". Notably they document that "large profitable firms with fewer growth opportunities (low market-to-book ratios) tend to hedge more". In this paper we argue that one potential explanation for the limited success of existing theories is that the literature has overlooked some determinants of hedging policies—notably the impact of manager-shareholder conflicts on risk management strategies.

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The notion that agency conflicts affect firms' policy choices is now widely accepted. While agency conflicts can take a variety of variety of forms, the literature on corporate risk management has more narrowly focused on shareholder-debtholder conflicts. In particular, this literature has shown that underinvestment incentives due to stockholder-debtholder conflicts may lead firms with more growth opportunities (higher market-to-book ratios) to hedge more (see Mayers and Smith, 1987, or Bessembinder, 1991). In this paper, we argue that a firm's risk management strategy should reflect not only the underinvestment costs associated with stockholder-debtholder conflicts but also the overinvestment costs due to manager-stockholder conflicts. In particular, firms that derive more of their value from assets in place (lower market-to-book ratios), although having lower costs of underinvestment, generally display larger costs of overinvestment. As a result, these firms may be more likely to hedge to control these overinvestment incentives, consistently with the evidence reported by Bartram et al. (2004).

A prerequisite for our analysis is a model that captures in a simple fashion the impact of agency conflicts on corporate risk management. In this paper, we base our analysis on a contingent claims model in the spirit of Mello and Parsons (1992). While most contingent claims models assume that shareholder protection is perfect, we consider a setting in which management derives private benefits from investment and tends to overinvest, thereby giving rise to agency costs of free cash flow. In our model, shareholders cannot control investment policy because investment decisions, although observable, are not verifiable and, thus, are not contractible. However, financing and hedging are observable and contractible; the board has to approve financial decisions. As a result, shareholders—through the board of directors—have discretion over financing and hedging policies. Based on this allocation of control rights, the paper derives valuation formulas for corporate debt and equity. These expressions are then used to analyze the interaction among investment, financing, and hedging policies.

One of the main contributions of this paper is to show that both financing and hedging policies affect manager-shareholder conflicts by limiting the firm's free cash flow. Following Jensen (1986), several authors have recognized the role of debt in limiting the manager's ability to invest in negative NPV projects. However, the role of other financial policies in controlling the free cash flow problem generally has not been explored. We argue that hedging not only can control shareholders' underinvestment incentives but managers' ability to overinvest as well. While a number of papers address issues relating to investment choices and risk management, these papers have more narrowly focused on the impact of risk management on underinvestment costs. For example, Mayers and Smith (1987) and Bessembinder (1991) show that hedging can control the underinvestment problem identified by Myers (1977); Froot et al. (1993) demonstrate that hedging can reduce the underinvestment cost associated with financing constraints. In this paper, we analyze the role of risk management in controlling both underinvestment and overinvestment costs. Within our model, optimal leverage reflects a trade-off between under- and overinvestment costs. Risk management improves firm value and affects optimal leverage by controlling both of these costs.

In Section 2, we present our basic model. We analyze the impact of financial policies on investment policy and show that risk management controls both overinvestment and underinvestment problems. In Section 3, we examine the impact of risk management on firm value and financing policies using an intertemporal version of the basic model. We also examine in this section the benefits associated with risk management in different economic environments. We offer our conclusions in Section 4.

2. The Basic Model

This section presents a model that captures the impact of agency conflicts on risk management within a particularly simple setting. Throughout the section, agents are risk neutral and equilibrium interest rates are zero. We construct a two-period model and, hence, focus on three dates. To finance an initial project at date $t = 0$, a firm acquires external funding either from shareholders or from bondholders. This initial project yields a random cash flow x at $t = 1$ given by

$$x = \mu + \phi, \tag{1}$$

where μ is a positive constant and ϕ is uniformly distributed on $[-e, e]$ with $e < \mu$. The cash flow from this initial project may be reinvested at $t = 1$. Following Stulz (1990) and Morellec (2004), we consider that the marginal product of investment is decreasing and given by a step function. Specifically, the payoff at $t = 2$ from investment is given by H, $H > 1$, per unit for the first I^* units and L per unit in excess of I^*, $L < 1$. Thus, investment up to I^* has a positive NPV whereas investment in excess of I^* has a negative NPV.

We introduce manager-stockholder conflicts and imperfect shareholder protection by assuming that the manager receives private benefits from investment. As in Hart and Moore (1995), we consider an extreme setting in which it always is optimal for the manager to invest. We also assume that perquisites increase with the projects' NPV. Thus, the manager exhausts positive NPV projects before investing in negative NPV projects. This specification allows us to capture Jensen's idea that the overinvestment problem is more severe for firms with larger cash flows [Harford (1999) provides empirical evidence supporting this view].

Agency costs of managerial discretion typically depend on the allocation of control rights within the firm. Throughout the paper, shareholders are represented by a board of directors that acts in their best interests. Following

Hart and Moore (1995) and Zwiebel (1996), we consider that cash flows and investment decisions, although observable, are not verifiable. In other words, x and I^* cannot be the basis of an enforceable, contingent contract and the board has to delegate decision-making authority with respect to investment and dividend policies.[1,2] However, financing policy is observable and contractible; the board has to approve financing decisions. Thus, the board can use its control of financing policy to constrain investment policy.[3]

2.1 FIRM VALUATION AND OPTIMAL LEVERAGE

We start by analyzing the impact of financing decisions on agency conflicts and firm value. In our model, the value of the firm is the sum of the values of its assets in place and its investment opportunities. Since investment decisions are not contractible, the value of the firm's investment opportunities depends on the investment policy selected by the manager and, thus, on the level of the resources available for investment.

As argued by Jensen (1986), debt can control the cost of managerial discretion by limiting free cash flow. In this section we assume that debt issued at date $t = 0$ matures at date $t = 1$. Proceeds from the debt issue may be paid as a dividend at date $t = 0$ or used to finance assets in place. Within our model, debt financing affects firm value in two ways. First, by reducing the resources available for investment at $t = 1$, debt constrains the manager from investing in negative NPV projects, thereby controlling the free cash flow problem. Second, by increasing default risk, debt reduces the number of states of nature where the firm invests in positive NPV projects, thereby inducing underinvestment.

We denote the values of debt and equity when the firm has issued debt with face value F by $\mathcal{D}(F)$ and $\mathcal{E}(F)$. If the firm can raise outside equity to finance positive NPV projects, it is optimal for shareholders to default when the present value of the cash flows to be received is less than the firm's outstanding liabilities, i.e. whenever $x + I^* (H - 1) < F$. Under this default

[1] The overinvestment problem could be eliminated if the board could set dividends prior to the manager's investment decision. Alternatively, a floor on dividends would serve to mitigate the problem. While such covenants are not observed in debt contracts, the use of preferred stock has the effect of stipulating a minimum on dividend payments. This suggests that control of overinvestment is a potentially important motive for issuing preferred shares.

[2] To capture this aspect of the contracting process, the Appendix presents an extension of the basic model in which the amount of positive NPV projects is unobservable to investors.

[3] When internal control mechanisms are ineffective, the policy choices of the manager might still be constrained by the external market for corporate control [see e.g., Zwiebel (1996) and Morellec (2004)].

policy, the values of equity and debt satisfy

$$\mathcal{E}(F) = \int_{F-I^*(H-1)}^{\mu+e} \frac{x - F + I^*(H-1)}{2e} dx + (L-1) \int_{F+I^*}^{\mu+e} \frac{x - F - I^*}{2e} dx, \tag{2}$$

and

$$\mathcal{D}(F) = \int_{F-I^*(H-1)}^{\mu+e} \frac{F}{2e} dx + \int_{\mu-e}^{F-I^*(H-1)} \frac{x}{2e} dx, \tag{3}$$

where $F - I^*(H-1) > \mu - e$. In this specification, the value of equity equals the cash flow from assets in place plus the NPV of the firm's investment opportunities in the non-default states. Debtholders recover the value of assets in place in default but are unable to exploit the firm's growth options.

When selecting debt policy, the objective of shareholders is to maximize their wealth, i.e. the sum of the proceeds from the debt issue and the value of equity after the debt issuance. This debt level is defined by $F \in \arg\max_{[0,b]} \mathcal{V}(F)$ where $\mathcal{V}(F) = \mathcal{E}(F) + \mathcal{D}(F)$. We then have the following result.

Proposition 1. *The debt level selected by shareholders satisfies*

$$F^* = \max\left\{\mu + e - I^* \frac{H-L}{1-L}, 0\right\}. \tag{4}$$

The selected leverage ratio increases with the cost of overinvestment (decreases with L) and decreases with the cost of underinvestment (decreases with H).

As argued by Jensen (1986), debt financing can mitigate the free cash flow problem. However, standard debt contracts promise the same payoff in all the states of nature. As a result, although debt financing reduces overinvestment when cash flows are high, it also induces underinvestment when cash flows are low. Although several authors have recognized the role of debt in controlling the free cash flow problem, the role of other financial policies generally has not been explored. We now turn to analyzing the impact of hedging policy on investment policy and firm value.

2.2 RISK MANAGEMENT AND INVESTMENT POLICY

The Modigliani-Miller theorem implies that hedging policy increases firm value if it lowers taxes, reduces contracting costs, or improves investment policy. Mayers and Smith (1987) and Bessembinder (1991) show that hedging can control the underinvestment problem identified by Myers (1977); Froot et al. (1993) demonstrate that hedging can reduce the underinvestment cost associated with financing constraints. In this literature, the agency cost of free cash flow has been largely ignored.

To motivate the following analysis, we start by examining the impact of cash flow volatility on investment. For any given debt policy, firm value is given by

$$\mathcal{V}(F) = \mu + I^* (H-1) \frac{\mu + e + I^* (H-1) - F}{2e} + (L-1) \frac{(\mu + e - I^* - F)^2}{4e}, \tag{5}$$

and is maximized for $F = F^*$. Replacing F^* by its expression in Proposition 1, we find that firm value satisfies at optimal leverage

$$\mathcal{V}(F^*) = \mu + \frac{(H-1)(I^*)^2}{2e} \left[H + \frac{1}{2} \frac{H-1}{1-L} \right]. \tag{6}$$

The second term on the right-hand side of this equation decreases with the variance of cash flows from assets in place, as reflected by e. In other words, higher volatility in operating cash flows implies larger costs of both overinvestment and underinvestment. Thus, firm value increases when cash flow volatility is reduced.

To illustrate the impact of hedging policy on investment decisions, assume that there is a forward contract on a commodity with price at $t = 1$ given by $s = \beta x + \eta$, where $\beta > 0$ and η is a random variable independent of x. Further assume that η has uniform distribution over $[-f, f]$ where $f < e$. The payment on the forward contract is then given by $Z = \beta(x - \mu) + \eta$. By taking positions in this forward contract, the manager can mitigate both overinvestment and underinvestment costs. If the manager does so by engaging in θ contracts, future net cash flows after hedging are

$$g(x, \theta) = (1 + \theta\beta) x - \theta\beta\mu + \theta\eta. \tag{7}$$

The number of forward contracts that minimizes the variance of future net cash flows is the one that minimizes the adverse investment incentives within the firm. This minimum variance hedge is defined by

$$\theta^* = -\frac{\beta e^2}{\beta^2 e^2 + f^2} > -\beta^{-1}. \tag{8}$$

When selecting financing and hedging policies, shareholders' objective is to maximize the sum of the value of equity after the debt issuance and the proceeds from the debt issue. These policy choices solve $\max_{\{F_h, \theta\}} \mathcal{V}(F_h, \theta)$ where $\mathcal{V}(F_h, \theta) = \mathcal{E}(F_h, \theta) + \mathcal{D}(F_h, \theta)$ accounts for firm value. We then have the following result (see the Appendix).

Proposition 2. *The hedging and financing policies selected by shareholders are given by*

$$\theta^* = -\beta e^2(\beta^2 e^2 + f^2)^{-1} \text{ and } F_h^* = F^* + \theta^* (\beta\mu - f) < F^*, \tag{9}$$

where F^* is the debt level selected by shareholders when the firm does not engage in risk management activities. At optimal leverage firm value satisfies:

$$\mathcal{V}\left(F_h^*, \theta^*\right) = \mu + \frac{(H-1)\,(I^*)^2}{2e} \frac{\beta^2 e^2 + f^2}{f^2} \left[H + \frac{1}{2}\frac{H-1}{1-L}\right] > \mathcal{V}\left(F^*\right). \tag{10}$$

By reducing the volatility of future cash flows, risk management reduces both overinvestment and underinvestment costs. As a result, for any debt level F, firm value is higher when the firm engages in hedging activities. Moreover, the optimal debt level is lower, reflecting the reduced benefits of controlling the free cash flow problem. Obviously the benefits associated with risk management depend on a number of dimensions of the firm's environment such as the ability to fund projects outside of the firm's core competencies or the firm's access to external capital markets. The next section examines this issue within an intertemporal version of the above model.

3. The Intertemporal Model

Throughout this section, agents are risk neutral and discount cash flows at a constant interest rate r. Time is continuous and defined over $[0, \infty)$. We consider a firm with assets in place that generate a per period operating income given by

$$\pi\,(x_t) = x_t - c, \tag{11}$$

where c is a constant cost and x is a cash flow shock governed by the process

$$dx_t = (r - \delta)x_t dt + \sigma x_t dZ_t,\ x_0 > 0. \tag{12}$$

In this equation, $(Z_t)_{t\geq 0}$ is a standard Brownian motion and $\delta > 0$ and $\sigma > 0$ are constant parameters. At each time t, cash flows from assets in place may be reinvested in new projects. As before, the number of positive NPV projects available to the firm is denoted by I^*. The marginal product of investment is $H > 1$ per unit for the first I^* units and $L < 1$ per unit for investment levels beyond I^*. Cash flows and investment decisions, although observable, are not verifiable and, thus, are not contractible.

As in Section 2, we assume that there is a forward contract on a commodity with spot price s_t that evolves according to the process:

$$ds_t = (r - \delta)\, s_t dt + \nu s_t dZ_t + \varphi s_t dW_t. \tag{13}$$

In this equation, W is a standard Brownian motion independent of Z, and ν and φ are constant parameters such that $\nu > \varphi$. The forward contract is for a fixed maturity $T - t$ and the time t price of the forward contract is given by:

$$f_t = e^{-(r-\delta)(T-t)} s_t. \tag{14}$$

Using Equations (13) and (14) and a simple application of Itô's lemma, it is immediate to show that the dynamics of forward prices are given by:

$$df_t = \nu f_t dZ_t + \varphi f_t dW_t. \tag{15}$$

For simplicity, we assume that the forward contract available at each instant has the same face value as the value of the cash flow. A similar specification is used for example in Bhanot and Mello (2006).

Since the forward price process is not perfectly correlated with the cash flow process, hedging cannot be perfect. The hedged cash flow h_t is determined by the cash flows from assets in place and the firm's position in forward contracts. Suppose that the firm implements the minimum variance hedge ratio θ. Because entering into a forward contract does not require the firm to incur a cost, the dynamics of hedged cash flows satisfy

$$dh_t = (r - \delta)\, h_t dt + \sigma_h h_t dZ_t^h, \tag{16}$$

where $\sigma_h^2 = (\sigma - \theta\nu)^2 + \theta^2\varphi^2$, Z^h is a standard Brownian motion and $\theta = \sigma\nu/(\nu^2 + \varphi^2)$. In this equation, the volatility parameter σ_h incorporates the impact of hedging on the volatility of cash flows from assets in place. It also reflects the residual risk incurred resulting from the imperfect hedging transaction.

3.1 FINANCIAL POLICIES AND FIRM VALUE

Suppose the firm has issued perpetual debt with contractual coupon payment F. Once debt has been issued, shareholders have the option to default on their debt obligations. As a result, debt financing affects firm value through three different channels. First, it induces bankruptcy costs. Second, it induces underinvestment in positive NPV projects. Third, it reduces the resources available for investment and thus improves the investment policy of the firm when cash flows are high. [We ignore the effects of taxes, which are well understood in this type of model; see for example Leland (1998).]

Denote the values of equity and debt by $\mathcal{E}(h, F, \theta)$ and $\mathcal{D}(h, F, \theta)$, the selected default threshold by z, and the first passage time of the process for the hedged cash flows $(h_t)_{t\geq 0}$ at y by $\mathcal{T}_y$. Because shareholders have the option to default on the debt contract, the values of corporate securities are given by the sum of the present value of the cash flows accruing to claimholders until the default time and the value of their claim in default. Assuming that debtholders recover a fraction $1-\alpha$ of the value of the firm's unlevered assets in default, we can write the values of equity and debt for any default policy z as:

$$\mathcal{E}(h,F,\theta) = \mathbf{E}\left\{ \int_0^{\mathcal{T}_z} e^{-rt}\left[h_t + (H-1)\,I^* - F - c\right] dt \,\middle|\, h_0 = h \right\}$$
$$+\mathbf{E}\left\{ \int_0^{\mathcal{T}_z} e^{-rt}\,(L-1)\left[h_t - F - c - I^*\right]^+ dt \,\middle|\, h_0 = h \right\}, \qquad (17)$$

and

$$\mathcal{D}(h,F,\theta) = \mathbf{E}\left\{ \int_0^{\mathcal{T}_z} e^{-rt} F dt + e^{-r\mathcal{T}_z}(1-\alpha)\,A(z) \,\middle|\, h_0 = h \right\}, \qquad (18)$$

where $a^+ = \max(0,a)$ and α accounts for proportional bankruptcy costs. In Equation (17), the first term on the right hand side represents the present value of *hedged cash flows* and positive NPV projects, net of the payments made to debtholders. The second term accounts for the cost of overinvestment. In this specification, default leads to liquidation and shareholders do not recover anything in default. In Equation (18), the value of corporate debt is equal to the sum of the cash flows that debtholders receive outside of default (F until $\mathcal{T}_z$) and their cash flow in default.

Solving these equations yields for any default policy z (see Appendix C):

$$\mathcal{E}(h,F,\theta) = \frac{1}{\delta}\left[h - z\left(\frac{h}{z}\right)^{\vartheta}\right] + \frac{(H-1)\,I^* - F - c}{r}\left[1 - \left(\frac{h}{z}\right)^{\vartheta}\right]$$
$$+ (L-1)\,\frac{\sigma_h (F + c + I^*)}{\lambda\,(\lambda - \sigma_h - b)\,(\lambda - b)}\left(\frac{h}{F + c + I^*}\right)^{\xi}$$
$$\times\left[1 - \left(\frac{h}{z}\right)^{\vartheta - \xi}\right], \qquad (19)$$

and

$$\mathcal{D}(h,F,\theta) = \frac{F}{r} + \left[(1-\alpha)\,A(z) - \frac{F}{r}\right]\left(\frac{h}{z}\right)^{\vartheta}, \qquad (20)$$

where $b = \left(r - \delta - \sigma_h^2/2\right)/\sigma_h$, $\lambda = \sqrt{2r + b^2}$, $\vartheta = -\,(b+\lambda)/\sigma_h$, and $\xi = -\,(b-\lambda)/\sigma_h$. The first two terms on the right hand side of Equation (19) represent the expected present value of the hedged cash flows and positive NPV projects. The third term is the cost of overinvestment. The first term on the right hand side of Equation (20) represents the value of risk-free debt. The second term accounts for the impact of default risk on the value of corporate debt, which is given by the product of the loss incurred in default and a stochastic discount factor, given by $h^{\nu} z^{-\nu}$.

The first-best default policy for shareholders consists in selecting the default threshold that maximizes equity value. This default threshold satisfies the smooth-pasting condition (see Leland, 1994, or Morellec, 2001):

$$\left.\frac{\partial \mathcal{E}(h, F, \theta)}{\partial h}\right|_{h=z} = 0. \tag{21}$$

Importantly, this stock-based definition implies that the firm is insolvent on a cash flow basis at the default date. Hence, shareholders have control rights over the decision to default. The financing and hedging policies selected by shareholders maximize the sum of the proceeds from the debt issue and the value of equity after debt has been issued. These policies solve

$$\max_{\{F,\theta\}\in\mathbb{R}_+^2} \{\mathcal{E}(h, F, \theta) + \mathcal{D}(h, F, \theta)\}. \tag{22}$$

Thus while the default threshold is selected ex post to maximize equity value, financing and hedging decisions are determined ex ante to maximize firm value.

The gains associated with risk management are illustrated with the numerical example described in Table I. Two firms with the same number of growth options and with identical debt outstanding are contrasted. One firm has no hedge in place, while the second has implemented the minimum variance hedge ratio. Input parameters for this example are set as follows:[4] the risk-free interest rate $r = 4.5\%$, the convenience yield $\delta = 2.5\%$, the volatility of returns on the firm cash flows $\sigma = 30\%$, the volatility of returns on the commodity price $\nu = 30\%$ and $\varphi = 10\%$, and bankruptcy costs $\alpha = 40\%$. The number of growth options available to the firm is $I^* = 4$. The return on investment is given by $H = 1.1$ per unit for the first I^* units, and $L = 0.8$ for investment levels beyond I^* as in Morellec (2004). Using the model described above, we can determine the firm, equity, and debt values. Given the parameters specified in Table I, the minimum variance hedge ratio is given by $\theta = 0.9$.

Figure 1 describes how the value of hedging computed in Table 1 evolves as input parameter values change when the value-maximizing amount of debt is floated. Consistent with economic intuition, the figure shows that the benefits

[4] These parameters roughly reflect a typical Standard and Poor's 500 firm. The risk-free rate is equal to the 30-year rate on treasury bonds quoted on July 15, 2006. The value of the volatility parameter has been chosen to match the volatility of equity returns in the US economy. Using Itô's lemma, this volatility can be computed as: $vol\,(de/e) = (\partial e/\partial x)\,(x/e)\,\sigma$. Bankruptcy costs are defined as the firm's going concern value minus its liquidation value, divided by its going concern value. Using this definition, Alderson and Betker (1995) and Gilson (1997) report liquidation costs equal to 36.5% and 45.5% for the median firm in their samples. We simply take the average, which is about 40%.

Table I. Firm value and corporate risk management

	Firm value	Debt value	Equity value	Coupon payment
Unhedged	156.06	69.53	86.53	4.09
Hedged	162.28	69.53	92.75	3.14
Value of hedging	6.22			

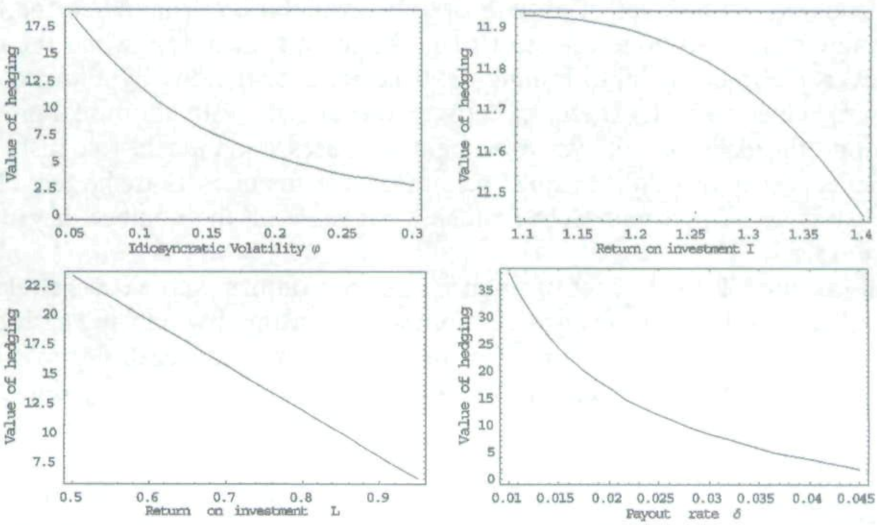

Figure 1. Value of hedging as a function of input parameter values when the value maximizing amount of debt is floated.

of risk management increase as the free cash flow problem becomes more severe (decrease in L and δ) or as the hedging instruments become more effective (decrease in φ).

Our analysis so far has assumed that shareholders could commit to a specific hedging strategy. That is, the values of corporate debt and equity incorporate the benefits associated with the firm's hedging strategy over the life of the debt issue. In general, shareholders will benefit from negotiating the hedging strategy simultaneously with the issuance of debt as creditors require a smaller nominal obligation (hedging reduces the coupon from 4.09 to 3.14) in exchange for the same capital contribution. This suggests that one reason why many firms use the same financial institution for hedging programs and credit lines is that the bank has an incentive to monitor the firm's hedging program. Thus, other contracting parties might offer different terms given that a firm establishes a line of credit and hedges with the same bank.

To examine further the impact of financing policies on firm value, Figure 2 plots firm value as a function of the number of growth options I^*. The solid line represents the value of an unlevered firm. The long-dashed line represents the value of a levered firm without hedging when the value-maximizing amount of debt is floated. The short-dashed line represents the value of a levered firm with hedging when the value-maximizing amount of debt is floated.

Consistent with economic intuition, Figure 2 shows that debt financing improves firm value by reducing the agency costs of managerial discretion. Figure 2 also shows that hedging creates value above and beyond debt financing. In particular, firm value is higher when using forward contracts. In addition, Figure 2 reveals that the impact of financial policies on firm value depends on the number of growth options available to firm. When the firm has few growth options, the cost of underinvestment is low while the cost of overinvestment is high. Issuing debt increases firm value by allowing the firm to achieve a better trade-off between these costs. With additional growth options, the likelihood of overinvestment decreases, and thus the free cash flow benefits of debt fall. At the same time, underinvestment costs are larger. Thus, the gains associated with debt financing decreases as the number of growth option rises.

In our model, the impact of financial policies on firm value can be related to changes in the firm's investment policy. Specifically, by reducing cash flow volatility, risk management reduces the probability of low cash flows as well as the probability of high cash flows. As a result, risk management reduces the costs of both overinvestment and underinvestment. Figure 3 plots deviations from value-maximization in investment policy as a function of the number of growth options available to the firm. The solid line represents an unlevered firm. The long-dashed line represents a firm that issues debt. The short-dashed line represents a firm that issues debt and uses forward contracts.

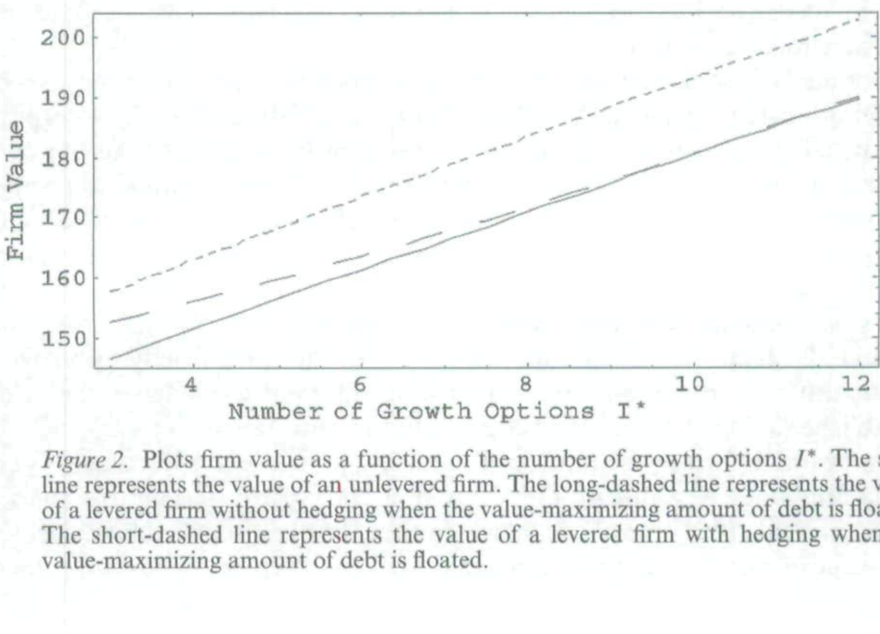

Figure 2. Plots firm value as a function of the number of growth options I^*. The solid line represents the value of an unlevered firm. The long-dashed line represents the value of a levered firm without hedging when the value-maximizing amount of debt is floated. The short-dashed line represents the value of a levered firm with hedging when the value-maximizing amount of debt is floated.

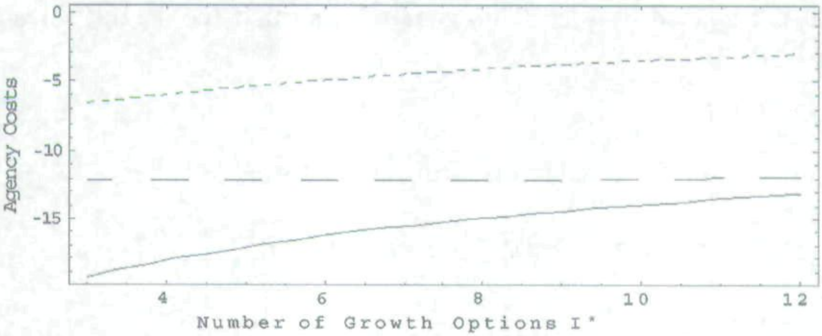

Figure 3. Plots deviations from value-maximization in investment policy as a function of the number of growth options available to the firm. The solid line represents an unlevered firm. The long-dashed line represents a firm that issues debt. The short-dashed line represents a firm that issues debt and uses forward contracts.

Figure 3 shows that distortions in investment policy account for 5% to 10% of firm value depending on the number of growth options available to the firm. In particular, firms that derive more of their value from assets in place (lower market-to-book ratios), although having lower costs of underinvestment, generally display larger costs of overinvestment. Thus, they may be more likely to hedge to control these overinvestment incentives. In addition, figure 3 reveals that financing and hedging policies are important in controlling agency costs within the firm. Finally, the figure also indicates that (1) hedge-augmented debt is more effective than standard debt in controlling those costs, and (2) the benefits associated with debt financing decrease with the number of growth options available to the firm. Again this result arises because more growth options implies less overinvestment and more underinvestment.

3.2 SUPPLY-SIDE ANALYSIS

The above analysis emphasizes the benefits of risk management, showing that hedging creates value above and beyond debt financing by reducing agency costs and default risk. In this section, we relax some of the assumptions made earlier to understand which firms are more likely to engage in hedging transactions.

NO ACCESS TO EXTERNAL FUNDS. There is evidence suggestive of great heterogeneity in access to external funds across firms and that this heterogeneity is important in explaining the investment behavior of firms. This heterogeneity should also be reflected in the firm's choice of a financial policy, as we now illustrate.

Suppose that the firm has no access to external funds. In that case the amount invested in new projects is capped by the cash flows from assets in place and default is triggered by a liquidity constraint so that the default threshold is defined by

$$h_f \equiv c + F \tag{23}$$

Without access to external funds, firm value satisfies

$$\begin{aligned}\mathcal{V}(x, F, \theta) = \mathbf{E}&\left\{\int_0^{\mathcal{T}_{h_f}} e^{-rt}\left[h_t - c + (H-1)\, I^* \mathbf{1}_{h_t > F+c+I^*}\right] dt \,\middle|\, h_0 = h\right\} \\ &+ \mathbf{E}\left\{\int_0^{\mathcal{T}_{h_f}} e^{-rt}\,(L-1)\left[h_t - F - c - I^*\right]^+ dt \,\middle|\, h_0 = h\right\} \\ &+ \mathbf{E}\left\{\int_0^{\mathcal{T}_{h_f}} e^{-rt}\,(H-1)\left[h_t - F - c\right] \mathbf{1}_{h_t \leq F+c+I^*} dt \,\middle|\, h_0 = h\right\}\end{aligned} \tag{24}$$

the solution to which is given by

$$\begin{aligned}\mathcal{V}(h, F, \theta) = \frac{h}{\delta} - \frac{c}{r} &+ \left[(1-\alpha)\, A\left(h_f\right) - \frac{h_f}{\delta} + \frac{c}{r}\right]\left(\frac{h}{h_f}\right)^{\vartheta} \\ &+ (H-1)\left[\frac{h}{\delta} - \frac{c+F}{r} - \left(\frac{h_f}{\delta} - \frac{c+F}{r}\right)\left(\frac{h}{h_f}\right)^{\vartheta}\right] \\ &+ (L-H)\, \frac{\sigma_h h^{\xi} (c + F + I^*)^{1-\xi}}{\lambda\,(\lambda - \sigma_h - b)\,(\lambda - b)}\left[1 - \left(\frac{h}{h_f}\right)^{\vartheta - \xi}\right]\end{aligned} \tag{25}$$

The first term on the right hand side of Equation (24) is the present value of a perpetual entitlement to the flow of income from the firm's assets. The second term represents the change in firm value occurring upon default weighted by the present value of \$1 contingent on default. The third term is the expected present value of the firm's growth options. The fourth term corrects the third term to reflect the change in the marginal product of investment occurring at I^*.

In the base case environment, firm value at optimal leverage is equal to \$86.30 without hedging whereas it is equal to \$93.76 with hedging. In this particular setup, this difference in value arises from an improvement in both credit quality and investment policy. In particular, for any given financing policy, implementing risk management strategies reduces the probability of default by reducing the volatility of cash flows. It also reduces deviations from value maximization in investment policy.

To illustrate the impact of risk management on investment policy, Figure 4 plots agency costs in the base case environment as the number of growth options varies. As before, the long-dashed line represents the value of a levered firm without hedging. The short-dashed line represents the value of a levered firm with hedging. As shown by the figure, hedging should be particularly valuable for firms with limited access to external capital markets.

CORRELATED CASH FLOWS AND INVESTMENT OPPORTUNITIES. The above analysis presumes that cash flows from assets in place and growth options are not related. Yet, a number of firms have investment projects whose profitability is related to that of assets in place. For example, while the contemporaneous gold price determines the level of cash flows from assets in place for a gold mining firm, it also determines the rents associated with the development of new mines. In particular, proven reserves typically become profitable only when the gold price is high enough to offset either large entry costs or the value of waiting to invest. This suggests that for such firms the amount of positive NPV projects is positively related to the cash flows from assets in place.

Consider for example that at any date t the number of growth options in the firm's investment opportunity set is given by

$$I_t^* = \rho_I x_t + I, \tag{26}$$

where $\rho_I \in (0, 1)$ and I is a positive constant. In order to analyze in a simple way the value implications of the correlation between cash flows and

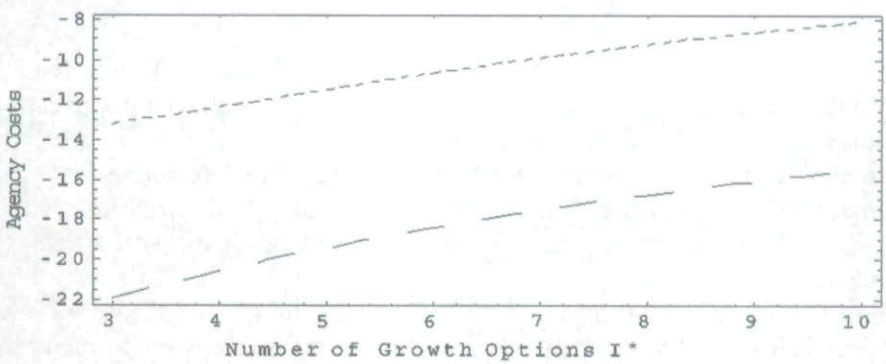

Figure 4. Plots agency costs in the base case environment when the firm does not have access to external capital markets. The long-dashed line represents the value of a levered firm without hedging. The short-dashed line represents the value of a levered firm with hedging.

investment opportunities, assume that the dynamics of hedged cash flows are

$$dh_t = \sigma_h h_t dZ_t^h, \ h_0 = x_0 > 0. \tag{27}$$

This specification implies that the expected number of growth options is $\mathbf{E}(I^*) = \rho_I x_0 + I$. Setting $I = \mathbf{E}(I^*) - \rho_I x_0$, allows for an analysis of the impact of the correlation coefficient ρ on firm value for firms having the same unconditional number of growth options $\mathbf{E}(I^*)$ (even though ρ_I varies across firms). In this setting and for any given default threshold, the value of debt is unaffected. The value of equity satisfies

$$\begin{aligned}
&\mathcal{E}(x, F, \theta) \\
&= \mathbf{E}_Q\left\{\int_0^{T_z} e^{-rt}\left[h_t - c - F + (H-1)\left(\rho_I h_t + I^*\right)\right]dt \,\middle|\, h_0 = h\right\} \\
&\qquad + (L-1)\,\mathbb{E}_Q\left\{\int_0^{T_z} e^{-rt}\left[h_t - (F + c + \rho_I h_t) + I^*\right]^+ dt \,\middle|\, h_0 = h\right\}
\end{aligned} \tag{28}$$

the solution to which is

$$\begin{aligned}
\mathcal{E}(x, F, \theta) = {} & \frac{1 + (H-1)\rho_I}{r}\left[h - z\left(\frac{h}{z}\right)^{\vartheta}\right] \\
& + \frac{(H-1)I^* - c - F}{r}\left[1 - \left(\frac{h}{z}\right)^{\vartheta}\right] \\
& + \frac{(L-1)\sigma_h(F + c + I^*)}{\lambda(\lambda - \sigma_h - b)(\lambda - b)}\left(\frac{h(1-\rho_I)}{F + c + I^*}\right)^{\xi} \\
& \times \left[1 - \left(\frac{h}{z}\right)^{\vartheta - \xi}\right].
\end{aligned} \tag{29}$$

Figure 5 plots agency costs of managerial discretion as a function of the correlation coefficient between cash flows from assets in place and investment opportunities. Three financing alternatives are considered: Equity, debt financing, and debt financing plus hedging. The solid line represents equity financing. The long-dashed line represents the value of a levered firm without hedging. The short-dashed line represents the value of a levered firm with hedging.

Figure 5 indicates that agency costs of managerial discretion decrease with the correlation coefficient between cash flows and investment opportunities. This result arises because the correlation between the cash flows from assets in place and the firm's growth options acts as a natural hedge that limits deviations from value-maximization in investment policy. In particular, the

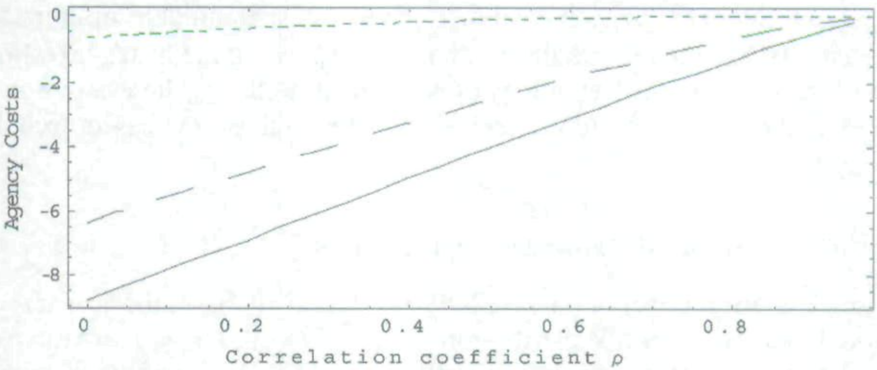

Figure 5. Plots agency costs of managerial discretion as a function of the correlation coefficient between cash flows from assets in place and investment opportunities. Three financing alternatives are considered: Equity, debt financing, and debt financing plus hedging. The solid line represents equity financing. The long-dashed line represents the value of a levered firm without hedging. The short-dashed line represents the value of a levered firm with hedging.

firm has more growth options when cash flows from assets in place are high and the likelihood of overinvestment is greater. The firm has fewer growth options when cash flows are low and the likelihood of underinvestment is greater. Because of this natural hedge, potential improvements in firm value associated with a specific financing policy are lower. This effect is illustrated in Figure 5, which shows that the improvement in firm value due to financing and hedging policies decreases as the correlation coefficient ρ increases. This suggests that hedging is particularly beneficial when the empire-builder has the ability to fund projects outside the firm's core competencies.

4. Conclusion

We present a model that highlights the relation between agency conflicts and risk management. We show that the costs of both underinvestment and overinvestment are essential in determining the firm's hedging policy. In particular, firms that derive more of their value from assets in place (lower market-to-book ratios), although having lower costs of underinvestment, generally display larger costs of overinvestment. Thus, our analysis suggests that firms with fewer growth opportunities may be more likely to hedge to control these overinvestment incentives, which is consistent with the recent evidence reported by Bartram et al. (2004). The paper also provides a number of comparative statics that emphasize the impact of a firm's economic environment on the benefits associated with risk management.

To keep the analysis as simple as possible we have made a number of assumptions. For example, when analyzing financing constraints we have followed most of the literature by presuming that the firm's dividend policy was exogenous. Similarly, to limit the dimensionality of shareholders' optimization problem, we have made specific assumptions regarding the firm's investment opportunity set and the technology of investment. Relaxing these assumptions would make the paper more realistic at the cost of increased technical difficulty.

Appendix A. Stochastic Investment Opportunities

Assume that the number of positive NPV projects available to the firm at $t = 1$, denoted by I, is uniformly distribution on $[\underline{I}, \overline{I}]$, $\underline{I} \geq 0$, $\overline{I} \leq \mu + e$. Moreover, suppose that investors know the distribution of I but cannot observe its realization. Because the number of growth options is unobservable and the manager always wants to invest, any claim by management that cash flows are too low to finance positive NPV projects is not credible. Therefore, firm value satisfies

$$\begin{aligned} \mathcal{V}(D) &= \int_{-e}^{e} \frac{\mu+\phi}{2e} d\phi + (L-1) \int_{\underline{I}}^{\overline{I}} \int_{F+I-\mu}^{e} \frac{\mu+\phi-F-I}{2e(\overline{I}-\underline{I})} d\phi dI \\ &\quad + (H-1) \int_{\underline{I}}^{\overline{I}} \frac{1}{\overline{I}-\underline{I}} \left[\int_{F-\mu}^{F+I-\mu} \frac{\mu+\phi-F}{2e} d\phi + \int_{F+I-\mu}^{e} \frac{I}{2e} d\phi \right] dI \end{aligned} \tag{A.1}$$

Using the same line of reasoning as in the main text, it is possible to show that the selected debt level is given by $F^* = \max\left\{\mu + e - c - \mathbb{E}(I) \frac{H-L}{1-L}, 0\right\}$.

Appendix B. Risk Management and Firm Value

To determine firm value, we need to find the probability density function (p.d.f.) of future net cash flows after hedging, $g(x, \theta)$. Let $Y_1 = x$ and $Y_2 = g(x, \theta)$. Because x and η are independent and uniformly distributed according on $[\mu - e, \mu + e]$ and $[-f, f]$, the joint p.d.f. of x and η is $f(x, \eta) = (4ef)^{-1}$. Thus, the joint cumulative distribution function of Y_1 and Y_2 is

$$\begin{aligned} \Pr(Y_1 \leq y_1, Y_2 \leq y_2) &= \Pr\left(x \leq y_1, \eta \leq \frac{1}{\theta}[y_2 - (1+\theta\beta)x] + \beta\mu\right) \\ &= \int_{\mu-e}^{y_1} \int_{-f}^{\frac{1}{\theta}[y_2-(1+\theta\beta)x]+\beta\mu} \frac{1}{2f}\frac{1}{2e} dx d\eta. \end{aligned} \tag{B.1}$$

Using this equation, we find that the joint p.d.f. of Y_1 and Y_2 is

$$h(y_1, y_2) = \frac{1}{4\theta ef}. \tag{B.2}$$

Since $-\beta^{-1} < \theta^* < 0$, $g(x, \theta^*)$ is increasing in x and decreasing in η and is distributed on $[\mu - e - \theta^*(\beta e - f), \mu + e + \theta^*(\beta e - f)]$. For

$$(1+\theta\beta)(\mu - e) - \theta\beta\mu + \theta f \le y_2 \le (1+\theta\beta)(\mu + e) - \theta\beta\mu - \theta f,$$

the marginal p.d.f. $G(y_2)$ of $Y_2 = g(x, \theta)$ is

$$\int_{(y_2+\theta\beta\mu-\theta f)/(1+\theta\beta)}^{(y_2+\theta\beta\mu+\theta f)/(1+\theta\beta)} h(y_1, y_2) dy_1 = \frac{1}{2e(1+\theta\beta)}. \tag{B.3}$$

Firm value is then given by

$$\begin{aligned}\mathcal{V}(F, \theta) = \mu + I^*(H-1) \int_{F-I^*(H-1)}^{\mu+e+\theta^*(\beta\mu - f)} G(y_2) dy_2 \\ + (L-1) \int_{F+I^*}^{\mu+e+\theta^*(\beta\mu-f)} \left(y_2 - F - I^*\right) G(y_2) dy_2.\end{aligned} \tag{B.4}$$

Substituting for $G(y_2)$ in the above expression yields:

$$\begin{aligned}\mathcal{V}(F, \theta) = \mu + \frac{\mu + e + \theta^*(\beta\mu - f) + I^*(H-1) - F}{2e(1+\theta^*\beta)} \\ + (L-1) \frac{[\mu + e + \theta^*(\beta\mu - f) - F - I^*]^2}{2e(1+\theta^*\beta)}\end{aligned} \tag{B.5}$$

Appendix C. Value of Corporate Securities

We assume throughout that the initial value of the commodity price is such that $f(x_0) \le I^*$. The value of the equity is then given by

$$\begin{aligned}\mathcal{E}(x, F, \theta) = \mathbf{E}\left\{ \int_0^{T_z} e^{-rt} \left[h_t - c - F + (H-1) I^*\right] dt \,\middle|\, h_0 = h \right\} \\ + \mathbf{E}\left\{ \int_0^{T_z} e^{-rt} (L-1) \left[h_t - c - F - I^*\right]^+ dt \,\middle|\, h_0 = h \right\}\end{aligned} \tag{C.1}$$

Using standard results concerning Brownian motion, it is possible to show that the first term on the right hand side is equal to

$$\frac{h}{\delta} - \frac{\pi z}{\delta}\left(\frac{h}{z}\right)^{\vartheta} - \frac{F + c - (H-1) I^*}{r}\left[1 - \left(\frac{h}{z}\right)^{\vartheta}\right], \tag{C.2}$$

Consider next the second term. We have

$$\mathbf{E}\left\{\int_0^{\mathcal{T}_z} e^{-rt}\left[h_t - F - c - I^*\right]^+ dt \,\middle|\, h_0 = h\right\}$$

$$= \mathbf{E}\left\{\int_0^{\mathcal{T}_z} e^{-rt} h_t \mathbf{1}_{h_t > F+c+I^*} dt - (F + c + I^*)\right.$$

$$\left.\times \int_0^{\mathcal{T}_z} e^{-rt}\mathbf{1}_{h_t > F+c+I^*} dt \,\middle|\, h_0 = h\right\}. \tag{C.3}$$

Consider the first integral on the right hand side of (C.3). Writing $Z_t^b = Z_t^h + bt$ with $b = \frac{1}{\sigma_h}\left(r - \delta - \sigma_h^2/2\right)$ and $a = \frac{1}{\sigma_h}\ln\left(\frac{F+c+I^*}{h}\right)$, gives

$$\mathbf{E}\left\{\int_0^{\mathcal{T}_z} e^{-rt} h_t \mathbf{1}_{h_t > F+c+I^*} dt \,\middle|\, h_0 = h\right\} = h\mathbf{E}\left\{\int_0^{T_{Z_d}} e^{-rt} e^{\sigma Z_t^b}\mathbf{1}_{Z_t^b > a} dt\right\}, \tag{C.4}$$

where $Z_d = \frac{1}{\sigma_h}\ln\left(\frac{z}{h}\right)$ and $T_{Z_d} = \inf\left\{t \geq 0 : Z_t^b = Z_d\right\}$. Denote by $\mathcal{Q}$ the physical probability measure. Applying Cameron-Martin-Girsanov theorem with $d\mathcal{Q}/d\mathcal{P}|_{\mathcal{F}_t} = e^{bZ_t - \frac{b^2}{2}t}$ yields

$$h\mathbf{E}_{\mathcal{P}}\left\{\int_0^{+\infty} e^{(\sigma_h+b)Z_t^b} e^{-\frac{\lambda^2}{2}t}\mathbf{1}_{Z_t^b > a} dt - \int_{T_{Z_d}}^{+\infty} e^{(\sigma_h+b)Z_t^b} e^{-\frac{\lambda^2}{2}t}\mathbf{1}_{Z_t^b > a} dt\right\}, \tag{C.5}$$

where $\lambda = \sqrt{2r + b^2}$ and $\left(Z_t^b, t \geq 0\right)$ is a standard $\mathcal{P}-$Brownian motion. To compute these integrals, we use the following lemma [see Karatzas and Shreve (1991, pp. 272)].

Lemma 1. *If $f : R \to R$ is a piecewise continuous function with*

$$\int_{-\infty}^{+\infty} |f(x + y)|\, e^{-|y|\sqrt{2\gamma}} dy < \infty; \forall x \in \mathbb{R},$$

for some constant $\gamma > 0$, and $(Z_t, t \geq 0)$ is a standard Brownian motion, the resolvent operator of Brownian motion $K_\gamma(f)$ is defined by

$$K_\gamma(f) \equiv \mathbf{E}\left\{\int_0^{+\infty} e^{-\gamma t} f(Z_t)\, dt\right\} = \frac{1}{\sqrt{2\gamma}}\int_{-\infty}^{+\infty} f(y)\, e^{-|y|\sqrt{2\gamma}} dy. \tag{C.6}$$

Using the above Lemma and the strong Markov property of Brownian motion, the second integral in (C.5) can be computed as follows

$$h\mathbf{E}_{\mathcal{P}}\left\{\int_{T_{Z_d}}^{+\infty} e^{(\sigma_h+b)Z_t^b} e^{-\frac{\lambda^2}{2}t}\mathbf{1}_{Z_t^b>a}dt\right\}$$

$$= h\mathbf{E}_{\mathcal{P}}\left\{e^{-\frac{\lambda^2}{2}T_{Z_d}}\int_0^{+\infty} e^{(\sigma_h+b)(Z_t^b+Z_d)} e^{-\frac{\lambda^2}{2}t}\mathbf{1}_{Z_t^b>a-Z_d}dt\right\}$$

$$= e^{(\sigma_h+b)Z_d-|Z_d|\lambda} h\mathbf{E}_{\mathcal{P}}\left\{\int_0^{+\infty} e^{(\sigma_h+b)Z_t^b} e^{-\frac{\lambda^2}{2}t}\mathbf{1}_{Z_t^b>a-Z_d}dt\right\}$$

$$= \frac{h}{\lambda} e^{(\sigma_h+b)Z_d-|Z_d|\lambda}\int_{a-Z_d}^{+\infty} e^{-|y|\lambda} e^{(\sigma_h+b)y}dy$$

$$= \frac{F+c+I^*}{\lambda\left(\lambda-\sigma_h-b\right)}\left(\frac{h}{z}\right)^{\vartheta}\left(\frac{z}{F+c+I^*}\right)^{\xi}, \tag{C.7}$$

where $b=\left(\mu-\sigma_h^2/2\right)/\sigma_h$, $\lambda=\sqrt{2r+b^2}$, $\vartheta=-\left(b+\lambda\right)/\sigma_h$ and $\xi=\left(\lambda-b\right)/\sigma_h$.

Similar calculations yield

$$h\mathbf{E}_{\mathcal{P}}\left\{\int_0^{+\infty} e^{(\sigma_h+b)Z_t^b} e^{-\frac{\lambda^2}{2}t}\mathbf{1}_{Z_t^b>a}dt\right\} = \frac{z^{\xi}\left(F+c+I^*\right)^{1-\xi}}{\lambda\left(\lambda-\sigma_h-b\right)}, \tag{C.8}$$

Combining these two equations gives

$$\mathbf{E}\left\{\int_0^{T_z} e^{-rt}h_t\mathbf{1}_{h_t>F+c+I^*}dt \,\middle|\, h_0=h\right\} = \frac{z^{\xi}\left(F+c+I^*\right)^{1-\xi}}{\lambda\left(\lambda-\sigma_h-b\right)}\left[1-\left(\frac{h}{z}\right)^{\vartheta-\xi}\right]. \tag{C.9}$$

The second term in Equation (C.3) is

$$\mathbf{E}\left\{\int_0^{T_z} e^{-rt}\mathbf{1}_{h_t>F+c+I^*}dt \,\middle|\, h_0=h\right\} = \frac{z^{\xi}\left(F+c+I^*\right)^{-\xi}}{\lambda\left(\lambda-b\right)}\left[1-\left(\frac{h}{z}\right)^{\vartheta-\xi}\right]. \tag{C.10}$$

Therefore, Equation (C.3) reduces to

$$\mathbf{E}\left\{\int_0^{T_z} e^{-rt}\left[h_t - c - F - I^*\right]^+ dt \,\middle|\, h_0 = h\right\}$$

$$= \frac{\sigma_h \left(F + c + I^*\right)^{1-\xi} h^\xi}{\lambda\left(\lambda - \sigma_h - b\right)\left(\lambda - b\right)}\left[1 - \left(\frac{h}{z}\right)^{\vartheta - \xi}\right] \tag{C.11}$$

which yields the value of equity.

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