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ABSTRACT

Cash Holdings and Credit Risk*

Intuition suggests that firms with higher cash holdings are safer and should have lower credit spreads. Yet empirically, the correlation between cash and spreads is robustly positive and higher for lower credit ratings. This puzzling finding can be explained by the precautionary motive for saving cash. In our model endogenously determined optimal cash reserves are positively related to credit risk, resulting in a positive correlation between cash and spreads. In contrast, spreads are negatively related to the ``exogenous'' component of cash holdings that is independent of credit risk factors. Similarly, although firms with higher cash reserves are less likely to default over short horizons, endogenously determined liquidity may be related positively to the longer-term probability of default. Our empirical analysis confirms these predictions, suggesting that precautionary savings are central to understanding the effects of cash on credit risk.

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Introduction

An important factor that may affect the probability that a distressed firm will default on its debt payments is the firm's holdings of cash and other liquid assets, which may in turn affect the firm's decision to retain a cash reserve that could otherwise be invested or paid out to shareholders. This paper studies the implications of the interaction between the possibility of default and the firm's cash policy for understanding the role of corporate liquidity in credit risk. Cash holdings play no role in most existing credit risk research. Although some studies, such as Altman (1968) and other empirical bankruptcy-predicting models, recognize that corporate liquidity may be important, they treat liquid assets as given. In this paper, we demonstrate that it is crucial to account for the fact that the firm's cash policy can be optimally chosen, depending in particular on its risk of default. The resulting endogeneity of cash holdings leads to empirical effects very different from those expected on the basis of traditional intuition about the role of cash in credit risk.

We first document that in cross-sectional regressions, credit spreads are *positively* correlated with the firm's cash holdings, even though firms with higher cash reserves intuitively are expected to be "safer." We explain this puzzling finding in a model of a levered firm that allows for the joint determination of cash and investment policies in the presence of financing frictions and distress costs. The model shows that riskier firms optimally choose to hold higher cash reserves, which results in a positive correlation between cash holdings and credit spreads in the cross-section. At the same time, spreads are negatively correlated with *exogenous* variations in cash holdings unrelated to credit risk factors. Consistent with these predictions, in our tests, the correlation between cash and spreads turns negative when we use instrumental variables for cash, as suggested by the model. We also elicit the role of liquidity in empirical default prediction models. We find that an increase in cash reserves reduces the default probability in the short term but increases it in the longer term. Again, these results underscore the crucial role that endogeneously determined precautionary savings play in the link between cash and credit risk.

Starting with Merton (1974) and Black and Cox (1976), most structural models of credit risk assume that the firm defaults when the market value of its assets falls below some threshold, such as that chosen by shareholders to maximize their value. In this framework, new equity typically can be issued at no cost when needed, and any temporary cash flow shortfall can be overcome by raising external financing – as long as the value of assets remains above the default threshold. As a result, the firm's cash holdings are irrelevant in this framework. Although Leland (1994), Longstaff and Schwartz (1995), Leland and Toft (1996), and others have extended the basic setup along many dimensions, most models still leave no room for an optimal cash policy in debt pricing or capital structure decisions.[1] It is therefore unsurprising that empirical studies of credit spreads or corporate bond returns do not consider the role of cash holdings (e.g., Collin-Dufresne, Goldstein, and Martin (2001), Duffee (1998), and Schaefer and Strebulaev (2008)). At the same time, corporate finance research argues that external financing may be costly, which gives rise to an optimal cash policy that depends on various factors, such as the firm's current and future investment opportunities.[2] Yet this literature has not considered the effect of credit risk on cash holdings or vice versa.

Intuition suggests that firms with higher liquid assets should have unambiguously lower credit spreads. In the presence of financing frictions, higher cash holdings reduce the probability that a cash shortage will force the firm into default despite fundamentally sound business (Davydenko (2007)). This view explains why empirical bankruptcy-predicting models (e.g., Altman (1968), Ohlson (1980), Zmijevski (1984)) usually include some measures of balance sheet liquidity. We find that, though appealing, this simple intuition is not consistent with the data. Empirically, credit spreads are positively, not negatively, correlated with cash holdings. The effect is robust, persistent, and significant, both statistically and economically. A one standard deviation increase in the cash-to-asset ratio corresponds to a 20 basis point increase in credit spreads. Moreover, the positive correlation is higher for riskier firms, even though for such firms the beneficial role of cash in mitigating credit risk should be higher. We argue that these findings are due to the endogenous nature of cash holdings in levered firms. In the presence of financing constraints and costs of financial distress, riskier firms may choose to maintain higher cash reserves in order to reduce the possibility of a cash shortage in the future. Such endogenous adjustments in cash holdings can induce a spurious positive correlation between credit spreads and cash holdings in equilibrium, because both increase with the underlying credit risk.

To illustrate the link between cash and credit risk, we construct a model of a levered firm with an endogenous investment and cash policy. Initially endowed with some cash reserve, the firm chooses how much to invest in a profitable long-term project and how much to retain as a cash buffer against a possible shortfall in the interim period, when its debt becomes due. Future cash flows cannot be pledged fully as collateral because of market frictions, and default is costly. In this setting, higher investment implies higher cash flows in the future, provided the firm does not default in the interim period. At the same time, higher cash reserves mean a lower probability of a cash shortage when the debt payment is due.

[1] Prominent exceptions include recently developed models by Acharya, Huang, Subrahmanyam, and Sundaram (2006), Anderson and Carverhill (2007), Asvanunt, Broadie, and Sundaresan (2007), and Gamba and Triantis (2008), which allow for optimal cash holdings in the presence of costly external financing. Papers like Kim, Ramaswamy, and Sundaresan (1993) and Anderson and Sundaresan (1996) model default as driven by cash flow shortages rather than low asset values, but typically assume that the firm's cash holdings are exogenous.

[2] Studies of corporate cash holdings include, among others, Kim, Mauer, and Sherman (1998), Opler, Pinkowitz, Stulz, and Williamson (1999), Almeida, Campello, and Weisbach (2004), and Bates, Kahle, and Stulz (2008).

The model predicts that optimal cash holdings increase with factors that increase the firm's default risk. An exogenous change in such factors affects credit risk not only directly but also indirectly as the firm adjusts its endogenously determined cash reserve in response. For example, if the expected future cash flows decline exogenously, the probability of default rises, causing credit spreads to increase. At the same time, the firm also optimally increases its cash holdings, which reduces the probability of a cash shortfall when the debt comes due. Thus, the indirect effect of the decrease in future cash flows is to reduce spreads as a result of optimally higher cash levels. We show that the direct effect dominates as long as constraints on external financing are binding. As a result, riskier firms have both higher optimal cash reserves *and* higher credit spreads, which causes the two to be positively related in the cross-section. At the same time, "exogenous" variation in cash holdings unrelated to credit risk factors is *negatively* correlated with spreads, in line with the simple intuition. The model identifies future long-term investment opportunities and managerial self-interest as two potential sources of exogenous variation in cash. Empirically, we find that the correlation between cash and spreads turns negative when we use instrumental variables implied by the model to identify exogenous variations in cash. Thus, *ceteris paribus*, firms with higher cash holdings do have lower spreads, but in the standard empirical specifications used in much of the credit risk literature this intuitive result becomes completely overturned by the effect of endogeneity.

We also study the role of corporate liquidity as a predictor of default. Since Altman's (1968) Z-score model, most empirical studies of default use various controls for balance sheet liquidity. However, despite their intuitive appeal, and much to the surprise of the researchers, these controls are typically found uncorrelated or even positively correlated with the probability of default.[3] We argue that the endogeneity of liquid asset holdings plays a central role in this setting too, shaping the term structure of default probabilities. Our model shows that a higher cash reserve reduces the probability of default in the short term but may increase it over a longer period, as the constrained firm that reduces the investment to conserve cash for immediate debt service faces a higher probability of a long-term cash flow shortfall. Consistent with these predictions, we find that though liquidity is negatively associated with the probability of default over very short horizons, for longer prediction horizons – the focus of much of the research in this area – the endogenously determined liquidity in our tests is *positively* associated with default. Overall, our findings call for more attention to the effect of balance sheet liquidity on credit risk than extant studies typically devote to this question, and emphasize the crucial role of the endogeneity of cash.

[3] In their classic papers, Ohlson (1980) and Zmijevski (1984) point out that liquidity proxies do not work as expected, but they nevertheless retain them in their models. Later studies by Begley, Ming, and Watts (1996), Shumway (2001), and Hillegeist, Keating, Cram, and Lundstedt (2004) also find that liquidity does not appear to reduce the probability of default over horizons of one year or more.

The remainder of this paper is organized as follows: Section I documents a positive correlation between cash holdings and credit spreads. Section II presents the model, and Section III describes our data. Section IV contains the main empirical analysis of the paper. Section V concludes. Proofs and model extensions are provided in the appendices.

I. Cash and spreads: An empirical puzzle?

To study the relationship between corporate bond spreads and cash holdings, we use a large sample of monthly bond prices of non-financial U.S. firms between December 1996 and December 2003. We measure credit spreads relative to a cash flow-matched portfolio of U.S. Treasury securities.[4] Table I presents the results of regressing spreads on cash with and without controls for credit risk factors commonly used in extant empirical credit risk studies, such as leverage, asset volatility, debt maturity, size, and time dummies that control for common movements in debt prices. To demonstrate the robustness of the results to econometric methodology, we estimate each specification using three common methodologies: OLS, cross-sectional regressions that use the means of each variable for each firm (CS), and Fama-MacBeth regressions (FMB).

Our focus is on the relationship between spreads and cash, which we measure relative to the firm's total book assets. Table I shows that both in univariate regressions, as well as in the presence of standard credit risk controls, the correlation between credit spreads and cash holdings is positive and strongly statistically significant. The implied economic effect is also considerable: In most regressions, a one standard deviation increase in the cash-to-asset ratio corresponds to an increase in the bond spread of about 15 basis points.[5]

[TABLE I HERE]

This evidence is counterintuitive and puzzling. Firms with high cash reserves are more likely to withstand a negative cash flow shock, which should make their debt safer. Thus, higher balance sheet liquidity implies a lower probability of default (e.g., Davydenko (2007)) and higher recovery rates for creditors conditional on default (e.g., Acharya, Bharath, and Srinivasan (2007)). Therefore, spreads should be lower, not higher, for firms with higher cash holdings. Yet the results in Table I reject this simple intuition. The positive correlation between cash and credit spreads is a robust phenomenon, observed for other bond data sets and

[4] We defer the detailed discussion of the data set and the description of variables to Section III.

[5] The effect of control variables is in line with economic intuition and corroborates evidence from other studies of spreads (e.g., Davydenko and Strebulaev (2007)). More levered, more volatile, and smaller firms are riskier and consequently have higher credit spreads.

time periods. Robustness tests, reported in Section IV, show that it is unaffected by controls for industry effects, debt covenants, and liquidity needs.

We might expect that even if for most firms default triggered by a cash shortage is a distant possibility, cash holdings should be relatively more beneficial for the riskiest firms, for which such a possibility looms large. Hence, the correlation between cash and spreads should be more negative for riskier firms, especially because credit risk explains more of the observed spread for such firms (Huang and Huang (2003)). Yet once again this intuition is in conflict with the data. Regressions in Table II, estimated separately for different rating groups, show that the coefficient for cash holdings is positive for all ratings, with statistical significance driven primarily by bonds close to the investment-grade/junk threshold (BBB and BB).[6] The puzzling result is that the cash coefficient increases monotonically as the rating deteriorates, so that it is almost 25 times as high for the lowest ratings (B–CCC) as for the AAA–AA-rated bonds. How can this evidence be explained?

[TABLE II HERE]

We suggest that the positive correlation between cash and spreads is due to the effect that the possibility of costly default has on the levered firm's optimal cash policy. If external financing in distress is restricted or unavailable (e.g., Asquith, Gertner, and Scharfstein (1994)), and financial distress is costly (e.g., Andrade and Kaplan (1998), Bris, Welch, and Zhu (2006)), then riskier firms may endogenously choose to hold higher cash reserves as a buffer against the possible cash flow shortfall. As a result, riskier firms may have not only higher credit spreads but also higher optimally chosen cash holdings, resulting in a spurious positive correlation between cash and spreads. The treatment of cash as an exogenous parameter therefore may be inadequate and yield counterfactual predictions.

The potentially ambiguous nature of the spread-cash relationship is illustrated by Figure 1, which summarizes the cash holdings of firms in different rating groups. Cash is roughly U-shaped in the credit rating: Safe AAA and AA firms have higher-than-average cash holdings and low debt levels, and are in all likelihood unconcerned about credit risk. Their high balance sheet liquidity and low net leverage are likely important reasons for why rating agencies rate them so highly in the first place. However, at the other end of the spectrum, speculative-grade (junk) firms (those rated below BBB–) also have larger-than-average cash holdings, and lower grades of junk generally correspond to higher cash reserves. We argue that this pattern is due to levered firms' precautionary motives for saving cash when external financing is restricted and potential default is costly. Despite their relatively high cash reserves, these firms remain riskier than A- or BBB-rated

[6] To conserve space, henceforth we report OLS regressions only. To maintain a sufficient number of firms in each rating group, we combine firms rated AAA and AA, and also all firms rated B and below.

firms because of their much higher levels of debt relative to their cash flows. Indeed, even relatively high cash holdings of 5.8% of net assets for B-rated firms fade to insignificance next to their leverage ratios, which on average exceed 66%. As a result of the pattern of cash holdings shown in Figure 1, cash turns out to be positively associated with spreads in cross-section, with a stronger relationship for riskier firms.[7]

[FIGURES 1 AND 2 HERE]

Figure 2 shows a similar relationship between cash and credit risk using the interest coverage ratio, defined as cash flow over interest payments, instead of the agency credit rating. Firms with lower cash flows relative to debt payments, represented by the left part of the graph, face a higher risk of a cash flow shortage. Figure 2 demonstrates that such firms have higher-than-average cash holdings.

To show how a positive correlation between cash and credit spreads can arise under *endogenous* cash policy, we first construct a model of cash in the presence of credit risk. We then present evidence that suggests that the positive correlation between cash and spreads is spurious rather that causal, and that it is reversed when we control for the endogeneity of cash holdings. Finally, we show how the endogeneity of cash affects the role of liquid assets in empirical studies of credit risk.

II. The model

A. Base case model setup

This section develops a simple model of the firm's endogenous cash policy in the presence of costly default and restricted access to outside financing. The model features a firm in a three-period investment economy. At date $t = 0$, the firm has access to a long-term investment opportunity that yields a deterministic cash flow of $f(I)$ at $t = 2$, where I is the amount invested at time 0, and $f(I)$ is a standard increasing concave production function. In the interim period $t = 1$, the firm's existing capital stock yields a single random cash flow of $\hat{\delta} = \delta + \psi$, where δ is a known constant, and ψ is a zero-mean cash flow shock, unknown at $t = 0$. The cash flow shock ψ is the only source of randomness in our model. The probability distribution of ψ is described by the density function $g(\psi)$, with the associated cumulative distribution function denoted

[7] One mitigating factor may be that very distressed firms, which are likely to be making losses, cannot retain cash out of their cash flow. The November 2008 warning by big U.S. automakers that without government funding they would burn through their cash reserves within months illustrates the case in point. The absence of flexibility at these levels of distress may explain the lack of statistical significance for the lowest ratings in Table II.

$G(\psi)$ and the hazard rate $h(\psi)$, defined as

$$h(\psi) = \frac{g(\psi)}{1 - G(\psi)}. \tag{1}$$

In what follows, we assume the hazard rate $h(\psi)$ to be weakly monotonic. This assumption is unrestrictive and often appears in economic applications, such as game theory and auctions (e.g., Fudenberg and Tirole (1991, p. 267)).[8]

At $t = 0$, the firm has a cash endowment of c_0, which can be fully or partially invested in the long-term project, or retained within the firm as a buffer against a future cash shortfall. The firm owes an amount B in debt, which is due at the interim date $t = 1$. In the model, debt is fixed and predetermined, whereas retained cash reserves can be chosen by the firm. We discuss this assumption in Subsection II.E and demonstrate that cash is significantly more flexible than debt. We also assume that debt cannot be renegotiated due to high bargaining costs; for example, it might be held by dispersed bondholders prone to co-ordination problems. If the firm has insufficient funds to repay the debt in full at $t = 1$, it defaults and is liquidated. We model the costs of financial distress by assuming that future cash flows from the the long-term investment, $f(I)$, are lost in default. Furthermore, the firm's access to external financing is restricted, so that at date $t = 1$ it can use only a fraction τ of its future cash flows as collateral for new financing, where $0 \leq \tau < 1$ and $\tau = 0$ corresponds to the case of extreme financing frictions, when the firm cannot raise *any* external financing against its future cash flows.[9] The firm's equityholders maximize the final period return and therefore do not pay dividends at dates 0 and 1. The risk-free rate of interest is normalized to zero, and in the base case, managers act in the best interest of shareholders. Figure 3 illustrates the model's timeline.

[FIGURE 3 HERE]

Before proceeding further, we note that the exact specification of the model can vary substantially without affecting the results qualitatively, as long as the following economically intuitive conditions are met: First, external financing cannot be raised against the full value of future cash flows; in other words, there must be some financing frictions at date 1. If the firm can pledge all of its future cash flows as collateral (i.e., if $\tau = 1$), then current and future cash holdings are perfect time substitutes, and there is no role for precautionary savings of cash. In reality, the condition of partial pledgeability, which we model in a reduced form, is likely

[8]Bagnoli and Bergstrom (2005) show that the hazard rate is weakly monotonic if function $(1 - G(\psi))$ is log-concave, which holds for uniform, normal, logistic, exponential, and many other probability distributions. See also footnote 14.

[9]One economic interpretation of τ is that it represents the extent to which future cash flows are verifiable at date 1. Low values of τ correspond to unverifiable cash flows that are difficult to pledge as collateral to providers of outside finance.

to be universally met.[10] Second, a non-trivial part of the cash flow from the current investment will be realized only after a portion of the outstanding debt is due, giving rise to a mismatch between cash flows and liabilities. Most capital expenditure items in practice are likely to satisfy this requirement, because they usually generate cash flows after some non-trivial debt payments is made. In the base case model, we assume that the investment outcome is realized in full only at date 2; this assumption can be relaxed so that the investment also can generate a cash flow at date 1. What is needed is a non-trivial fraction of cash flows expected after the debt payment is due, so that firm survival at the intermediate stage is a worthy option. Third, we assume that default results in a deadweight loss, as found empirically by, for example, Bris, Welch and Zhu (2006). It is also worth noting that the opportunity costs of carrying cash, which in our model are represented by the net present value of long-term investment, may arise for a variety of reasons apart from capital investment.[11] In this sense, investment in the model should be understood more broadly to encompass the value of allocating cash to its first-best alternative use, as opposed to keeping it on the balance sheet.

At date $t = 0$, the firm's manager chooses the level of long-term investment I, which is financed out of the cash endowment c_0. The remaining cash is carried over from period 0 to period 1. Thus, the retained cash reserve is

$$c = c_0 - I. \tag{2}$$

At date $t = 1$, the firm additionally receives a random cash inflow of $\hat{\delta}$, and can also borrow up to $\tau f(I)$. If its total cash at this point is enough to repay the debt due, B, then the firm makes the payment and survives until the next period $t = 2$, when the shareholders receive the liquidating cash flow $f(I)$. Otherwise, the firm is liquidated, future cash flows are lost, equity is wiped out, and the creditors recover the amount $c + \hat{\delta}$. The maximum amount of cash available for debt service at date 1 is therefore $c + \delta + \psi + \tau f(I)$, which is the sum of the cash reserve c, the random cash flow $\hat{\delta} = \delta + \psi$, and the newly borrowed amount $\tau f(I)$. The "default boundary," or the minimum cash flow shock that allows the firm to repay B in full and avoid default, is:

$$\psi_B = B - c_0 - \delta + I - \tau f(I). \tag{3}$$

The total payoff to equityholders is the sum of the initial cash endowment, the period 1 cash flow, and the payoff from long-term investment, less the invested amount and debt payment, provided that the firm does

[10] For a straightforward modeling of such partial pledgeability based on a moral hazard problem, see Holmstrom and Tirole (1998).

[11] For example, Kim, Mauer, and Sherman (1998), Anderson and Carverhill (2007), and Asvanunt, Broadie, and Sundaresan (2007) assume that cash has a convenience yield because of taxes or agency issues.

not default on its debt. The market value of equity is therefore

$$E = \int_{\psi_B}^{\infty} [-I + c_0 + \delta + \psi - B + f(I)] g(\psi) d\psi. \tag{4}$$

Conditional on survival, raising new financing at $t = 1$ in this setting is value neutral, so we assume without loss of generality that the firm always raises the maximum available amount, $\tau f(I)$. The equity value in Equation (4) can be rewritten as

$$E = \int_{\psi_B}^{\infty} [(\psi - \psi_B) + (1 - \tau) f(I)] g(\psi) d\psi, \tag{5}$$

where $\psi - \psi_B$ is the amount of cash left in the firm after B is repaid, and $(1 - \tau) f(I)$ is shareholders' claim on period 2 cash flow, conditional on the firm not defaulting in the interim.

In period 0, the firm's shareholders face the following trade-off in deciding whether to invest cash or to retain it until the next period. On the one hand, higher retained cash holdings imply lower investment, which results in lower cash flows generated by the long-term investment. On the other hand, an increase in cash holdings reduces the probability of a cash shortage at date 1, increasing the likelihood that the firm survives until date 2 to reap the benefits of the long-term investment.

The market value of the firm's debt, D, is

$$D = B - \int_{-\infty}^{\psi_B} [B - (c + \hat{\delta})] g(\psi) d\psi, \tag{6}$$

which can be interpreted as the face value of debt B, adjusted for the loss that creditors expect to incur in default states $[-\infty, \psi_B]$. Because interest rates are zero, the credit spread, denoted s, equals the total debt yield, given by

$$s = \frac{B}{D} - 1. \tag{7}$$

In what follows, we study how changes in various parameters affect credit spreads and cash holdings. The effect of any variable x on the credit spread can be decomposed into two components. First, the spread may depend on x directly. Second, it may be affected indirectly if changes in x induce a change in the cash reserve c, which in turn affects spreads. Formally,

$$\frac{ds}{dx} = \frac{\partial s}{\partial x} + \frac{\partial s}{\partial c} \times \frac{dc}{dx}. \tag{8}$$

It is easy to show that changes in the spread are negatively correlated with changes in cash holdings, so that $\frac{\partial s}{\partial c} < 0$, which is the intuitive result that higher cash holdings result in lower credit spreads *provided everything else is held constant.* At the same time, the direct effect of x on the spread, $\frac{\partial s}{\partial x}$, and on cash holdings, $\frac{dc}{dx}$, depends on the nature of x. As an important special case, some variables may affect spreads only indirectly through their effect on the chosen cash reserve, so that $\frac{\partial s}{\partial x} = 0$. We refer to variations in cash induced by such variables as "exogenous" and discuss them in Subsection II.C. For credit risk-related factors that affect spreads directly as well as indirectly, through their effect on the firm's optimal cash holdings, the overall effect in Equation (8) depends on whether the two effects work in the same direction and, if not, which of them dominates.

B. Endogenous cash policy and credit risk

In this subsection, we show that variations in the firm's expected cash flow δ may result in a positive correlation between credit spreads and optimal cash holdings. Managers maximize the value of equity by choosing the appropriate level of investment I. From Equation (4), equityholders' optimization problem yields the following first order condition:[12]

$$\frac{\partial E}{\partial I} = \int_{\psi_B}^{\infty} [-1 + f'(I)] g(\psi) d\delta_1 - [-I + (c_0 + \delta + \psi_B - B) + f(I)] g(\psi_B) \frac{d\psi_B}{dI} = 0. \tag{9}$$

Substituting the expression for ψ_B from Equation (3) and rearranging, we can rewrite this first-order condition as

$$f'(I) = \frac{1 + (1-\tau) f(I) h(\psi_B)}{1 + \tau(1-\tau) f(I) h(\psi_B)}. \tag{10}$$

In the first-best case of unrestricted investment, the standard maximization solution would yield $f'(I) = 1$. In our model, the right-hand side in Equation (10) is greater than 1 as long as there are financing frictions (i.e., $\tau < 1$) and the firm's ability to repay the debt at the chosen investment level is uncertain (i.e., $g(\psi_B) > 0$). It follows that the firm's optimal investment in our model, I^*, is lower than the first-best level.[13]

To understand the intuition behind the optimal investment and cash policies, note that we can re-write

[12] It is easy to show that the second-order condition for maximization is satisfied. We also assume that initial cash holdings are high enough for the first-order condition to yield an interior solution, i.e. $c_0 > I^*$.

[13] The economic mechanism that generates this under-investment is very different from that in the standard debt overhang problem in Myers (1977), which, in contrast to our assumptions, essentially requires debt to be long term and investment to be short term. One of the solutions suggested to the debt overhang problem is to use debt of shorter maturity. In our case, however, it may only worsen the outcome.

the first-order condition as follows:

$$(f'(I) - 1) \times (1 - G(\psi_B))\, dI = (1 - \tau) f(I) \times g(\psi_B) d\psi_B. \tag{11}$$

The left-hand side in Equation (11) is the net value gain from increasing investment by dI, equal to $(f'(I) - 1)dI$, conditional on survival in the interim period, the probability of which is $1 - G(\psi_B)$. The right-hand side gives shareholders' expected marginal loss from default, equal to the value of equity at the default boundary $(1 - \tau)f(I)$ multiplied by $g(\psi_B)d\psi_B$, which is the marginal increase in the probability of default due to the shift in the default boundary by $d\psi_B$.

Let c^* denote the firm's optimally chosen cash reserve, $c^* = c_0 - I^*$, and s^* represent its credit spread in equilibrium, $s^* = s(c^*)$. When the model parameters change, the firm adjusts its optimal cash policy in response. At the same time, the credit spread also changes, both as a direct consequence and as a result of the adjustment in optimal cash holdings c^*. The following proposition summarizes the effect of the expected interim cash flow δ on equilibrium cash holdings, as well as its net effect on the credit spread.

Proposition 1. *If the hazard rate $h(\cdot)$ is non-decreasing, then*

1. *Equilibrium cash reserve c^* is a non-increasing function of δ for any $\tau < 1$; and*
2. *There exists a threshold level of pledgeability $\bar{\tau}$, such that the equilibrium credit spread s^* is decreasing in δ for any $\tau < \bar{\tau}$.*

The first part of Proposition 1 states that if the hazard rate $h(\cdot)$ is non-decreasing[14] and external financing is restricted ($\tau < 1$), "riskier" firms with lower expected interim cash flow, which face a higher risk of a cash flow shortage at the time when debt is due, optimally choose a higher cash reserve. Empirical evidence in support of this prediction appears in Figure 2, which shows that for firms with low interest coverage ratios for which our effects are relevant, cash holdings are decreasing with the size of the cash flow (scaled by debt service).

The second part of Proposition 1 states that despite their larger cash buffer, firms with lower cash expected cash flows have higher credit spreads, provided that restrictions on external financing are binding (that is, the pledgeability of assets is sufficiently low). Thus, the direct effect of the lower cash flow is to increase spreads by more than the indirect effect, through the rise in precautionary savings, decreases them.

[14] The sufficient condition of a monotonic $h(\cdot)$ means that the conditional default probability at the default boundary increases with the level of the boundary. This condition is satisfied in particular in most, if not all, structural models of credit risk. See also footnote 8.

Formally, in Equation (8) with $x = \delta$, we have $\frac{\partial s}{\partial \delta} < 0$ (other things being equal, an increase in the cash flow reduces spreads), $\frac{dc^*}{d\delta} \leq 0$ (higher cash flow means lower precautionary savings), and even though $\frac{\partial s}{\partial c^*} < 0$ (lower savings mean higher spreads), the first effect dominates, so that $\frac{ds}{d\delta} < 0$ (overall, spreads and cash flows are negatively correlated). Hence, both the spread s^* and the cash reserve c^* increase when expected cash flows fall. In practice, this means that when cash flow levels are allowed to vary over time or in the cross-section, this variation is likely to induce a positive correlation between cash holdings and spreads.

It is worth noting that, when asset pledgeability τ is high, an increase in expected cash flow δ may for some combinations of functions f and h result in higher credit spreads because of the following asset shifting problem. When investment cash flows are highly pledgeable, and when investment productivity is declining only slowly, an increase in the interim cash flow by one dollar can induce an increase in investment by more than a dollar, as shareholders expect to be able to borrow more against a larger pool of collateral at $t = 1$. Thus, the composition of funds available for debt service shifts toward a lower precautionary cash reserve in combination with higher new borrowing. Even though in new equilibrium the probability of default is lower, in default states creditors' recovery rates are disproportionately lower, because there is less cash in the firm, and long-term investment has no value in default. Thus, under such scenarios the overall effect of the increase in expected interim cash flow may be to increase spreads.[15]

C. Exogenous variations in cash

The discussion so far indicates that variations in factors that affect both credit risk and the optimally chosen cash reserve can induce a positive cross-sectional correlation between them in equilibrium. In this subsection, we look at the effect of "exogenous" variations in cash, which are not induced by variations in credit risk factors. Suppose that cash holdings also depend on a variable x that does not affect spreads directly, so that in Equation (8), $\frac{\partial s}{\partial x} = 0$, implying that x can be correlated with spreads only through its effect on cash. Then, variations in cash induced by variations in x are negatively correlated with spreads, corresponding to the simple intuition that firms with more cash should be "safer" and have lower credit spreads. It is easy to prove the following result.

Proposition 2. *If $\frac{\partial s}{\partial x} = 0$, the credit spread s is negatively related to variations in cash holdings induced by changes in x.*

[15] Note that asset shifting ceases to be a problem when financing frictions are very low. Indeed, in the limiting case of $\tau = 1$, cash holdings and investment cash flows are perfect time substitutes, so that investment is at its first-best level, and precautionary savings play no role. In this case, higher expected interim cash flow simply enlarges the total pool of assets without affecting cash holdings, and thus results in lower credit spreads.

What economic factors might affect cash holdings but not the value of debt, other than indirectly through their effect on cash? Examples include cash windfalls or losses unrelated to managers' cash policy decisions. For instance, the firm may win a lawsuit, resulting in a cash inflow from the defendant. Alternatively, firms with similar underlying credit risk characteristics may *optimally* choose different levels of cash in response to differences in factors that are not directly related to credit risk. As an illustration, we augment the model to allow managers' optimally chosen cash holdings to depend on growth options (future investment opportunities) and the structure of managerial compensation.

Growth options: We model the firm's growth options as an investment opportunity that will be open to the firm at the interim date $t = 1$ and will yield a cash flow at date 2. If this investment is not pledgeable at $t = 1$, then its presence does not affect the value of the debt that must be repaid at date 1, other than through its effect on cash reserves. For simplicity, assume that these growth options have a fixed value of $z > 0$, independent of other firm characteristics. If the firm defaults on its debt, this investment opportunity is lost, perhaps due to loss of customers, the inability to retain management, or the non-transferability of human capital. Crucially, though the growth option increases the value of equity conditional on survival and hence enhances shareholders' incentive to conserve cash to avoid default, it does not benefit creditors directly.

Formally, equityholders' value can be written, similar to Equation (4), as:

$$E = \int_{\psi_B}^{\infty} [-I + c_0 + \delta + \psi - B + f(I) + z] g(\psi) d\psi \ , \tag{12}$$

and the first-order condition that determines the firm's investment policy takes the following form:

$$f'(I) = \frac{1 + [(1-\tau)f(I) + z]\, h(\psi_B)}{1 + \tau\, [(1-\tau)f(I) + z]\, h(\psi_B)}. \tag{13}$$

This first-order condition implies that the presence of growth options decreases initial investment, because the incentive to survive is now stronger. As we show in Appendix B, the total effect of the change in growth options on credit spreads consists of only the indirect effect through the optimal cash balance. Hence, cross-sectional variations in optimal cash holdings induced by growth options should be negatively correlated with credit spreads.

Managerial losses in distress: Default involves private costs for the management. Gilson (1989) notes that such costs may arise because of the loss of future income, firm-specific human capital, or non-pecuniary benefits, such as power and prestige, and because of adverse reputation effects. He finds empirically that the top management of distressed firms is almost three times as likely to be replaced as that of non-distressed firms.

Managers' private costs of distress, however, likely depend on the structure of their compensation contracts. Differences in managerial compensation across firms thus should result in different incentives for managers to avoid default, because the private costs differ. Thus, for managers of two firms with the same underlying credit risk, the precautionary motive for saving cash may be weaker or stronger, depending on their compensation structure. In this way, differences in managerial compensation induce an exogenous variation in cash holdings.

Suppose that the firm's risk-neutral manager owns a share $\theta > 0$ of the equity E and incurs a fixed, private cost $\gamma > 0$ if the firm defaults. For a given ownership level θ, the manager's incentive to retain cash increases with the private cost of distress γ. Conversely, given γ, the manager's incentive to hold cash declines with her ownership of the firm θ. The overall effect on the manager's chosen cash policy depends on the ratio of managerial cost to equity stake, $\frac{\gamma}{\theta}$, which can be interpreted as a measure of agency problems between the manager and equityholders. The higher the manager's private cost of default and the lower her equity stake, the more conservative the firm's cash policy (relative to one that maximizes the overall value of equity), resulting in lower credit spreads for the same underlying level of credit risk. Formally, the manager's objective is to choose investment I to maximize:

$$M = \theta \times E - \gamma G(\psi_B). \tag{14}$$

We show in Appendix B this case is very similar to that of growth options, and the cross-sectional correlation between cash holdings and spreads induced by variations in the agency factor $\frac{\gamma}{\theta}$ is negative.

D. Cash and the probability of default

Another aspect of credit risk that we investigate analytically is: How are cash holdings correlated with the future likelihood of default? We show that the answer to this question depends on the horizon over which we measure the likelihood of default. In choosing the optimal cash reserve, the firm's managers trade off the reduction in the risk of default at date 1 (short-term effect) against investment returns realized only at date 2 (long-term effect). We extend our model to show that higher cash reserves reduce the likelihood of default in the short run, but through lower future profits, they may in fact increase it in the long run.

Consider a modification of our earlier setting, in which the firm's total debt consists of two tranches of different maturities, so that some debt with a face value of B_1 is due at the interim date 1, whereas that with a face value of B_2 is due at date 2. We assume for simplicity that no part of investment return $f(I)$ is pledgeable at date 1 (i.e., $\tau = 0$), whereas it is fully pledgeable at date 2. (Partial pledgeability in both periods does not affect our conclusions.) The threshold level of date 1 cash flow shock, below which the firm cannot meet its payment at date 1, is given by $\psi_{B_1} = B_1 - (c_0 + \delta - I)$, which is decreasing in the cash reserve $c = c_0 - I$.

Next, consider the risk of default at date 2. Suppose that the firm has not defaulted at date 1, so that $\psi > \psi_B$. Then, the firm's available resources for debt payment at date 2 are the surplus cash reserve carried over from period 1, which is equal to $\delta + \psi + c - B_1$, and the investment cash flow $f(I)$.[16] Default occurs at date 2 whenever $(\delta + \psi + c - B_1) + f(I) < B_2$, which implies a default boundary below which the firm defaults at date 2, expressed in terms of date 1 cash flow shock, as $\psi_{B_2} = \psi_{B_1} + B_2 - f(I)$, . Because we assume that cash flows at date 2 are known with certainty, if the firm survives at date 1 and its outstanding debt B_2 is lower than the investment return $f(I)$, then its conditional likelihood of default at date 2 is zero. If B_2 is higher than the investment return $f(I)$, there is a positive probability of default at date 2 as well. To avoid default in future, the firm's remaining cash after date 1 debt repayment must be sufficiently high.[17]

The effect of the initial level of investment on the date-2 default boundary is described by

$$\frac{d\psi_{B_2}}{dI} = \frac{d\psi_{B_1}}{dI} - f'(I) = 1 - f'(I). \tag{15}$$

Because the probability of default in period 2 is increasing in ψ_{B_2}, this equation formalizes the the following trade-off: Higher cash reserves decrease the probability of default at date 1, $\frac{d\psi_{B_1}}{dI} > 0$. However, since $1 - f'(I) < 0$ (see the equivalent first-order condition (10)), the probability of default in the longer-term increases as the firm increases its cash reserve at the expense of long-term investment.[18] Thus, we obtain

[16] For simplicity, we assume that the firm carries its surplus cash reserve to date 2. In general, if the debt B_2 due is very high, equityholders may have a strategic motive to pay out the cash reserves as dividends in earlier periods, as otherwise all this cash would simply accrue to creditors (Acharya, Huang, Subrahmanyam, and Sundaram (2006)). We assume that covenants restrict such strategic dividends, as is typically the case.

[17] Note that with complete revelation of information about the interim cash flow $\hat{\delta}$ at date 1, anticipated default at date 2 should simply trigger default at date 1. However, a small amount of residual uncertainty, either in the investment return $f(I)$ or in an additional date 2 cash flow, would suffice to avoid such an outcome.

[18] A similar effect may be induced by managerial short-termism, which could be an exogenous factor driving cash holdings above their optimal level, and reducing default risk in the near future at the cost of lost profitable investment opportunities.

the following result:

PROPOSITION 3. *An increase in cash balances reduces the likelihood of default at date 1 and increases the likelihood of default at date 2.*

E. Discussion

Before taking the above set of results to data, we discuss two issues: First, we show that variation in firm leverage, like that in cash flows, can induce a positive correlation between cash holdings and credit spreads; second, we discuss our assumption that firm leverage is predetermined.

E.1. The effect of varying firm leverage

Proposition 1 establishes that cash balances and credit spreads may be positively related in the cross-section of firms, because the expected cash flow affects both credit spreads and the precautionary motive for holding cash in equilibrium. The same effect may also arise due to variation in firm characteristics other than cash flow coverage when they affect both spreads and optimal cash holdings.

Consider variations in debt levels across firms. In particular, suppose that the firm's debt level increases. The direct effect of this increase is to raise spreads. However, at the same, time optimal cash holdings also rise, which dampens the effect of higher debt levels on spreads. Appendix B (Proposition B1) shows that the direct effect dominates, much as in the case of varying cash flows in Proposition 1. Therefore, more indebted firms have both higher cash levels and higher spreads, implying a positive cross-sectional correlation between the two.

E.2. Predetermined vs. flexible debt policy

In the analysis so far, we have assumed that the level of debt B is fixed and predetermined. To shed more light on this assumption, we first argue that cash holdings are more flexible than debt levels, which provides a justification for studying the optimal cash policy after debt is in place. We then discuss how our results might change if debt is allowed to be endogenous in the model.

When capital markets are imperfect, fluctuations in cash flows may affect all components of corporate financing. We argue, however, that cash holdings are likely to be especially sensitive to such imperfections. In response to expected negative shocks to cash flows, financially constrained firms can try to reduce their credit exposure by adjusting their long-term and short-term borrowing levels, as well as changing their cash reserves. The effect on each financial asset depends on the relative adjustment costs. Because cash holdings can be increased relatively easily by retaining cash from the current period's profits,[19] adjustments to cash holdings in response to variation in expected cash flows should be disproportionately large relative to adjustments in other sources of funds, such as debt financing.[20] Dynamic capital structure theories (e.g., Fisher, Heinkel, and Zechner (1989), Goldstein, Ju, and Leland (2001), and Hackbarth, Miao, and Morellec (2006)) show that waiting times to restructure debt optimally could be substantial, even for small transactions costs, an implication supported by recent empirical evidence (e.g., Leary and Roberts (2005)).

Empirically, cash is indeed significantly more variable than both equity and debt. For the median non-financial firm in Compustat with a non-trivial amount of debt in the capital structure, the coefficient of variation (standard deviation divided by the mean) for cash as a proportion of total assets is 0.80, compared with 0.36 for total debt over total assets and only 0.27 for book equity over total assets, with differences significant at the 1% level.[21] These comparisons suggest that the cash policy is likely to be more easily adjusted than debt levels.

As an illustration of how endogenising the level of debt in the model may affect the analysis, consider the effect of an increase in the expected cash flow when managers can adjust both cash holdings and debt levels simultaneously. Then, the direct effect is still unambiguously to decrease optimal cash holdings as well as credit spreads. However, the optimal leverage ratio is likely to increase, which induces an increase in optimal cash holdings and spreads. Thus, two opposite effects are at work, and their net effect is an empirical question.

III. Data description

A. Empirical strategy

Our model shows that optimally chosen cash holdings depend on various credit risk factors that also affect credit spreads, such as debt coverage ratios, volatility, leverage, and so forth. According to the model, the positive correlation between cash and spreads documented in Tables I and II reflects that cash is

[19] Alternatively, cash can be raised from external sources. However, if external financing is costly today and equally available in the future, firms will not want to access it solely to increase today's cash savings.

[20] This argument mirrors that of Carpenter, Fazzari, and Petersen (1994), who study the response of inventories to fluctuations in internal finance and consider all other components of investment fixed, because inventories have lower adjustment costs.

[21] These statistics are calculated using annual Compustat data between 1980 and 2006, excluding financial firms with SIC codes between 6000 and 6999, firms with fewer than 10 annual observations, and those for which total debt is less than 5% of total book assets.

endogenously an increasing function of credit risk, rather than that increases in cash *cause* spreads to rise. To test this hypothesis, we first re-estimate the regressions of spreads, adding finer controls for variations in firm-specific credit risk than those used in typical cross-sectional studies. We expect that in the presence of such controls, the correlation of spreads with cash will be reduced. We then use instrumental variables to show that, consistent with the model and the simple intuition but in contrast with standard OLS regressions, exogenous variations in cash are *negatively* related to spreads.

Moreover, if firms with higher cash holdings have higher spreads, we would expect a similar positive association between cash and probability of default. We therefore re-examine the role of liquid asset holdings in empirical default-predicting models such as Altman's (1968) Z-score and show that the correlation between cash and the probability of default depends on the prediction horizon, underscoring the importance of accounting for the endogenous nature of cash. Finally, we look at changes in cash holdings associated with changes in credit quality and find that firms increase their cash reserves when they become riskier.

B. Data sources and sample selection

We study yield spreads on bonds included in the Merrill Lynch U.S. Investment Grade Index and High Yield Master II Index between December 1996 and December 2003. The Merrill Lynch indices include corporate bonds with a par amount of at least 100 million dollars and remaining maturity of at least one year. The bond pricing database consists of monthly bid quotes from Merrill Lynch bond trading desks. We augment these data with descriptive bond information from the Fixed Income Securities Database (FISD) provided by Mergent. We manually merge the data with quarterly Compustat and CRSP, taking account of mergers, name changes, and parent/subsidiary relationships. Finally, we use expected default frequencies (EDFs) and estimates of the volatility of assets supplied by Moody's/KMV.

During the sample period, the two Merrill Lynch indices include 429,420 monthly corporate bond quotes. We exclude observations that we cannot reliably merge with FISD and Compustat, and in most of our tests, unless specifically stated otherwise, we also exclude bonds issued by financial companies (SIC codes 6000–6999). We eliminate non-fixed coupon bonds; asset-backed issues; bonds with embedded optionalities, such as callable, puttable, exchangeable, and convertible securities; and bonds with sinking fund provisions. Finally, we exclude bonds with remaining time to maturity of less than one year or more than thirty years, because the data on the risk-free rate that we use to estimate spreads are not available for these maturities.

C. Spread measurement and control variables

Our primary focus is on the correlation between credit spreads and cash holdings. We calculate the spread as the difference between the bond's promised yield implied by its price, and the yield on a portfolio of risk-free zero-coupon securities (STRIPS) with the same promised cash flow, as suggested by Davydenko and Strebulaev (2007). This estimation method controls accurately for the shape of the term structure. Our initial data set is an unbalanced panel of monthly observations of spreads. A potential issue with this data structure is that large firms with many outstanding bonds may be overrepresented in any given month. Because we are interested in the relationship between credit risk and cash reserves, which are firm– rather than bond-specific variables, using all bond-month observations may bias the results toward large firms. We address this issue by averaging all spreads for a given firm in a given month and using one observation per firm-month in our analysis. We similarly use the average bond maturity of all bonds for which spreads are available; all other variables in our tests are measured at the firm level. In untabulated tests, we confirm that the results are unchanged when we use all bond-month rather than firm-month observations.

We measure cash reserves using the ratio of cash and near-cash to total book assets. In regressions of spreads, we control for firm-level credit-risk variables, such as leverage, volatility, and debt maturity. Because of their importance in structural models of credit risk, these controls are routinely used in empirical studies of spreads (e.g., Collin-Dufresne, Goldstein, and Martin (2001)). We estimate the (quasi-) *market leverage* ratio as the book value of total debt divided by the sum of the book value of debt and the market value of equity at the end of the previous fiscal quarter. Another factor featuring prominently in credit risk models, the volatility of assets, is not directly observable. We use estimates of *firm asset volatility* supplied by Moody's/KMV, which employs a proprietary algorithm based on the Merton (1974) model to infer volatility from the time series of equity prices.

To control for the term premium in corporate bond yields, we use the average remaining *time to maturity* of all sample bonds outstanding for the firm at each observation date. We include the logarithm of total book assets to control for all influences that the firm's size may exert on debt spreads. Finally, Collin-Dufresne, Goldstein, and Martin (2001) find that a significant part of monthly changes in spreads is driven by unidentified systematic factors. To control for all economy-wide factors, including the risk-free rate of interest, we use monthly dummies in our regressions.

D. Descriptive statistics

Table III shows the composition of our sample by rating and by industry. The sample consists of 82,676 monthly bond prices of 480 unique bond issuers. Most of our regressions include one firm observation per month; we have 24,594 such observations. Three quarters of the sample are concentrated in the two lowest investment-grade categories, A and BBB. Junk bond spreads (those rated BB and lower) constitute 16.4% of the firm-month data set. This composition is similar to that documented in other corporate bond and credit default swap data sets (e.g., Collin-Dufresne, Goldstein, and Martin (2001), Davydenko and Strebulaev (2007), Schaefer and Strebulaev (2008)). The number of firms in each rating class does not stay the same, because ratings change over time. Statistics reported in the first column show ratings for the 480 firms as of the day they first appear in the sample. During our sample period, more firms were downgraded than upgraded; in addition, firms are excluded from the database when they default. As a result, there are more junk firms in our firm-month data set than is suggested by the first column of the table. For example, six firms in the sample were rated CCC at least once, compared with just one firm that entered the sample with that rating. Panel B of Table III also shows the composition of the sample by industry. The highest proportion of firms are in manufacturing, followed by utilities and transportation, and then consumer goods.

[TABLE III HERE]

Panel A of Table IV presents the descriptive statistics for the bond spreads for the whole sample, as well as for different rating groups. The mean spread in the sample is 197 basis points, and the median is 135 basis points. Spreads are higher for lower-rated bonds. Untabulated comparisons of bonds with different maturities suggest that for a given rating, spreads typically increase in maturity. It is interesting to note that the average BB spread (385 basis points) is more than twice as high as that for BBB bonds (181 basis points). This jump in the spread is likely attributable to not only the increase in the probability of default but also the lower liquidity of speculative-grade bonds (BB and below) compared with investment-grade bonds.

[TABLE IV HERE]

Panel B of Table IV presents descriptive statistics on firm-specific variables. Because all of our firms have public bonds outstanding, it is not surprising that they are relatively large in size, with median total book assets of almost $6.5Bn. They also have relatively high leverage ratios compared with broad Compustat samples not conditioned on the presence of public bonds in the capital structure. Statistics on leverage and asset volatility are similar to those in other credit risk studies. Looking at firm characteristics by rating (not reported), we find that firms with higher ratings are larger, less levered, and more profitable; have slightly larger capital expenditures; and return substantially more cash to shareholders via dividends and repurchases than do riskier firms.

Expressed as a proportion of total assets, cash holdings of our firms are lower than those in the broader Compustat samples typically used in empirical studies of cash holdings. For instance, in Opler, Pinkowitz, Stulz, and Williamson (1999), the average ratio of cash to net assets (total assets minus cash) is 17%, and the median is 6.5%, compared with 4.4% and 2.0%, respectively, in our sample. These substantial differences arise in part because our sample does not include firms with zero or near-zero leverage, which tend to hold significant amounts of cash (Strebulaev and Yang (2006)), and in part because bond issuers are likely to be less financially constrained and value cash holdings less (which should work against our finding of any effects related to the optimally chosen cash policy). The differences are all the more significant given that our sample corresponds to recent years, during which corporate cash holdings increased substantially.[22] Figures 1 and 2 illustrate that cash holdings are U-shaped in measures of credit risk, with the safest and riskiest firms holding more cash than average.

IV. Empirical results

A. Exploring the cash-spread correlation

A.1. Is cash a proxy for credit risk?

Our theory shows how the positive correlation between cash and spreads can arise as a byproduct of the precautionary motive for holding cash reserves by levered firms, which results in riskier firms having both more cash and higher credit spreads. Yet if this is the explanation, then why is cash still positive and significant after controlling for credit risk factors used in empirical studies of spreads, such as leverage and volatility? One potential explanation is that these standard proxies do not fully control for the underlying credit risk. Empirical studies typically explain only 30% to 50% of the cross-sectional variation in credit spreads (e.g., Davydenko and Strebulaev (2007)). As a result, in regressions of Tables I and II, cash may be a proxy for residual credit risk not fully accounted for by these factors. To investigate this possibility,

[22] Bates, Kahle, and Stulz (2008) document that the overall corporate cash holdings now exceed total corporate debt, so that the aggregate leverage is negative.

we look at how the correlation between cash and spreads is affected by additional controls for credit risk, beyond those typically used in standard specifications used in empirical studies of spreads.

These tests are presented in columns (1) to (5) of Table V. Compared with the univariate regression (1), regression (2) introduces standard controls for leverage and asset volatility.[23] The correlation between cash and spreads falls slightly but remains significant. The fall in magnitude is to be expected if cash is increasing with credit risk, which in turn is correlated with leverage and volatility. However, the coefficient for cash remains statistically significant even in the presence of these controls. Leverage and volatility likely do not fully explain variations in credit risk that affect bond spreads, so cash remains correlated with the residual credit risk not explained by these variables.[24]

Existing credit risk literature provides little guidance on additional firm-specific credit risk controls beyond leverage and volatility. As a simple approach, we use credit ratings, which summarize credit agencies' opinions of the firm's creditworthiness, taking into account not only its financial characteristics but also industry conditions, the strength of the management team, and other relevant, frequently soft, information. Hence, we include a set of dummy variables for each S&P rating notch (AAA, AA+, AA, AA–, etc.) in our regressions. The results are reported in columns (3) and (4) of Table V. Adding rating dummies increases the R^2 in regression (3) by 11%, even in the presence of leverage and volatility controls. Additional controls for size, bond maturity, and systematic factors (by means of monthly dummies) further raise the explanatory power of these regressions by 6%, so that regression (4) explains 63% of the variation in spreads. Thus, though ratings provide an admittedly crude summary of credit risk, as evidenced by leverage and volatility remaining strongly significant determinants of spreads,[25] they clearly have significant incremental explanatory power.

For our purposes, the important result in regressions (3) and (4) is that when we add ratings to control for credit risk, the correlation between spreads and cash holdings becomes small and statistically indistinguishable from zero. This result is consistent with the conjecture that the positive relationship found in more standard regressions, such as those shown in Tables I and II, arises because cash holdings and credit spreads are both driven by common credit risk factors not fully controlled for in those regressions, rather than because increases in cash cause spreads to increase.

One potential criticism of relying on credit ratings is that the role of cash in the rating agencies' decision

[23] We obtain very similar results when we use equity volatility or the Schaefer-Strebulaev (2008) proxy for the volatility of assets instead of the Moody's/KMV estimate.

[24] Linear terms in leverage and volatility explain only about 43% of the variation in spreads in our sample.

[25] This finding is unsurprising, given ratings' granularity and that they are usually adjusted slowly in response to changing credit conditions, due to rating agencies' desire to achieve a balance between "ratings stability" and accuracy (Cantor and Mann (2007)).

process is unclear.[26] To address this potential issue, in regression (5), we use the Moody's/KMV's expected default frequency (EDF) as a control variable instead of ratings. The EDF is based on Merton's (1974) structural model of credit risk, calibrated using Moody's/KMV's private algorithm in conjunction with its proprietary database of default histories (Crosbie and Bohn (2001)). Importantly, the Merton model assigns no role to cash as a potential credit risk factor. The EDF is a non-decreasing function of the distance to default, which in turn is essentially a volatility-scaled measure of leverage. The EDF is estimated from the time series of leverage ratios and equity values, with a twist that the non-linear transformation at the heart of the Moody's/KMV algorithm results in a measure that is more closely associated with credit risk than are simple linear combinations of leverage and volatility.

Regression (5) of Table V shows that the EDF provides as much explanatory power for spreads as do leverage, volatility, and the full set of rating dummies combined. In unreported tests, univariate regressions of spreads on the EDF produce an R^2 of 52.2%, compared with regressions on leverage and asset volatility, which together explain 42.8% of the variation in spreads. Moreover, if both the EDF and rating dummies are included, the R^2 increases from 63% in column (5) to as much 72%, far above the 30-50% range more typical in cross-sectional studies of spreads. In short, the EDF explains significantly more of the variation in credit risk than do leverage and volatility.

For our purposes, the important result of regression (5) is that the correlation of spreads with cash holdings becomes insignificant when the EDF is used to control, in a non-linear way, for the influences that leverage and volatility exert on bond spreads. This, again, suggests that the positive correlation documented previously can be explained by precautionary savings, which result in a positive dependence of endogenously chosen cash on credit risk, which is not fully accounted for in standard regressions.

[TABLE V HERE]

A.2. Exogenous variations in cash

Our model further predicts that exogenous variations in cash holdings (those not induced by variations in underlying credit risk factors) should be negatively related to spreads. In this subsection, we test this prediction using the instrumental variable approach. Intuitively, in our framework instrumental variables are factors that induce cross-sectional variation in cash holdings unrelated to the underlying credit risk. Admittedly, finding empirical instruments that satisfy these requirements is a difficult task. The model

[26] It is worth noting, however, that our conclusions are reinforced rather than weakened if rating agencies award higher ratings to firms with higher cash reserves.

suggests two potential instruments. First, more profitable future investment opportunities (growth options) should result in the firm's retaining more cash for the future, regardless of its level of credit risk. Yet once the higher cash reserve is in place, it provides a safety cushion for creditors, decreasing credit spreads. To proxy for *growth options*, we use the median ratio of R&D expenditures to sales in the firm's three-digit SIC industry in each calendar year.[27]

Second, the model suggests the ratio of managerial private costs of financial distress to the fraction of the firm's equity that the manager owns as another instrument. The higher this fraction, the higher is the manager's incentive to hoard cash (above the level that maximizes the value of equity) to avoid default and the associated private costs. We assume that the CEO's salary and bonus are at risk if the firm defaults. Accordingly, our *agency term* is the ratio of the CEO's salary, bonus, and other monetary compensation to the market value of her shares and options, estimated using the ExecuComp database.[28]

We employ these two instruments in instrumental variable regressions of spreads using specifications that mirror those in columns (1) to (5) of Table V. The results of these tests appear in columns (6) to (10) of the same table. The effect of the control variables in IV and OLS regressions is similar. However, in contrast to OLS, the coefficient for the (instrumented) cash holdings is negative and significant. Thus, the IV regressions confirm the prediction that exogenous variations in cash are negatively correlated with spreads.

Overall, our regressions of spreads on cash holdings show that, although in standard tests spreads are positively correlated with cash, this correlation disappears in the presence of finer controls for credit risk. Moreover, the simple intuition that higher cash holdings should make firms safer, which implies a negative relationship between cash and spreads, is correct. However, to uncover this intuitive result, we must overturn the effect of endogeneity of cash, which strongly dominates empirically. Thus, accounting for the fact that firms can choose their cash holdings optimally is of first-order importance for understanding the role of liquid assets in credit risk.

A.3. Robustness and extensions

Table VI shows that the positive correlation between cash and spreads in base case OLS regressions, as well as the sign reversal in instrumental variable regressions, are robust to the inclusion of various factors

[27]We prefer R&D to the market-to-book ratio as a proxy for growth opportunities, because in addition to other well-known problems with market-to-book (Erickson and Whited (2000)), in our setting, it is also mechanically correlated with the market leverage ratio, which renders it unsuitable as a potential instrument. Graham (2000) employs the ratio of R&D to sales at the level of a firm to proxy growth options. We adopt the industry counterpart to avoid endogeneity concerns.

[28]ExecuComp reports the Black-Scholes value of *new* option grants but not the current value of previously granted options. We use the algorithm suggested by Himmelberg and Hubbard (2000) to estimate the total market value of the CEO's options.

that may affect the firm's level of cash. Regressions (1) and (2) address the concern that different firms may have different liquidity needs due to the nature of their business, and these needs may be correlated with credit risk. We control for this possibility by including the current ratio (current assets over current liabilities) in our regressions and find no effect on our results. In untabulated tests, we obtain similar results when we use the cash ratio (cash over current liabilities) instead.

Another possibility is that differences in cash holdings across firms may be related to covenants that restrict minimum liquidity levels. To test this hypothesis, we construct dummy variables summarizing the presence of various covenants using data from the LPC DealScan database.[29] Regressions (3) and (4) control for covenants that prescribe minimum liquidity levels, yet these controls are insignificantly related to spreads and do not alter our conclusions. In untabulated tests, we also control for covenants that restrict capital expenditures, and thus can also affect cash, with very similar results.

Finally, to demonstrate that our results are not due to patterns of cash holdings and credit risk across different industries, in regressions (5) and (6), we control for industry effects by including dummy variables for the 49 Fama-French industries. These controls have little effect on the cash coefficient in the OLS regression, though in the IV regression (6), cash becomes insignificant because one of our two instruments is industry-based. Overall, the positive correlation between cash and spreads, documented in Tables I and II, reflects a robust phenomenon in the data.

[TABLE VI HERE]

One potential alternative explanation for the positive correlation between liquidity and credit spreads, suggested by Myers and Rajan (1998), is based on the moral hazard problem. Their theory suggests that cash-rich firms cannot commit to avoid squandering existing cash and may therefore face higher borrowing costs compared with firms with fixed assets that cannot be as easily dissipated. The original Myers and Rajan (1998) model describes the behavior of financial firms, for which liquid assets can be destroyed most easily. Consequently, one way to explore whether moral hazard underlies the effects we document is to compare the cash-spread coefficient for non-financial firms with that for financial firms.

The base case OLS regression for financial firms is reported in column (7) of Table VI. In contrast to those of non-financial firms, spreads of financial firms are *negatively* and significantly correlated with cash holdings in standard specifications. The negative correlation is also found in univariate regressions (not shown), and is consistent with the fact that financial firms on average have higher credit quality (with higher

[29] The details of how these variables are constructed are available upon request.

concentration on the left of the ratings spectrum in Figure 1), and for them credit risk is less important in determining their cash policy. In light of this evidence, the explanation of our results for non-financial firms, based on the precautionary motive for saving cash, appears more plausible than that based on moral hazard.

B. Balance sheet liquidity and the probability of default

Although our evidence shows that the effect of endogeneity on the relationship between cash and credit risk is of first-order importance, empirical credit risk studies do not account for this possibility. Because default is often thought of as caused by cash shortages, most empirical default-predicting models include various proxies for balance sheet liquidity, treating them as independent variables expected to reduce the probability of default. Among the best known models, Altman's (1968) Z-score includes WC/TA, the ratio of working capital (the difference between current assets and current liabilities) to total assets; Zmijevski's (1984) model and the ZETA-score model of Altman, Haldeman, and Narayanan (1977) use the current ratio CA/CL (current assets over current liabilities); and Ohlson's (1980) O-score uses both WC/TA and CL/CA to proxy for liquidity. However, despite the intuitive appeal and widespread use of these liquidity measures, Begley, Ming, and Watts (1996), Shumway (2001), and Hillegeist *et al.* (2004), as well as Ohlson (1980) and Zmijevski (1984) in their original work, find them unrelated or even positively associated with default. In this subsection, we address this puzzling result.

Our model predicts that the correlation between liquidity and the probability of default depends on the trade-off between the firm's incentive to conserve cash to survive a liquidity shortfall in the short run, and a reduction in investment that reduces expected cash flows over the longer horizon. If the firm is constrained in accessing outside financing and faces a non-trivial possibility of a liquidity shortfall in the near future, it may decide to conserve more cash at the expense of longer-term cash flows. Higher balance sheet liquidity would then result in a lower short-term probability of a liquidity crunch, but it may also lead to lower future cash flows and thus a higher probability of default over longer horizons.

To test the hypothesis that the correlation between liquidity and default depends on the prediction horizon, we estimate hazard models of default for our sample firms over three horizons: one quarter, one year, and three years. We use the Default Research Service database from Moody's to identify all public bond defaults in our sample, including missed payments, distressed bond exchanges, and bankruptcy filings.[30] We estimate multiperiod logit regressions, equivalent to discrete hazard models (Shumway (2001)), using

[30] With the exception of Altman, Haldeman, and Narayanan (1977), all the papers cited previously are restricted to predicting formal bankruptcy filings. Because failure to repay debt does not necessarily involve bankruptcy, we use the wider definition of default adopted by rating agencies.

specifications suggested by Altman (1968) and Zmijevski (1984) and separating cash from their liquidity measures.

We report the results of these tests in Table VII. The regressions in columns (1) and (2) are estimated for the short-term prediction horizon. The dependent variable in these regressions is 1 if the firm defaults within the next fiscal quarter, and 0 otherwise. As expected, proxies for balance sheet liquidity are negatively correlated with the short-term probability of default, both in the Z-score specification and in the Zmijevski model, though only for working capital (with and without cash) is the effect statistically significant. This result is consistent with Davydenko (2007), who finds that firms with restricted access to external financing are more likely to default over the next quarter when their liquid assets fall short of current liabilities.

In contrast to the short-term predictions, columns (3) to (6) show that these same measures of liquidity may be *positively* related to the probability of default at one and three years, and more so for the three-year horizon than for the one-year horizon. This finding echoes the evidence in extant bankruptcy-predicting studies, which usually use one year as the prediction horizon and find liquidity measures to be uncorrelated or positively correlated with bankruptcy.

[TABLE VII HERE]

Overall, these tests suggest that the effect of balance sheet liquidity on the probability of default for horizons longer than a few months cannot be captured adequately by a standard approach that treats liquid assets as an independent variable. We thus once again emphasize the importance of acknowledging that firms can choose their cash policy endogenously, depending in particular on the underlying probability of default.

C. Regressions of changes in cash

The evidence shown so far is consistent with the hypothesis that in cross-section, riskier firms hold higher cash reserves. By the same logic, a change in credit risk for any given firm should trigger an adjustment in its cash policy. For instance, we expect firms that have been recently downgraded by credit rating agencies to increase the amount of cash they retain in order to reduce the probability of a cash shortage in the face of the change in credit risk that triggered the downgrade. Moreover, the nature of such adjustments in cash holdings may differ depending on the firm's situation. Firms that are not generating sufficient cash flow may be unable to increase their cash holdings as a precautionary measure, which is more likely for the unprofitable, riskiest firms that need cash the most.[31] This reasoning suggests that there may be a concave relationship between changes in ratings and changes in cash reserves.

To test this hypothesis, we regress annual changes in cash holdings on the change in the credit rating, assigning the AAA rating a code of 1, AA+ 2, AA 3, and so on.[32] We also use a set of variables suggested by Almeida, Campello, and Weisbach (2004) to control for other factors that may affect changes in cash holdings. The most important of these variables is the annual cash flow, which is the most likely source of cash for firms that want to increase their cash reserve.

Table VIII reports the results of estimating these regressions for a broad Compustat sample of non-financial firms[33] and separately for different rating groups. The positive correlation between changes in cash and ratings means that decreases (increases) in credit quality are associated with increasing (decreasing) cash reserves (positive values of the *rating change* variable correspond to downgrades and increases in credit risk). Columns (3) to (7) suggest that the relationship between changes in cash and credit risk is concave. For the safest firms, there is virtually no relationship between the firm's rating and its cash policy. These firms typically have access to short-term financing, such as commercial paper, on short notice. The effect is very different for firms rated BBB, for which a downgrade would mean falling either very close to or into the junk category, implying a cancelation of commercial paper programs and substantially higher financing costs. Our tests show that these firms react to downgrades by increasing their cash reserves. We find similar results for BB-rated firms as well, consistent with the regressions of spreads in Table II, in which statistical significance is driven primarily by bonds with ratings close to the investment-grade/junk threshold. In contrast to these medium-low ratings, for firms at the extreme end of junk in column (7) rating downgrades do not result in significant increases in cash holdings. This result is to be expected, because the cash flows of these struggling firms are too low to allow them to increase their savings. Overall, tests of Table VIII corroborate our prior evidence that riskier firms choose higher cash reserves, consistent with the precautionary motive for saving cash in the presence of credit risk.

[TABLE VIII HERE]

[31] For example, in November 2008 General Motors informed investors that its continuing operating losses were likely to cause the troubled automaker to run out of cash within several months. Unable to raise financing amid a large-scale economy-wide credit crisis, GM announced that it would cut capital spending, advertisement, and production in order to conserve cash. Yet it also made clear that without an emergency "bridge loan" from the government, GM's cash reserves would soon be depleted to the extent that it would be forced to file for bankruptcy.

[32] An industry convention is that a change from, say, BBB- to BB+ is one notch. A change from AA+ to BBB+, for example, is three notches down.

[33] Because these tests do not use credit spreads, we include in them all annual Compustat observations for non-financial firms with a credit rating.

V. Concluding remarks

In this paper, we document a robust positive correlation between cash holdings and credit spreads. This finding runs contrary to the simple intuition that higher cash reserves make corporate debt safer. We argue that it arises because of endogenous adjustments in cash holdings by firms that worry about the possibility of a liquidity shortage, which can trigger costly default in the presence of restrictions on external financing. Our model shows how such effects can arise when future cash flows are only partially pledgeable and when default is costly. At the same time, exogenous variations in the firm's cash holdings that are unrelated to credit risk factors are negatively correlated with spreads. The simple intuition that predicts that firms with high cash holdings should be safer can account only for the direct effect of cash on spreads; it misses the indirect effect due to the endogeneity of cash, which, as our evidence suggests, dominates in practice. One immediate implication is that recognizing, as some studies have done, that balance sheet liquidity affects credit risk, yet treating it as an independent variable, is likely to be counterproductive.

Our model of the optimal cash policy is static in nature. It would be useful to build a more general, dynamic model of cash with shocks to interim cash flows that affect credit risk, along with features such as managerial risk-aversion and growth options that affect cash policy directly, to improve our understanding of empirically observed spreads. Developing such a dynamic model, along the lines of Acharya et al. (2006), Anderson and Carverhill (2007), and Asvanunt, Broadie, and Sundaresan (2007), and calibrating it to the empirically observed cash-spread relationship is an important goal for further research.

The severe credit crisis caused by the subprime debacle (ongoing at the time of writing) highlights the relation between cash policy and corporate debt pricing. The looming recession implies lower future expected cash flows. At the same time, the unwillingness of banks to extend credit means that firms cannot rely on external sources of financing should a liquidity crisis occur. Both factors increase the value of a marginal dollar of cash and elevate the importance of cash management policies to a new level. The perception of market practitioners becomes that "In a period in which credit is being rationed, the price of leveraged assets declines and cash is king."[34] Disentangling the various effects that such shocks in the economic environment have on cash policy and credit risk provides an important avenue for further research.

[34]See "Corporate America sits on its cash," *Financial Times*, 2008/09/24.

Appendix A: Proofs of Propositions 1 to 3

Proof of Proposition 1. Define function $m(I^*, \delta)$, where I^* is the optimal investment level from the first-order condition (10), as

$$m(I^*, \delta) = f'(I^*) - \frac{1 + (1-\tau)f(I^*)h(\psi_B)}{1 + \tau(1-\tau)f(I^*)h(\psi_B)}. \tag{A1}$$

Part 1. Because $c^* = c_0 - I^*$,

$$\frac{dc^*}{d\delta}\frac{\partial c^*}{\partial \delta} = -\frac{\partial I^*}{\partial \delta} = -\Big(- \frac{\frac{\partial m}{\partial \delta}}{\frac{\partial m}{\partial I^*}}\Big). \tag{A2}$$

The second-order condition of optimization implies that $\frac{\partial m}{\partial I^*} \leq 0$. To see it, re-write it as

$$\frac{\partial m}{\partial I^*} = f''(I^*) - \frac{(1-\tau)^2(f'(I^*)h(\psi_B) + f(I^*)h'(\psi_B)(1 - \tau f'(I^*)))}{(1 + \tau(1-\tau)f(I^*)h(\psi_B))^2}, \tag{A3}$$

which is non-positive because $f'' < 0$, $h' > 0$, and $f'(I^*) < \frac{1}{\tau}$ (the latter holds from the first-order condition (10)). Also,

$$\frac{\partial m}{\partial \delta} = -\frac{(1-\tau)^2 f(I^*)h'(\psi_B)\frac{\partial \psi_B}{\partial \delta}}{(1 + \tau(1-\tau)f(I^*)h(\psi_B))^2} > 0, \tag{A4}$$

because $\frac{\partial \psi_B}{\partial \delta} = -1$. Therefore, $\frac{\partial c^*}{\partial \delta} \leq 0$.

Part 2. From definitions of D and s (Equations (6) and (7)), it follows that

$$\frac{\partial s}{\partial \delta} = -\frac{B}{D^2}\frac{\partial D}{\partial \delta} = -\frac{B}{D^2}(G(\psi_B) + g(\psi_B)\tau f(I^*)), \tag{A5}$$

and

$$\frac{\partial s}{\partial c^*} = -\frac{B}{D^2}\frac{\partial D}{\partial c^*} = -\frac{B}{D^2}(G(\psi_B) + g(\psi_B)\tau f(I^*) - \tau^2 f(I^*)f'(I^*)g(\psi_B)). \tag{A6}$$

Therefore,

$$\frac{ds}{d\delta} = \frac{\partial s}{\partial \delta} + \frac{\partial s}{\partial c^*}\frac{\partial c^*}{\partial \delta} = -\frac{B}{D^2}\Big(G(\psi_B) + g(\psi_B)\tau f(I^*)\Big)\Big(1 + \frac{\partial c^*}{\partial \delta}\Big) + \frac{B}{D^2}\tau^2 f(I^*)f'(I^*)g(\psi_B)\frac{\partial c^*}{\partial \delta}. \tag{A7}$$

Because $\frac{\partial c^*}{\partial \delta} \leq 0$, for this quantity to be negative, it is sufficient to establish that $\frac{\partial c^*}{\partial \delta} > -1$. From Equation (A2)

$$\frac{\partial c^*}{\partial \delta} = -\frac{-\frac{(1-\tau)^2 f(I^*)h'(\psi_B)\frac{\partial \psi_B}{\partial \delta}}{(1+\tau(1-\tau)f(I^*)h(\psi_B))^2}}{f''(I^*) - \frac{(1-\tau)^2(f'(I^*)h(\psi_B) + f(I^*)h'(\psi_B)(1-\tau f'(I^*)))}{(1+\tau(1-\tau)f(I^*)h(\psi_B))^2}}. \tag{A8}$$

The right-hand of this equation is greater than -1 if and only if

$$Z(\tau) \equiv f''(I^*) - f'(I^*)\left(1 - \tau f'(I^*)\right)^2\left(h(\psi_B) - \tau f(I^*)h'(\psi_B)\right) < 0. \tag{A9}$$

Note that when $\tau = 0$,

$$Z(0) = f''(I^*) - f'(I^*)h(\psi_B) < 0. \tag{A10}$$

Because $Z(\tau)$ is continuous in τ, there exist such $\bar{\tau} > 0$ that for all $\tau < \bar{\tau}$, the condition (A9) is satisfied. □

Proof of Proposition 2. Because $\frac{\partial s}{\partial x} = 0$, it follows that

$$\frac{ds}{dx} = \frac{\partial s}{\partial c}\frac{\partial c}{\partial x}. \tag{A11}$$

In the proof of Proposition 1, we showed that

$$\frac{\partial s}{\partial c^*} = -\frac{B}{D^2}\frac{\partial D}{\partial c^*} = -\frac{B}{D^2}(G(\psi_B) + g(\psi_B)\tau f(I^*)\Big(1 - \tau f'(I^*)\Big). \tag{A12}$$

Since $f'(I^*) < \frac{1}{\tau}$, $\frac{\partial s}{\partial c^*} < 0$. Therefore, the sign of $\frac{ds}{dx}$ is the opposite of the sign of $\frac{\partial c}{\partial x}$. □

Proof of Proposition 3 is provided in the main text. □

Appendix B: Statements and proofs of discussed extensions

For simplicity, in our discussion of model extensions, we will assume that no part of time 2 cash flow is pledgeable at $t = 1$, so that $\tau = 0$.

Proposition B1. *Suppose $\tau = 0$. Then, if the hazard rate $h(\cdot)$ is non-decreasing:*

1. *Equilibrium cash reserve c^* is a non-decreasing function of debt principal B; and*
2. *Equilibrium credit spread s^* is increasing in B.*

Proof of Proposition B1 *Part 1.* Using the definition of m (see Equation (A1)) and the results contained in the proof of Proposition 1, it is sufficient to establish that $\frac{\partial m}{\partial B} < 0$. Taking the derivative and simplifying, we obtain

$$\frac{\partial m}{\partial B} = -f(I^*)h'(\psi_B)\frac{d\psi_B}{dB} = -f(I^*)h'(\psi_B) < 0, \tag{B1}$$

and therefore, $\frac{\partial c^*}{\partial B} \geq 0$.

Part 2. Using the definitions of D and s (Equations (6) and (7)),

$$\frac{\partial s}{\partial B} = \frac{1 - \frac{B}{D}\frac{\partial D}{\partial B}}{D}, \tag{B2}$$

which implies that $\frac{\partial s}{\partial B} < 0$ if and only if

$$\frac{\partial D}{\partial B} < \frac{D}{B}. \tag{B3}$$

From the definition of D,

$$\frac{\partial D}{\partial B} = 1 - G(\psi_B), \tag{B4}$$

and

$$\frac{D}{B} = 1 - G(\psi_B) + \frac{\int^{\psi_B}(c + \delta + \psi)g(\psi)d\psi}{B}, \tag{B5}$$

from which the result follows. Also,

$$\frac{\partial s}{\partial c^*} = -\frac{B}{D^2} G(\psi_B) < 0. \tag{B6}$$

We already have established that $\frac{\partial c^*}{\partial B} \geq 0$, so it follows that

$$\frac{ds}{dB} = \frac{\partial s}{\partial B} + \frac{\partial s}{\partial c^*}\frac{\partial c^*}{\partial B} < 0. \tag{B7}$$

□

Proposition B2. *The equilibrium level of cash holdings c^* is positively related to the growth option z. Credit spread s is negatively related to the growth option z only through the change in optimal cash balance.*

Proof of Proposition B2. Similar to the proof of Proposition 1, define $m(I^*, z)$ as

$$m(I^*, z) = f'(I) - \frac{1 + [(1-\tau)f(I) + z]\, h(\psi_B)}{1 + \tau\,[(1-\tau)f(I) + z]\, h(\psi_B)}.$$

It is easy to show (as in Proposition 1) that the second-order condition implies $\frac{\partial m}{\partial I^*} < 0$. Now,

$$\frac{\partial m}{\partial z} = -\frac{1}{(1 + \tau\,[(1-\tau)f(I) + z]\, h(\psi_B))^2} h^2(\psi_B)(1-\tau) < 0, \tag{B8}$$

and therefore, $\frac{\partial c}{\partial z} > 0$. The result on credit spread follows because $\frac{\partial s}{\partial z} = 0$ by assumption, and $\frac{\partial s}{\partial c} < 0$ (for the reasons established in (A5)). □

Proposition B3. *The equilibrium level of cash holdings c^* is positively related to the agency parameter $\frac{\gamma}{\theta}$. Credit spread s is negatively related to the agency parameter $\frac{\gamma}{\theta}$ only through the change in optimal cash balance.*

Proof of Proposition B3. The first-order condition of the manager's objective function (14) can be written as

$$\frac{\partial M}{\partial I} = \theta \int_{\psi_B}^{\infty} [-1 + f'(I)] g(\psi) d\delta_1 - [-I + (c_0 + \delta + \psi_B - B) + f(I)] g(\psi_B) \frac{\partial \psi_B}{\partial I} - \gamma g(\psi_B) \frac{\partial \psi_B}{\partial I} = 0, \tag{B9}$$

which results in a condition identical to (13), with z replaced by $\frac{\gamma}{\theta}$. The result then follows from applying the proof of Proposition B2.□

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Table I. Regressions of bond spreads

This table reports the results of regressions of credit spreads on cash holdings and other variables. The dependent variable is the annualized bond spread in percentage points relative to a cash flow-matched portfolio of STRIPS, averaged over all outstanding straight bonds for each firm-month observation in the sample. *Cash/Assets* is cash and near-cash divided by total book assets. *Leverage* is the book value of total debt divided by the sum of the book value of debt and the market value of equity. *Asset volatility* is the annualized standard deviation of asset returns estimated by Moody's/KMV. *Log(Assets)* is the logarithm of the total book assets of the issuing firm in millions of dollars. *Maturity* is the remaining bond maturity in years on the observation date, averaged over all bonds with available spreads for each firm-month observation in the sample. The sample consists of monthly observations for non-financial U.S. firms between December 1996 and December 2003. Accounting variables and equity prices are measured at the end of the previous fiscal quarter. Regressions (1) and (4) are estimated using OLS with standard errors adjusted for firm clustering using the Huber/White estimator. Cross-sectional regressions (2) and (5) use the means of all variables for each firm. Fama-MacBeth regressions (3) and (6) are time-series averages of the coefficients from monthly cross-sectional regressions estimated over the whole period (85 months), with standard errors adjusted for serial correlation using the Newey-West procedure. Absolute values of t-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	OLS	CS	FMB	OLS	CS	FMB
	(1)	(2)	(3)	(4)	(5)	(6)
Cash/Assets	3.14**	6.27***	1.96***	2.86***	2.39*	2.75***
	(2.57)	(3.76)	(3.58)	(3.35)	(1.90)	(8.57)
Leverage				6.19***	5.56***	6.29***
				(14.53)	(17.82)	(10.44)
Asset volatility				9.92***	9.23***	10.0***
				(8.53)	(7.94)	(12.03)
Log(Assets)				-0.25***	-0.22***	-0.300***
				(4.84)	(4.28)	(9.94)
Maturity				0.00	0.00	-0.001
				(0.72)	(0.38)	(0.12)
Const.	1.82***	1.78***	2.01***	-0.39	10.59	0.530***
	(26.29)	(16.59)	(12.14)	(0.67)	(0.29)	(3.59)
Monthly dummies	No	No		Yes	Yes	
N	24,258	24,258	24,258	21,110	21,110	21,110
Adj. R^2	0.01	0.03	0.01	0.51	0.80	0.45
No. of months			85			85

Table II. Regressions of spreads by rating

This table reports the results of OLS regressions of credit spreads by rating group. The dependent variable is the annualized bond spread in percentage points relative to a cash flow-matched portfolio of STRIPS, averaged over all outstanding straight bonds for each firm-month observation in the sample. *Cash/Assets* is cash and near-cash divided by total book assets. Firm-month observations for different firms are grouped by firms' senior unsecured rating as of the observation date. *Leverage* is the book value of total debt divided by the sum of the book value of debt and the market value of equity. *Asset volatility* is the annualized standard deviation of asset returns estimated by Moody's/KMV. *Log(Assets)* is the logarithm of the total book assets of the issuing firm in millions of dollars. *Maturity* is the remaining bond maturity in years on the observation date, averaged over all bonds with available spreads for each firm-month observation in the sample. The sample consists of monthly observations for non-financial U.S. firms between December 1996 and December 2003. Accounting variables and equity prices are measured at the end of the previous fiscal quarter. Standard errors are adjusted for firm clustering using the Huber/White estimator. Absolute values of t-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	AAA–AA (1)	A (2)	BBB (3)	BB (4)	B–CCC (5)
Cash/Assets	0.23	0.90	2.78**	4.17**	5.59
	(0.65)	(1.49)	(2.40)	(2.15)	(1.54)
Leverage	1.00***	1.38***	2.87***	6.99***	14.00***
	(3.26)	(4.53)	(9.05)	(7.64)	(6.56)
Asset volatility	0.21	1.97***	4.32***	8.17***	9.29**
	(0.30)	(4.33)	(5.58)	(5.37)	(2.34)
Log(Assets)	-0.02	-0.11***	-0.20***	0.02	-0.74*
	(1.43)	(5.00)	(4.40)	(0.15)	(2.00)
Maturity	0.01***	0.01***	0.01**	0.04	0.06
	(5.25)	(5.61)	(2.07)	(1.09)	(1.00)
Const.	0.46*	0.93***	0.77	-2.97***	-1.46
	(1.86)	(4.77)	(1.61)	(2.66)	(0.48)
Monthly dummies	Yes	Yes	Yes	Yes	Yes
N	1,803	7,067	8,819	2,504	898
Adj. R^2	0.74	0.59	0.44	0.48	0.56

Table III. Sample size and industry composition

This table shows the number of unique firms, as well as spreads (bond-months), firm-months, and firm quarters in the sample, by rating and by broad industry group. For firms whose rating changes during the sample period, the 'Firms' column of Panel A reports the senior unsecured rating as of the first date the firm appears in the data set. For other columns, ratings are as of the observation date. The bond sample consists of straight fixed-coupon bonds without embedded optionalities, with remaining maturity between one and thirty years, issued by non-financial U.S. firms. Spreads on these bonds are observed at monthly intervals between December 1996 and December 2003.

	Firms	Spreads	Firm-months	Firm-quarters
Panel A: Observations by rating				
AAA	8	1,224	449	155
AA	36	6,090	1,672	575
A	159	30,627	8,029	2,762
BBB	191	33,281	10,448	3,606
BB	60	8,364	2,859	1,013
B	25	2,444	989	357
CCC	1	646	148	57
Panel B: Observations by industry				
Consumer goods	70	14,167	3,748	1,304
Manufacturing	93	12,505	4,528	1,570
High tech & Telecoms	53	8,884	2,378	829
Wholesale & Retail trade	61	12,478	3,537	1,221
Oil & Chemicals	58	9,324	3,220	1,108
Utilities & Transportation	81	14,439	4,012	1,392
Other industries	64	10,879	3,171	1,101
Total	480	82,676	24,594	8,525

Table IV. Descriptive statistics

This table reports summary statistics on credit spreads and other variables by firm-month observation. Panel A reports the annualized bond spread in percentage points, averaged over all outstanding straight bonds for each firm-month observation in the sample, by the firm's senior unsecured rating as of the observation date. The benchmark risk-free yield is the yield on a cash flow-matched portfolio of STRIPS. STRIPS yields are observed as of the observation date and are linearly approximated for dates between the maturity dates of two STRIPS. Panel B reports firm characteristics for the sample of firm-months, as of the end of the previous fiscal quarter. *Total assets* is the total book assets of the issuing firm in billions of dollars. *Cash/Assets* is cash and near-cash divided by total book assets. *Cash/Net assets* is cash and near-cash divided by total book assets minus cash. *Leverage* is the book value of total debt divided by the sum of the book value of debt and the market value of equity. *Asset volatility* is the annualized standard deviation of asset returns estimated by Moody's/KMV. *Maturity* is the remaining bond maturity in years on the observation date, averaged over all bonds with available spreads for each firm-month observation in the sample. The sample consists of monthly observations for non-financial U.S. firms between December 1996 and December 2003.

	Mean	Median	25%	75%	St. dev.	N
Panel A: Statistics on credit spreads						
All	196.7	135.4	87.6	215.9	203.4	24,594
AAA	79.5	74.1	57.5	95.4	27.3	449
AA	78.4	70.5	54.3	93.6	35.9	1,672
A	114.9	100.7	73.0	142.1	60.0	8,029
BBB	181.1	152.4	104.0	210.1	125.0	10,448
BB	384.6	322.9	222.0	455.7	269.9	2,859
B	635.8	537.5	361.2	792.5	372.7	989
CCC	859.3	737.2	470.0	1,211.9	489.1	148
Panel B: Statistics on independent variables						
Total assets, $Bn	14.72	6.46	2.95	16.47	33.02	24,315
Cash/Assets	0.039	0.020	0.009	0.048	0.051	24,258
Cash/Net assets	0.044	0.020	0.009	0.051	0.066	24,258
Leverage	0.326	0.298	0.164	0.461	0.198	23,021
Asset volatility	0.188	0.179	0.146	0.217	0.063	21,962
Bond maturity	8.99	7.25	4.55	12.14	6.04	24,496

Table V. Credit risk controls and exogenous variations in cash

The dependent variable is the annualized bond spread in percentage points relative to a cash flow-matched portfolio of STRIPS, averaged over all outstanding straight bonds for each firm-month observation in the sample. Regressions (1) to (5) are estimated using OLS. Regressions (6) to (10) are instrumental variable regressions that use the *R&D/Sales* ratio of the median firm in the same three-digit SIC industry each year, as well as the *Agency term*, defined as the ratio of the CEO's salary and bonus to the value of her equity holdings and options in the firm, as instruments for *Cash/Assets*. *Leverage* is the book value of total debt divided by the sum of the book value of debt and the market value of equity. *Asset volatility* is the annualized standard deviation of asset returns estimated by Moody's/KMV. Regressions (3)–(5) and (8)–(10) include a set of dummy variables for rating gradations from AA to CCC, by notch. The sample consists of monthly observations for non-financial U.S. firms between December 1996 and December 2003. Standard errors are adjusted for firm clustering using the Huber/White estimator. Absolute values of t-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	OLS					IV				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Cash/Assets	3.14**	2.39***	-0.08	0.70	0.34	-6.31***	-4.18**	-6.20***	-4.29**	-3.57***
	(2.57)	(2.62)	(0.10)	(0.90)	(0.50)	(3.06)	(2.27)	(3.07)	(2.44)	(3.67)
Leverage		6.94***	4.48***	3.38***			6.32***	4.27***	3.15***	
		(16.75)	(13.09)	(9.44)			(12.37)	(11.10)	(7.90)	
Asset volatility		13.42***	9.45***	4.92***			14.42***	11.37***	6.33***	
		(13.52)	(12.55)	(5.76)			(12.05)	(12.78)	(6.08)	
Log(Assets)				-0.16***	-0.34***				-0.15***	-0.30***
				(3.74)	(7.96)				(3.17)	(6.71)
Maturity				0.01***	0.00				0.01***	0.01
				(3.23)	(0.25)				(3.28)	(1.40)
EDF					0.63***					0.70***
					(16.31)					(14.36)
Monthly dummies	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Rating dummies	No	No	Yes	Yes	No	No	No	Yes	Yes	No
Const.	1.82***	-2.94***	-1.35***	0.27	3.69***	1.99***	-2.72***	-1.10***	0.50	3.43***
	(26.29)	(11.33)	(6.01)	(0.51)	(9.69)	(18.59)	(9.09)	(4.94)	(0.94)	(8.81)
N	24,258	21,110	21,110	21,110	21,875	17,703	16,497	16,497	16,497	16,990
Adj. R^2	0.01	0.46	0.57	0.63	0.63	0.01	0.39	0.52	0.59	0.63

Table VI. Robustness and extensions

The dependent variable is the annualized bond spread in percentage points relative to a cash flow-matched portfolio of STRIPS, averaged over all outstanding straight bonds for each firm-month observation in the sample. Odd-numbered regressions are estimated using OLS. Even-numbered regressions are instrumental variable regressions that use the *R&D/Sales* ratio of the median firm in the same three-digit SIC industry each year, as well as the *Agency term*, defined as the ratio of the CEO's salary and bonus to the value of her equity holdings and options in the firm, as instruments for *Cash/Assets*. *Leverage* is the book value of total debt divided by the sum of the book value of debt and the market value of equity. *Asset volatility* is the annualized standard deviation of asset returns estimated by Moody's/KMV. *Current ratio* is the ratio of current assets to current liabilities. *Cash covenant* is a dummy variable that equals 1 if the firm's bank debt covenants restrict liquidity levels. Regressions (5) and (6) include a set of dummy variables for the 49 Fama-French industries. Except for regression (7), the sample consists of monthly observations for non-financial U.S. firms between December 1996 and December 2003. In regression (7), the sample consists of financial U.S. firms over the same period. Standard errors are adjusted for firm clustering using the Huber/White estimator. Absolute values of t-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	Cash needs		Covenants		Industry		Financials
	OLS	IV	OLS	IV	OLS	IV	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cash/Net assets	2.72***	-5.58***	2.86***	-4.38**	2.90***	-3.96	-1.34***
	(2.99)	(2.91)	(3.33)	(2.44)	(3.37)	(1.11)	(3.45)
Leverage	6.40***	3.16***	6.18***	3.18***	6.46***	3.47***	2.76***
	(14.46)	(7.66)	(14.29)	(7.94)	(14.76)	(8.42)	(4.84)
Asset volatility	9.74***	6.16***	9.92***	6.44***	8.47***	5.80***	6.46***
	(8.35)	(6.12)	(8.46)	(6.08)	(7.57)	(4.89)	(4.09)
Log(Assets)	-0.23***	-0.11**	-0.25***	-0.15***	-0.26***	-0.11**	-0.29***
	(4.17)	(2.13)	(4.82)	(3.21)	(4.82)	(2.42)	(5.75)
Maturity	0.00	0.01***	0.00	0.01***	0.01	0.02***	0.04***
	(0.59)	(2.92)	(0.72)	(3.41)	(1.14)	(4.11)	(3.13)
Current ratio	0.04	0.21***					
	(0.54)	(2.69)					
Cash covenant			0.01	-0.44			
			(0.04)	(1.31)			
Industry dummies					Yes	Yes	
Rating dummies	No	Yes	No	Yes	No	Yes	No
Monthly dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
const.	-0.58	0.02	-0.39	0.50	-0.02	0.49	1.50***
	(0.90)	(0.03)	(0.67)	(0.93)	(0.03)	(0.93)	(3.09)
N	20,178	15,864	21,110	16,497	20,923	16,420	5,384
Adj. R^2	0.52	0.59	0.51	0.59	0.55	0.62	0.45

Table VII. Measures of liquidity in default-predicting models

This table reports quarterly logit regressions of public bond defaults. In regressions (1) and (2), the dependent variable equals 1 if the firm defaults within the following fiscal quarter, and 0 otherwise. In regressions (3) and (4), the dependent variable equals 1 if the firm defaults in 12 to 15 months, and 0 otherwise. In regressions (5) and (6), the dependent variable equals 1 if the firm defaults in 36 to 39 months, and 0 otherwise. WC is working capital, TA is the book value of total assets, RE is retained earnings, ME is the market value of equity, TL is the book value of total liabilities, S is sales, CA is current assets, CL is current liabilities, and NI is net income. The sample consists of firm-quarter observations for non-financial firms in the sample between December 1996 and December 2003, excluding post-default. Standard errors are adjusted for firm clustering using the Huber/White estimator. Absolute values of t-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	1 quarter		1 year		3 years	
	(1)	(2)	(3)	(4)	(5)	(6)
			Altman's (1968) Z-score			
WC/TA	-1.66***		2.01***		3.87***	
	(3.72)		(3.74)		(5.51)	
Cash/TA		-0.84		2.21**		5.01***
		(0.47)		(2.50)		(7.03)
(WC-Cash)/TA		-1.69***		1.91***		2.87***
		(3.73)		(2.89)		(2.97)
RE/TA	-0.12	-0.10	-0.30**	-0.28*	-0.50***	-0.37***
	(1.13)	(0.99)	(2.11)	(1.86)	(4.28)	(2.72)
EBIT/TA	-2.52**	-2.45**	-1.93***	-1.90***	-0.88	-0.54
	(2.10)	(2.02)	(4.38)	(4.20)	(1.48)	(0.73)
ME/TL	-5.22**	-5.19**	-1.38***	-1.39***	-0.28	-0.34
	(2.51)	(2.49)	(2.62)	(2.63)	(1.44)	(1.59)
S/TA	0.19	0.22	-2.67***	-2.60**	-0.80	-0.28
	(0.39)	(0.47)	(2.77)	(2.53)	(0.96)	(0.39)
Const.	-2.78***	-2.83***	-3.49***	-3.51***	-4.91***	-5.01***
	(6.23)	(5.79)	(10.89)	(10.42)	(17.24)	(18.38)
N	17,950	17,945	17,950	17,945	17,950	17,945
Adj R^2	0.32	0.32	0.09	0.09	0.045	0.049
			Zmijewski's (1984) model			
CA/CL	-0.05		0.03*		0.08***	
	(0.76)		(1.68)		(4.00)	
Cash/CL		-0.21		0.04*		0.08***
		(1.28)		(1.84)		(3.86)
(CA-Cash)/CL		-0.00		0.02		0.11
		(0.06)		(0.32)		(1.42)
NI/TA	-4.33***	-4.33***	-1.71***	-1.73***	-0.00	0.24
	(4.06)	(4.04)	(3.15)	(3.12)	(0.00)	(0.25)
TL/TA	1.71***	1.71***	1.03***	1.03***	1.16***	1.17***
	(3.38)	(3.37)	(4.61)	(4.59)	(4.53)	(4.59)
Const.	-6.36***	-6.35***	-5.79***	-5.77***	-6.09***	-6.13***
	(15.51)	(15.68)	(30.02)	(28.02)	(27.83)	(25.62)
N	21,627	21,568	21,627	21,568	21,627	21,568
Adj R^2	0.11	0.11	0.019	0.019	0.022	0.022

Table VIII. Regressions of changes in cash holdings

This table reports the results of regressions of annual changes in cash holdings, defined as $(Cash_t - Cash_{t-1})/Assets_{t-1}$. Regressions in columns (1) and (2) are estimated for the whole sample. Regressions in columns (3) to (7) group firms by their senior unsecured rating at the beginning of the period (at time $t-1$). *Rating change* is the difference in notches between the firm's ratings at the end and the beginning of the year, where AAA is coded 1, AA+ as 2, AA as 3, etc. *Cash flow* is earnings before depreciation and amortization net of interest, less taxes and common dividends. *Market to book* is the book value of assets less the book value of equity plus the market value of equity, divided by book assets. *Log(Assets)* is the logarithm of the total book assets in millions of dollars. *Expenditures* is the capital expenditures over total book assets. *Acquisitions* is acquisitions spendings over total book assets. *NWC* is the current assets net of cash minus current liabilities. *Short-term debt* is debt in current liabilities over total book assets. All these variables are measured at year-end t. The sample consists of all annual Compustat observations, excluding firms with SIC codes between 6000 and 6999. Standard errors are adjusted for firm clustering using the Huber/White estimator. Absolute values of t-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	All firms		AAA-AA	A	BBB	BB	B-CCC
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rating change	0.10**	0.11**	-0.03	0.22	0.35***	0.32***	0.06
	(2.38)	(2.51)	(0.08)	(1.13)	(3.25)	(3.17)	(0.98)
Cash flow	11.30***	14.91***	18.99*	12.42***	9.68***	19.37***	15.61***
	(10.14)	(11.32)	(1.91)	(3.75)	(3.23)	(5.26)	(9.21)
Market to book	0.16	0.45***	0.32	0.36*	0.56***	0.62***	0.72***
	(1.31)	(4.39)	(1.21)	(1.75)	(4.25)	(2.84)	(2.83)
Firm size	0.17***	0.10***	0.27	0.04	0.12**	0.09	0.56***
	(5.37)	(2.83)	(1.28)	(0.83)	(2.52)	(1.54)	(5.68)
Expenditures		-6.64***	-11.58	-8.94**	-5.35***	-9.55***	-5.77***
		(6.17)	(1.63)	(2.39)	(3.00)	(5.19)	(3.54)
Acquisitions		-7.93***	-7.34	-4.30**	-8.56***	-8.24***	-9.25***
		(8.39)	(0.81)	(2.01)	(5.06)	(6.04)	(5.25)
Δ NWC		-12.18***	-35.65	-15.67***	-8.71***	-13.27***	-12.28***
		(9.91)	(1.08)	(4.32)	(3.21)	(5.48)	(6.91)
Δ Short debt		0.00**	0.00	0.00*	0.00**	0.00***	0.00***
		(2.48)	(0.78)	(1.71)	(2.01)	(2.84)	(2.96)
Const.	-1.89***	-1.20***	-3.08	-0.89	-1.44***	-1.37**	-4.48***
	(6.19)	(4.00)	(1.15)	(1.35)	(2.99)	(2.27)	(5.96)
N.	19,227	17,038	355	1,976	4,312	4,065	6,175
R^2	0.03	0.06	0.08	0.06	0.04	0.09	0.07

Figure 1. Cash holdings by rating

This graph shows the mean and median cash holdings of firms by their senior unsecured rating. Ratings are reported using the S&P convention, by notch (AAA, AA+, AA, AA-, etc.).

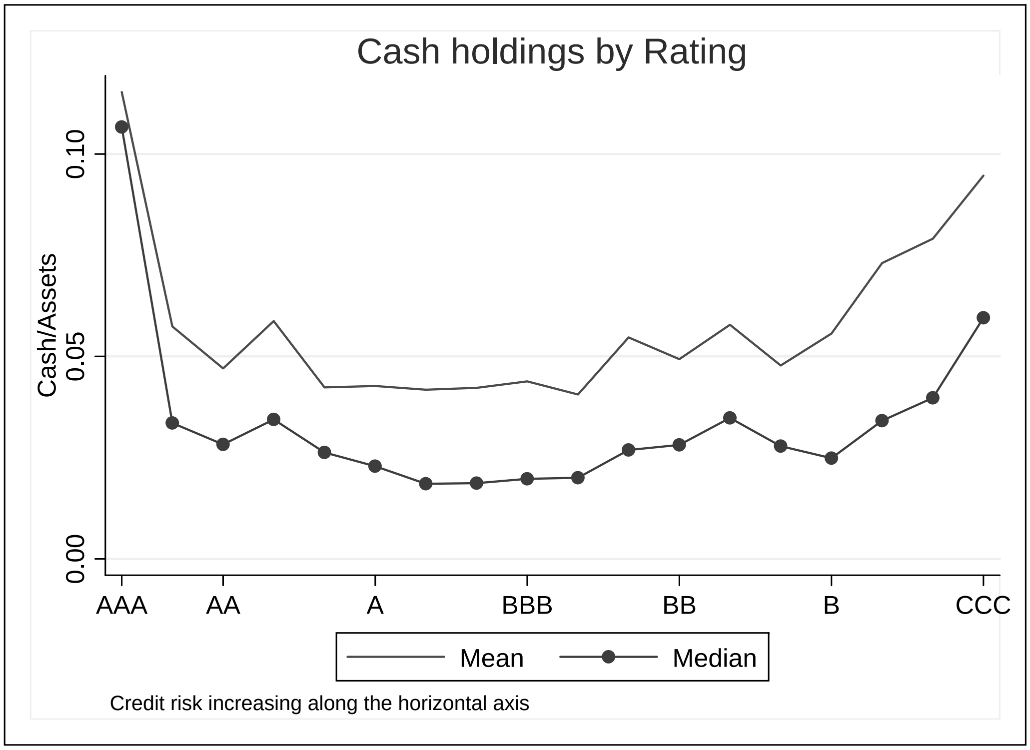

Figure 2. Cash holdings by interest coverage

This graph shows the mean and median cash holdings of firms by deciles of the *interest coverage ratio*, calculated as EBITDA divided by interest expense.

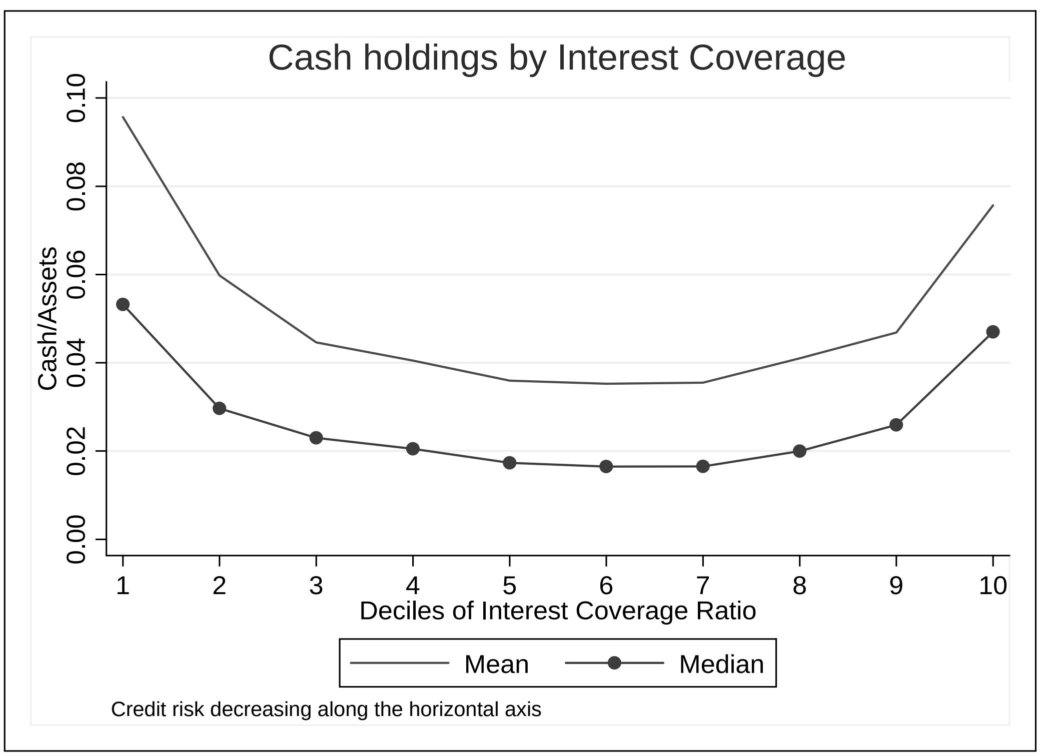

Figure 3. Timeline of the model