

# CASH HOLDINGS AND CREDIT RISK

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## **Abstract**

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 spurious positive correlation between cash and spreads. By contrast, spreads are negatively related to the “exogenous” component of cash holdings independent of credit risk factors. Similarly, although firms with higher cash reserves are less likely to default over short horizons, longer term endogenously determined liquidity may be *positively* related to the probability of default. Our empirical analysis confirms these predictions, suggesting that endogenous 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 defaults on its debt payments is the firm's holdings of cash and other liquid assets. This observation may itself feature prominently in the levered firm's decision to retain a cash reserve, which 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 our understanding of the role of liquidity 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 are intuitively expected to be "safer." We explain this puzzling finding in a model of a levered firm that allows for 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. At the same time, spreads are negatively correlated with exogenous variations in cash holdings that are 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 suggested by the model. We also elicit the role of liquidity in empirical default-predicting models, once again emphasizing the crucial role that endogeneously determined precautionary savings play in the link between cash and credit risk.

Credit risk and corporate debt pricing have been a focus of much debate for many years. Yet, even though the holdings of cash and other liquid assets are commonly thought to affect default, few of these studies explicitly consider the role of cash. Starting with Merton (1974) and Black and Cox (1976), most structural models assume that the firm defaults when the market value of its assets falls below some threshold, such as that corresponding to zero equity price. 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 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), Collin-Dufresne and Goldstein (2001), and others have extended the basic setup along many dimensions, most of them still leave no room for an optimal cash policy in debt pricing or capital structure decision.<sup>1</sup> It is therefore unsurprising that empirical studies of credit spreads or corporate bond returns do not look at the role of cash holdings (see Collin-Dufresne, Goldstein, and Martin (2001), Eom, Helwege, and Huang (2004), and Schaefer and Strebulaev (2007)).

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<sup>1</sup>Prominent exceptions include recently developed models by Acharya, Huang, Subrahmanyam and Sundaram (2006), Anderson and Carverhill (2007), and Asvanunt, Broadie, and Sundaresan (2007), which allow for optimal cash holdings in the presence of costly external financing.

In contrast to the assumption of frictionless financing, corporate finance research argues that firms may have difficulties raising external funds. This makes cash holdings relevant for constrained firms, and gives rise to an optimal cash policy that depends on various factors, such as the firm's current and future investment opportunities, although the role of the firm's capital structure and credit risk in determining its optimal cash policy has not been explored.<sup>2</sup>

Intuition suggests that firms with higher liquid assets should have unambiguously lower credit spreads. Firstly, in the presence of financing frictions higher cash holdings reduce the probability of a cash shortage forcing the firm into default despite fundamentally sound business (Davydenko (2007)). This view explains why empirical bankruptcy-predicting models (e.g. Altman (1968), Ohlson (1974), Zmijewski (1984)) usually include some measures of balance sheet liquidity (although, as we discuss below, not the mixed evidence regarding the ability of these variables to predict default in such models). Secondly, conditional on default, creditors' recovery rates are higher for firms with higher current assets (Acharya, Bharath, and Srinivasan (2007)), as the value of such assets is better preserved in liquidation. With lower probabilities of default and higher recovery rates conditional on default, debt of firms with substantial cash reserves should be safer and bear lower credit spreads.

We find that, although 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. 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 adjustment in cash holdings can result in a spurious positive correlation between credit spreads and equilibrium cash levels, as both increase in the underlying credit risk. If the probability of default were to rise for exogenous reasons, the precautionary endogenous increase in cash holdings could decrease the expected loss from default and dampen the adverse effect that the deterioration of credit has on debt prices.

To illustrate the link between cash and credit risk, we construct a model of a levered firm with endogenous investment and cash policy. Initially endowed with some cash reserve, the firm chooses how much of it to invest in a profitable long-term project, and how much to retain as a cash buffer against a possible future

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<sup>2</sup>Studies of corporate cash holdings include Kim, Mauer, and Sherman (1998), Opler, Pinkowitz, Stulz, and Williamson (1999), Almeida, Campello, and Weisbach (2004), Bates, Kahle, and Stulz (2006), Harford, Mansi, and Maxwell (2006), Dittmar and Mahrt-Smith (2007), and Acharya, Almeida, and Campello (2007).

cash flow shortfall at the time when its debt becomes due. Future cash flows cannot be fully pledged as collateral, implying the existence of market frictions. At the heart of the model is the idea that at least some cash flows are contingent on the firm's ability to meet its debt obligations either from cash flows or from retained cash holdings. Hence, the firm faces a trade-off between investing available cash in projects that will generate cash flows in the future only if the interim debt payments are made, and retaining cash in order to reduce the likelihood of default, increasing the probability that future benefits from the investments will be realized. This setting allows us to analyze the effect of various credit risk factors on its cash reserves, and the link between cash, credit spreads, and the probability of default.

The model predicts that optimal cash holdings increase in 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 level of debt increases exogenously, the probability of default rises as a direct result, causing 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 debt increase is to decrease spreads due to higher cash levels. We show that the direct effect typically dominates. As a result, riskier firms have both higher optimal cash reserves and higher credit spreads, which causes the two to be positively correlated in cross-section. At the same time, "exogenous" variations in cash holdings that are unrelated to credit risk factors are *negatively* correlated with spreads, as they reduce the probability of default and increase creditors' recovery conditional on default, as the simple intuition suggests they should. The model identifies future long-term investment opportunities and managerial self-interest as potential sources of exogenous variations in cash. Taking these predictions to the data, we find that the positive correlation between cash and spreads is reduced in the presence of better controls for credit risk factors, and turns negative when we use instrumental variable regressions to identify exogenous variations in cash. Our evidence confirms that the positive correlation between cash and spreads in cross-sectional regressions is spurious rather than causal, arising from the dependence of both variables on firm-specific credit risk factors.

We also clarify the role of liquidity as a predictor of default. Since Altman's (1968)  $z$ -score model, most empirical studies of default have used some 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.<sup>3</sup> We argue that the endogeneity of liquid asset holdings once again plays a central role in this setting. Our model shows that a higher cash reserve reduces

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<sup>3</sup>In their classic papers, Ohlson (1980) and Zmijewski (1984) point out that liquidity proxies do not work as expected, but nevertheless retain them in their models. Later studies by Begley *et al.* (1996), Shumway (2001), and Hillegeist *et al.* (2004) also find that liquidity does not appear to reduce the probability of default.

the probability of default in the short run, but may increase it in the long run, as the constrained firm that reduces investment in order to conserve cash for immediate debt service increases the probability of a long-term cash flow shortfall. Consistent with these predictions, we find that, although liquidity is negatively associated with the probability of default over very short horizons, for longer prediction horizons which are the focus of much of the research in this area, the endogenously determined liquidity in our tests is *positively* associated with default.

Our findings suggest that corporate liquidity may be an important factor that affects credit risk. As discussed previously, cash is considered irrelevant in most structural credit risk models. Papers like Kim, Ramaswamy, and Sundaresan (1993), Anderson and Sundaresan (1996), and Ross (2005) model default as driven by cash flow shortages rather than low asset values, but typically assume that the firm's cash holdings are exogenous. Empirical models of default such as Altman (1968), Ohlson (1974), and Zmijewski (1984), allow liquidity to play a role, but also treat it as given. Our paper shows that recognizing the endogenous nature of cash reserves is crucial for understanding the relationship between liquidity and credit risk. To model credit risk accurately, it may be necessary to keep track of the firm's optimal cash holdings in the presence of financing costs in a dynamic setting, as suggested recently by Acharya et al. (2006), Anderson and Carverhill (2007), and Asvanunt, Broadie, and Sundaresan (2007). We find that both cash and leverage are positively related to spreads, which implies that cash cannot be treated as negative debt in credit risk studies.<sup>4</sup> Finally, our finding that default risk may affect cash holdings for levered firms contributes to the growing literature that studies the determinants of corporate cash holdings.

The remainder of the paper is organized as follows. Section I documents a positive correlation between cash holdings and credit spreads. Section II presents the model. Section III describes our data. Section IV reports further regression analysis of spreads, cash holdings, and the probability of default. Section V summarizes our findings and provides a discussion of their implications. Proofs and model extensions are given 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 2003. We measure credit

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<sup>4</sup>For another precautionary rationale for why cash may not be equivalent to negative debt, see Acharya, Almeida and Campello (2004). They focus on a hedging motive for constrained firms in substituting between cash and debt reductions, that is, to equalize future marginal products of investment.

spreads relative to a cash-flow matched portfolio of U.S. Treasury securities. Table I presents the results of regressions of spreads on cash with and without controls for standard credit risk factors used in extant empirical studies of spreads, such as leverage, volatility, debt maturity, size, and time dummies that control for common movements in spreads.<sup>5</sup> Each specification is estimated using three methodologies: OLS, cross-sectional regressions that use means of each variable for each firm (CS), and Fama-MacBeth regressions (FMB).

The effect of control variables is in line with other studies of spreads (e.g. Davydenko and Strebulaev (2007)). More levered and more volatile firms and small firms are riskier, and consequently have higher credit spreads. Our focus, however, is on the relationship between spreads and cash, which we measure relative to the firm's total assets. Table I shows that both in univariate regressions (columns (1) to (3)) as well as in the presence of standard credit risk controls used in the literature, the correlation between credit spreads and cash holdings is positive and strongly statistically significant. The economic significance of the implied effect is also considerable: in most regressions, a one standard deviation increase in *cash/assets* corresponds to an increase in the bond spread of about 20 basis points.

[TABLE I HERE]

This evidence is counter-intuitive and puzzling. Indeed, given that 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)), 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 spreads is a robust phenomenon in the data, and is also observed for other bond data sets and time periods. Subsection IV.A shows that it is unaffected by controls for industry effects, covenants, and liquidity needs.

One 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 riskiest firms for which such a possibility looms large. Hence, the correlation between cash and spreads should be more negative for riskier firms, especially given that for such firms credit risk explains more of the observed spread (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 not only is the correlation positive for all rating groups, but it also increases

<sup>5</sup>We defer the detailed discussion of the dataset and the description of independent variables until Section III.

monotonically as the rating deteriorates.<sup>6</sup> In these regressions of spreads, the cash coefficient is 17 times as high for the lowest ratings (B-CCC) as for A-rated bonds. How can this evidence be explained?

[TABLE II HERE]

We suggest that these findings are due to the effect that the possibility of default has on the levered firm's optimal cash policy. If external financing in distress is restricted or unavailable, and if default is costly, 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 end up having not only higher credit spreads, but also higher optimally chosen cash holdings, resulting in a spurious positive correlation between cash and spreads. As a result, the treatment of cash as an exogenous parameter in studies of credit risk may be inadequate and yield counterfactual predictions.

The potentially ambiguous nature of the spread-cash relationship is illustrated in Figure 1, which summarizes cash holdings of firms in different rating groups. It shows that cash holdings are roughly U-shaped in the credit rating. Safe AAA and AA firms have higher than average cash holdings, low debt levels, and are in all likelihood unconcerned about credit risk. Indeed, their high balance sheet liquidity and low net leverage are likely to be important reasons why the rating agencies rate them so highly in the first place, consistent with the common wisdom that higher cash holdings make the firm safer. 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 the precautionary motive for saving cash by levered firms faced with a possibility of default. Despite their high cash reserves, these firms are still riskier than A- or BBB-rated firms due to the much higher levels of debt. Indeed, even relatively high cash holdings of 5.8% of net assets for B-rated firms pale into insignificance next to their leverage ratios in excess of 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.

[FIGURE 1 HERE]

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. In the model, both debt yields and equilibrium cash holdings increase in credit risk factors. We then present evidence that suggests that the

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<sup>6</sup>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.

positive correlation between cash and spreads is spurious rather than 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. Benchmark model setup

This section develops a model of the firm's endogenous cash policy with investment uncertainty and credit risk under costly outside financing. Cash policy is the firm's instrument in mitigating financing constraints in the presence of required debt payments. Our goal is to understand the relationship between the optimal cash levels retained by the firm and the pricing of corporate debt. Since cash is arguably a more flexible instrument than debt, in the model we first solve for the optimal cash policy given a particular level of debt, and study the effect of changes in debt levels and other firm characteristics on cash holdings.<sup>7</sup> One reason why debt is more difficult to adjust than cash is the presence of fixed transactions costs of refinancing. Dynamic capital structure studies (Fisher, Heinkel, and Zechner (1989), Goldstein, Ju, and Leland (2001), Strebulaev (2007)) show that waiting times to restructure debt optimally could be very large even for small transaction costs, an implication supported by recent empirical evidence (Leary and Roberts (2005)). In contrast to debt, it is easier to increase cash reserves by retaining the current period's cash flow within the firm instead of investing it or paying it out to shareholders.<sup>8</sup>

The model features a firm in a three-period investment economy. At date 0 the firm is endowed with some initial cash reserve, which can be invested or retained as a buffer against future shortfall. It also has assets in place of  $K$  units, which can be thought of as the value of book assets or the initial fixed cost of investment. These existing assets yield a cash flow in each period  $t = 0, 1, 2$ . We denote the period- $t$  cash flow as  $\delta_t$ . An important feature of the model is that the intermediate cash flow from existing assets,  $\delta_1$ , is stochastic and unknown at date 0. We assume that information is symmetric, so that neither investors nor managers know the future profitability of the firm. The probability distribution of  $\delta_1$  is described by the density function  $g(\delta_1)$ , which is common knowledge. (We discuss the assumptions regarding the properties of this distribution in detail below). As can be easily shown, particular assumptions on the current cash

<sup>7</sup>The assumption of an exogenous debt level is made for simplicity. As discussed in Subsection II.E, relaxing this assumption may strengthen or weaken our conclusions, depending on the correlation of optimal leverage with other firm characteristics.

<sup>8</sup>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.

flow,  $\delta_0$ , and on the cash flow in the last period,  $\delta_2$ , are unimportant, and therefore without loss of generality we assume them to be zero.

At date 0, the firm is endowed with an amount of cash  $c_0$ , and can divide this cash between investment and retained cash holdings. It also has a profitable investment opportunity, and must choose the level of investment  $I$ . This investment produces a certain cash flow at date 2 described by a standard increasing concave production function  $f(I)$ .<sup>9</sup> The firm has outstanding debt at date 0, with the payment of principal  $B$  due at date 1. The book value of debt  $B$  is fixed and pre-determined, a scenario consistent, for example, with fixed costs of issuing debt. To pay its debt obligation, the firm can use its income stream at date 1 and cash saved at date 0. In other words, future time-2 cash flows from the long-term investment cannot be collateralized at  $t = 1$ . This implies that existing cash and that generated by the current investment are not perfect time substitutes. (We relax this assumption in Section B.2 by introducing the possibility of partial pledgeability without affecting the economic insights). Furthermore, the liquidation value of assets at date 1 is assumed to be zero. Thus, investment is lost if the firm defaults on its debt, implying that default is costly. Finally, we assume for simplicity that at date 0 the firm has exhausted its debt capacity, and therefore it must use the current cash flow and existing cash balances to finance its investment.<sup>10</sup> 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.

Before proceeding further, it is worth discussing the setup and crucial assumptions of the model. The exact specification can vary substantially without affecting the results qualitatively, as long as two economically intuitive conditions are met. First, external financing cannot be raised against the full value of future cash flows; in other words, there are financing frictions that restrict the firm's ability to raise cash at date 1. If the firm can pledge all its future cash flows as collateral, then 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 to be universally met, for example, because of asymmetry in information, liquidation costs, and the importance of human capital. Second, some cash flows from the current investment are realized after some portion of the outstanding debt is due. Most capital expenditure items in practice are likely to satisfy this requirement, since they usually generate cash flows after some non-trivial debt payments must be 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 can also generate a cash flow at date 1. What is needed is a non-trivial fraction of cash flows expected at date 2, after the debt payment is due, to make the survival at an intermediate

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<sup>9</sup>We assume that the production function is deterministic for simplicity of exposition; our conclusions do not depend on this assumption.

<sup>10</sup>Alternatively, it can be assumed that there are costs of issuing new debt and equity.

stage a worthy option. Another way to express the same idea is to say that default at date 1 results in a loss of value.

At date 0 the firm's managers decide how to split its cash endowment  $c_0$  between investment  $I$  and cash reserves to be retained until date 1. Thus, its cash holdings carried over from period 0 to period 1 are given by:

$$c_1 = c_0 - I. \tag{1}$$

Both the cash balance and the realization of cash flows from the assets in place in period 1,  $\delta_1$ , are available at date 1 for debt service. The level of financial slack at date 1,  $S$ , can then be written as:

$$S = c_1 + \delta_1 - B. \tag{2}$$

The firm is solvent at date 1 if  $S$  is non-negative. In this case, the firm makes the required debt payment and survives until date 2 to collect the cash flow from investment,  $f(I)$ . If the firm does not have sufficient internal resources to pay its debt ( $S < 0$ ), then in the benchmark model it defaults and is liquidated, and future cash flows are lost. Thus, in period 0 the firm faces the following trade-off in deciding whether to invest its cash or to retain it until the next period. On the one hand, higher retained cash holdings imply lower investment, which in turn results in lower cash flows from long-term investment at date 2. 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 rip the benefits of the investment.

The “default boundary”, or the minimum level of period-1 cash flow that triggers default, is  $\delta_{1,B} = B - c_1 = B - (c_0 - I)$ . Denote as  $\delta_{\max}$  the highest possible value of the first-period cash flow. Equityholders' value can then be written as:

$$E = \int_{\delta_{1,B}}^{\delta_{\max}} [-I + (c_0 + \delta_1 - B) + f(I)]g(\delta_1)d\delta_1, \tag{3}$$

where the total payoff to equityholders can be decomposed into the initial cash outflow of  $I$ , the difference between the cash balance and the debt payment at date 1, and the realization of the final cash flow, provided that the firm does not default on its debt.

The market value of the firm's debt,  $D$ , can be written as follows:

$$D = B - \int_{\delta_{\min}}^{\delta_{1,B}} [B - (c_1 + \delta_1)]g(\delta_1)d\delta_1, \tag{4}$$

where  $\delta_{\min}$  is the lowest possible value of the first-period cash flow. The above expression can be interpreted as the face value of debt  $B$  minus the loss  $L = (B - D)$  that creditors expect to incur in default states  $[\delta_{\min}, \delta_{1,B}]$ . Debt yield (or credit spread) at date 0 is given by:

$$s = \frac{B}{D} - 1 = \frac{B}{(B - L)} - 1. \quad (5)$$

How are changes in the firm's cash holdings  $c_1$  related to changes in the credit spread  $s$ ? In what follows, to address this question it will sometimes be more convenient to look at the relationship between cash and credit loss  $L$ , since Equation (5) shows that spreads and losses are positively related through a monotonic transformation. We demonstrate that the nature of the relationship between the expected credit loss and variations in cash depends on whether the variation is "exogenous" and unrelated to the credit risk of the firm, or whether it is an "endogenous" response to variations in credit risk variables that, in addition to inducing changes in optimal cash holdings, also directly affect credit spreads.

The effect of any variable  $x$  on credit spreads can be decomposed into two components. First, the spread may directly depend on  $x$  and, second, it may also be affected indirectly if changes in  $x$  affect optimal cash holdings,  $c_1$ , and changes in cash result in changes in spreads. Formally,

$$\frac{ds}{dx} = \frac{\partial s}{\partial x} + \frac{\partial s}{\partial c_1} \times \frac{dc_1}{dx}. \quad (6)$$

It is easy to show that changes in the spread are negatively correlated with changes in cash holdings, so that  $\frac{\partial s}{\partial c_1} < 0$ . At the same time, the direct effects of  $x$  on the spread ( $\frac{\partial s}{\partial x}$ ) and on cash holdings ( $\frac{dc_1}{dx}$ ) depend on the nature of  $x$  and can be either positive or negative. As an important special case, some variables may affect spreads only indirectly through their effect on the chosen cash holdings, 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 both directly and indirectly through their effect on the firm's optimal cash holdings, the overall effect in Equation (6) depends on whether the two effects work in the same direction, and if not, which of them dominates. For example, if a change in  $x$  directly increases the expected loss from default, it may also induce a precautionary increase in cash holdings, which in turn would reduce spreads, dampening the first effect. The overall correlation between induced changes in spreads and cash holdings depends on the nature of the particular underlying factor involved; below, we study a number of such factors, starting with the level of debt.

## B. Endogenous cash policy and credit spreads

In this subsection, we show that if the variation in cash holdings is due to factors that also affect the credit risk of the firm, then the relationship between cash holdings and credit spreads may be positive if the indirect effect (that affects credit spreads via changes in optimal cash holdings) dominates.

### B.1. The effect of debt on spreads and equilibrium cash holdings

We first look at how equilibrium investment and cash holdings depend on the firm's level of debt,  $B$ , assumed exogenous in the model. Managers maximize the value of equity by choosing the appropriate level of investment. From Equation (3), their optimization problem yields the following first order condition:

$$\frac{\partial E}{\partial I} = \int_{\delta_{1,B}}^{\delta_{\max}} [-1 + f'(I)]g(\delta_1)d\delta_1 - [f(I) + (c_0 - I) - B + \delta_{1,B}]g(\delta_{1,B})\frac{\partial \delta_{1,B}}{\partial I} = 0. \quad (7)$$

We can re-write (7) as<sup>11</sup>

$$f'(I) - 1 = \frac{f(I)g(\delta_{1,B})}{1 - G(\delta_{1,B})}, \quad (8)$$

where  $G(\cdot)$  is the cumulative density function associated with density  $g(\cdot)$ , so that  $1 - G(\delta_{1,B})$  is the probability that the firm will be able to make the required debt payment, conditional on a given level of investment. Once the firm's investment  $I$  is chosen, the retained cash reserve is  $c_1 = c_0 - I$ . Note that in the first-best case of unrestricted investment, the standard maximization solution would yield a well-known result  $f'(I) = 1$ . The right-hand side expression in Equation (8) is positive as long as the firm's ability to repay the debt is uncertain. Therefore, the firm's optimal investment,  $I^*$ , is lower than the first-best level. 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. Indeed, 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.

Define the hazard rate of the distribution function  $g(\delta_1)$  as:

$$h(\delta_1) = \frac{g(\delta_1)}{1 - G(\delta_1)}. \quad (9)$$

The next proposition gives a sufficient condition under which the optimally chosen cash level is increasing in book debt.

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<sup>11</sup>It is easy to show that the second-order maximization condition is satisfied.

PROPOSITION 1. *Let  $c^*$  be the cash reserve optimally chosen for a given level of debt,  $B$ . Then if the hazard rate  $h(\cdot)$  is non-decreasing, so that  $h'(\delta_1) \geq 0$ , then  $c^*$  is a non-decreasing function of  $B$ .*

The requirement that the hazard rate be nondecreasing is frequently found in game-theoretic and auction models. It is not restrictive, as is satisfied for a broad range of distributions, such as normal, lognormal, and uniform. Under this condition, Proposition 1 states that an increase in the level of debt results in an increase in optimal cash holdings:  $\frac{dc^*}{dB} > 0$ . If cash levels increase with debt, what is the relationship between equilibrium cash holdings and debt prices induced by this dependence? The next proposition addresses this question.

PROPOSITION 2. *Assume that the hazard rate condition of Proposition 1 is satisfied. Then:*

1. *Creditors' expected loss  $L$  is increasing in the face value of debt  $B$ .*
2. *If, in addition, the elasticity of credit loss  $L$  with respect to  $B$ ,  $\frac{B}{L} \frac{dL}{dB}$ , is greater than one, then the credit spread  $s^*$  is increasing in the face value of debt  $B$ .*

Equation (6) shows that there are two different effects that changes in the face value of debt have on the expected loss. First, there is the intuitive direct effect: *ceteris paribus*, larger debt levels result in a higher probability of default and higher credit spreads ( $\frac{\partial s}{\partial B} > 0$ ). This is the relationship that is exploited in most models and empirical studies. Additionally, in our model there is a second, indirect effect due to the endogeneity of cash holdings, since according to Proposition 1, when the level of debt increases, the firm in equilibrium optimally saves more cash and invests less, so that  $\frac{dc^*}{dB} > 0$ . Proposition 2 states that if the hazard rate  $h(\cdot)$  is non-decreasing, then the direct effect of changes in debt on credit loss always dominates. Hence, both the expected loss  $L$  and the retained cash  $c^*$  increase when debt levels increase. In practice, this means that when debt levels are allowed to vary over time or in the cross-section, this variation induces a spurious positive correlation between cash holdings and spreads. Moreover, if the elasticity of credit loss with respect to the face value of debt is greater than 1, then the net effect is that cash and credit spreads are positively related.<sup>12</sup>

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<sup>12</sup>The elasticity condition is likely to be satisfied when the misalignment of creditors' and equityholders' interests is high. For example, when the investment project  $f(I)$  is very profitable, equityholders are likely to invest a larger fraction of the initial cash reserve, which results in an increase in credit spreads, because creditors do not benefit from higher cash flows generated by long-term investment.

*B.2. The effect of other firm characteristics on the optimal cash policy*

Proposition 2 establishes that cash balances and credit spreads may be positively related in the cross-section of firms, since the level of debt both affects credit spreads and also drives the precautionary motive for holding cash. In practice, the same effect may arise due to variation in firm characteristics other than debt, if they affect both the expected default loss and also the endogenously determined level of cash holdings. Examples of such variables include pledgeability of future cash flows (which proxies for how easily the firm can raise financing at the interim date), the profitability of the firm's assets in place, and the volatility of the firm's cash flows. Below, we discuss the effect of these variables on the equilibrium relationship between cash and spreads. The formal statement of all results is delegated to Appendix B.

**Pledgeability of interim-date cash flows:** We relax the assumption that external financing is completely unavailable at date 1, by assuming that at date  $t = 1$  the firm can raise external financing against a fraction  $\tau$  of future cash flows. That is, by pledging  $f(I)$  as collateral, the firm can raise  $\tau f(I)$  in cash from external sources. Upon relaxing external financing constraints in this manner, the above results concerning the effect of variation in leverage on cash holdings and credit spreads (Propositions 1 and 2) continue to hold.<sup>13</sup> In Appendix B we prove that the firm's optimal cash holdings decrease in the ease of financing,  $\tau$ , provided that  $\tau$  is sufficiently large. The last requirement is necessary because if future cash flows are sufficiently pledgeable, then investment itself has a precautionary function.<sup>14</sup> The importance of this additional result stems from the facts that the direct effect of the ease of financing on credit spreads is negative, but the indirect effect through the cash holdings may be positive (since cash decreases in  $\tau$  for high values of  $\tau$ ). If the direct effect dominates, then changes in pledgeability induce a positive correlation between equilibrium cash balances and credit spreads.

**Profitability:** One way of modeling variations in firm profitability is by assuming that the cash flow at date 1 shifts by some constant amount  $p$  in all states, so that  $\hat{\delta}_1 = (\delta_1 + p)$ . It is straightforward to show that optimal cash holdings decline in the profitability parameter  $p$ , since higher future profitability increases the expected cash flow from assets in place, and thus reduces the probability of a cash shortage. Although the direct effect of profitability on spreads is also negative, the indirect effect through cash holdings is positive, since lower cash leads to higher spreads. The appendix shows that the direct effect dominates, provided that the hazard rate condition of Proposition 1 is satisfied. As a result, credit spread and cash are negatively

<sup>13</sup>The results on the extended model in the presence of partial pledgeability are available upon request.

<sup>14</sup>In general, it cannot be guaranteed that the effect on investment is monotonically increasing in  $\tau$  even for small values of  $\tau$ , since in this region cash continues to play a significant precautionary role as well.

related. In other words, while profitability may be an underlying driver of cash holdings, it is unlikely to be the source of a positive equilibrium relationship between cash and spreads.

**Volatility:** What is the effect of the volatility of the interim cash flows from the assets in place,  $\delta_1$ , on spreads and optimal cash holdings? Intuitively, volatility introduces two mechanisms which affect the cash-investment trade-off in the presence of risky debt. First, the precautionary motive leads the firm to increase its cash reserves in order to reduce the probability of a cash shortage at date 1. Second, there is a risk-shifting incentive to increase investment at the expense of cash holdings, betting on the good outcome in the interim period. Intuitively, the precautionary motive dominates when the probability of default is low, while the risk-shifting motive dominates when the probability of default is high. The direct effect of an increase in volatility is to raise spreads, while the indirect effect is to reduce spreads when the precautionary motive dominates (and increase spreads further if the risk-shifting motive dominates). If the precautionary motive dominates, then the relationship between spreads and cash induced by changes in volatility may be positive. Appendix B puts a structure on the above discussion by introducing parametric assumptions on  $g(\delta_{1,B})$ , and establishes that optimal cash holdings increase in volatility if the default threshold is sufficiently low.

### *C. Exogenous variations in cash*

Having shown that the correlation between spreads and cash can be spuriously positive due to the endogeneity of cash, we now consider the scenario in which a variation in exogenous variable  $x$  induces a change in the optimal cash balances, but does not affect credit risk *other than through its effect on cash*. This scenario produces variations in cash that we refer to as “exogenous”, since they are not correlated with factors that also directly affect the market value of debt. In other words, in equation (6),  $\frac{\partial s}{\partial x} = 0$ , so that

$$\frac{ds}{dx} = \frac{\partial s}{\partial x} + \frac{\partial s}{\partial c_1} \times \frac{dc_1}{dx} = \frac{\partial s}{\partial c_1} \times \frac{dc_1}{dx}. \quad (10)$$

If a change in factor  $x$  causes cash to increase, it then decreases the credit spread as a result, so that  $ds$  and  $dc_1$  have opposite signs. This formalizes the intuition that exogenous increases in cash holdings should be negatively related to credit spreads. We obtain the following proposition.

**PROPOSITION 3.** *If  $\frac{\partial s}{\partial x} = 0$ , then the credit spread  $s$  is negatively related to variations in cash holdings induced by changes in  $x$ .*

What economic factors might affect cash holdings but not the value of debt, other than indirectly through

their effect on cash? The possibilities are many. One such factor could be an unexpected cash windfall or cash loss not due to managers' optimizing decisions. As an example, the firm may win a lawsuit that does not change its investment opportunities, but results in a cash inflow from the defendant. Alternatively, a part of the firm's cash holdings can be due to managers' optimal response to factors that do not directly affect the firm's credit risk. Below, we consider two such candidate factors, namely, growth options and managers' private losses in financial distress.

**Growth options:** We model the firm's growth options as investment opportunities that may arise at the interim date  $t = 1$ . Cash flows from these investment opportunities will only be realized at date 2, and if they are not pledgeable at  $t = 1$ , then their presence does not affect the value of debt that has to be repaid at date 1. For simplicity, we assume that these investment opportunities are unrelated to the current level of investments or other firm characteristics, and have a fixed value of  $z > 0$ , which can also be interpreted as the expected value of the growth option. We also assume that if the firm defaults on its debt, this growth option is lost, for example, due to loss of customers or the inability to retain management or to transfer human capital to new management.<sup>15</sup>

Under these assumptions, equityholders' value can be written similar to (3) as:

$$E = \int_{\delta_{1,B}}^{\delta_{\max}} [-I + (c_0 + \delta_1 - B) + f(I) + z]g(\delta_1)d\delta_1, \quad (11)$$

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

$$f'(I) - 1 = \frac{[f(I) + z]g(\delta_{1,B})}{1 - G(\delta_{1,B})}. \quad (12)$$

The first-order condition (12) implies that the presence of growth options decreases initial investment since 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. In other words, the equilibrium relationship between cash holdings and credit spreads induced by growth options is negative. Note that the growth option  $z$  can also capture the deadweight costs of bankruptcy or financial distress incurred by the firm, which are saved in case default is averted.

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<sup>15</sup>Note that, interpreted generally,  $Z$ , can be any required future cash outlay unrelated to debt payment, rather than simply capital investment.

**Managerial losses in distress:** One commonly considered variant of privately incurred distress costs are private costs incurred by the management. Suppose that the firm's risk-neutral manager owns a share  $\theta$  of the equity  $E$ , and incurs a fixed, private cost  $\gamma$  in case of financial distress, where  $\theta > 0$  and  $\gamma > 0$ . In the model, the only way that the manager can affect the probability of default is by adjusting the firm's cash holdings.<sup>16</sup> We show below that the equilibrium relationship between cash holdings and credit spreads induced by the managerial agency parameter  $\frac{\gamma}{\theta}$  is negative. Intuitively, in addition to the firm-level precautionary motive, now there is also a managerial precautionary motive to hold cash. For a given ownership level  $\theta$ , the managerial motive to hold cash increases in the private costs of distress  $\gamma$ . Conversely, given  $\gamma$ , the manager's motive to hold cash declines in her ownership of the firm  $\theta$ . The overall effect depends on the ratio of managerial cost to her equity stake,  $\frac{\gamma}{\theta}$ , which can be interpreted as a measure of agency problems between managers and equityholders. For example, poor governance of the firm may lead to lower exposure of management to cash flow risk of the firm, and increase their propensity to deviate from the optimal investment (and, in turn, cash) policy. The excessive holding of cash reserves by management reduces credit risk and spreads for the firm.

Formally, manager's objective is to choose investment  $I$  to maximize

$$M = \theta \times E + \gamma \times (1 - G(\delta_{1,B})) . \quad (13)$$

The first order condition determining the equilibrium investment is given by

$$f'(I) - 1 = \frac{[f(I) + \frac{\gamma}{\theta}]g(\delta_{1,B})}{1 - G(\delta_{1,B})} . \quad (14)$$

As discussed in Appendix B, similarly to the case of growth options, the equilibrium relationship between cash holdings and credit spreads induced by agency costs is negative.

#### *D. Cash and long vs. short-term default risk*

Having established the relationship between cash holdings and credit spreads and the subtlety of this relationship arising from the precautionary motive for holding cash, we now examine the implications of cash holdings for the probability of default. In choosing the optimal cash reserve, the firm's managers trade off the reduction in the risk of default at date 1 against investment returns that are realized only at date 2. We

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<sup>16</sup>Thus, we assume away the manager's ability to alter the firm's debt levels and the volatility of its operations, which are clearly relevant empirically.

extend our model to show that cash reserves reduce the risk of default in the short run (in period 1), but through lower future profits may in fact increase this risk in the long run (in period 2).

Consider a modification of our earlier setting, where the firm's total debt now consists of two tranches of different maturities, so that some debt with a face value of  $B_1$  is due at date 1, while that with a face value of  $B_2$  is due at date 2. We will assume as before that no part of investment return  $f(I)$  is pledgeable at date 1, whereas it is fully pledgeable at date 2 (Partial pledgeability at date 1 and date 2 would also suffice.) As in our previous analysis, the likelihood of default risk at date 1 is determined by the threshold point of date-1 cash flow below which the firm cannot meet its payment at date 1, given by  $\delta_{1,B} = B_1 - (c_0 - I)$ , which is decreasing in the cash reserve  $c_1 = (c_0 - I)$ .

Next, consider the risk of default at date 2. Suppose that the firm has not defaulted at date 1, so that  $\delta_1 > \delta_{1,B}$ . Then, the firm's available resources for debt payment at date 2 are the surplus cash reserve,  $c_2$ , equal to  $(\delta_1 + c_1 - B_1)$ , and the investment return  $f(I)$ .<sup>17</sup> Hence, default occurs at date 2 whenever  $(\delta_1 + c_1 - B_1) + f(I) < B_2$ . This implies a default boundary in terms of date 1 cash flow, which we denote as  $\delta_{1,B_2}$ , given by  $\delta_{1,B_2} = \delta_{1,B} + B_2 - f(I)$ , below which the firm will default at date 2. 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  $f(I)$ , then 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.<sup>18</sup>

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

$$\frac{d\delta_{1,B_2}}{dI} = \frac{d\delta_{1,B}}{dI} - f'(I) = 1 - f'(I). \quad (15)$$

This equation formalizes the tradeoff of precautionary cash holdings. As argued above, investment (cash reserve) increases (decreases) the probability of default at date 1:  $\frac{d\delta_{1,B}}{dI} > 0$ . However, since  $1 - f'(I) < 0$  (see the equivalent first-order condition (7)), the probability of default in the longer-term is higher as the firm increases its cash reserve at the expense of long-term investment. Thus, we have proved the following proposition:

**PROPOSITION 4.** *An increase in cash balances reduces the likelihood of default at date 1 and increases*

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<sup>17</sup>For simplicity, we assume that the firm carries its surplus cash reserve to date 2. In general, if the debt due  $B_2$  is very high, then 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 often the case in practice.

<sup>18</sup>Note that with complete revelation of information on interim cash flow  $\delta_1$  at date 1, one could argue that 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  $\delta_2$ , would suffice to avoid such an outcome.

the likelihood of default at date 2.

Proposition 4 implies that cash holdings may be negatively related to the probability of default for short prediction horizons, but positively – for long horizons.<sup>19</sup>

### E. Discussion

To summarize our theoretical results, our model predicts that the endogenous adjustment in the firm's cash holdings in response to various factors that affect credit risk, such as debt levels, volatility, and financing constraints, can result in a positive correlation between spreads and cash. At the same time, spreads are negatively correlated with the exogenous part of the variation in the firm's cash holdings that is due to factors that do not affect the firm's credit risk directly. We also show that cash balances may have different effects on the short-term and long-term likelihoods of default.

One caveat to the above results is that they are derived by varying one of the parameters of the model (such as leverage, profitability, or growth options) while keeping others fixed. In reality, these firm characteristics are not independent. One variable that is likely to be endogenous and adjusted on a relatively frequently basis (though not as frequently as cash) is leverage. To see how this complicates the analysis, consider one intuitive example. Suppose that the firm has a growth option similar to that described in Subsection II.C, but managers can choose *both* cash holdings and leverage at the same time. Then, the exogenous effect of growth options on cash is still unambiguously positive. However, the presence of growth options that is lost if the firm defaults is also likely to decrease the optimal leverage ratio, which would induce a reduction in optimal cash holdings. Thus, two opposite effects are at work, and without knowing how leverage and growth options are correlated in the data, it is difficult to generalize the model's predictions.

As another example, consider the effect of profitability. In the trade-off model of capital structure, an increase in profitability tends to increase optimal leverage. Therefore, the direct effect of profitability on cash, as we discussed, is clearly negative, but now in addition there is also an indirect effect through the increase of debt, resulting in higher optimal cash holdings. Without knowing the relationship between leverage and profitability in the data, the model will not provide us with more economic insights. Therefore, it should be clear that all results above are *ceteris paribus* and that endogeneity can be working simultaneously at several layers.

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<sup>19</sup>A similar effect may also be induced by managerial short-termism, which might be an exogenous factor driving cash holdings above their optimal level, reducing default risk in the near future at the cost of lost profitable investment opportunities.

### III. The data

#### *A. Data sources and sample selection*

We study yield spreads on bonds included in the Merrill Lynch US 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 price database consists of monthly bid quotes from Merrill Lynch bond trading desks. We augment the pricing 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.

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, 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, since the data on the risk-free rate that we use to estimate spreads are not available for these maturities.

#### *B. 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 for the shape of the term structure accurately. Our initial data set is an unbalanced panel of monthly observations of spreads. A potential issue with this data structure is the high representation of large firms with many outstanding bonds in any given month. Because we are interested in the relationship between credit risk and cash reserves, which are firm– rather than bond-specific, using all bond-month observations may potentially bias the results towards 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 in fact unchanged when we use all bond-months 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 observable. We use the approach suggested by Schaefer and Strebulaev (2007), and estimate the *firm asset volatility* as the leverage-weighted average of the firm's one-year historic equity volatility, and the average bond volatility for the same rating from Schaefer and Strebulaev (2007). 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 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 such factors, we use monthly dummies in our regressions.

Our results are insensitive to these particular definitions of our variables. They are nearly identical if cash is measured as a fraction of assets net of cash, rather than total assets, or if, following Collin-Dufresne, Goldstein, and Martin (2001), we use equity volatility instead of the Schaefer-Strebulaev proxy for asset volatility. They would be strengthened if instead of monthly dummies we used market indicators such as the risk-free rate (Duffee (1998)) or VIX, related to implied market volatility (Schaefer and Strebulaev (2007)).

### *C. 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 only 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)). It is worth noting that 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, the firm is excluded from the database when it defaults. 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 to 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 & transportation and consumer good production.

[TABLE III HERE]

Panel A of Table IV presents descriptive statistics on 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 to be attributable not only to the increase in the probability of default, but also to 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 our firms have public bonds outstanding, it is not surprising that they are relatively large in size, with the median total book assets of almost \$6.5 Bn. They also have relatively high leverage ratios than broader 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 studies of bond spreads. Looking at firm characteristics by rating (not reported), we find that firms with higher ratings are larger, less levered, more profitable, have slightly larger capital expenditures, and return substantially more cash to shareholders via dividends and repurchases than riskier firms.

Expressed as a proportion of total assets, cash holdings of our firms are lower than those in broader Compustat samples that are typically used in empirical studies. For instance, in Opler et al. (1999) the average ratio of cash to net assets (total assets minus cash) is 17% and the median is 6.5%, compared to 4.4% and 2.0% in our sample. These substantial differences are due in part to the fact that 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 to the fact that bond issuers are likely to be less financially constrained and value

cash holdings less. The differences are all the more significant given the fact that our sample corresponds to recent years, during which corporate cash holdings increased substantially. Indeed, Bates, Kahle, and Stulz (2006) document that the overall corporate cash holdings now exceed total corporate debt, so that the aggregate leverage is negative. Figure 1 illustrates that cash holdings are U-shaped in the credit rating, with the safest and riskiest firms holding more cash than average.

## IV. Empirical results

Our model demonstrates that when cash holdings are chosen endogenously by the levered firm, optimal cash may depend on various credit risk factors that also affect spreads. As a result, OLS regressions that treat cash as an exogenous parameter may yield misleading results. We now show that the positive correlation between cash and spreads documented in Tables I and II is spurious rather than causal, and is reversed when we use instrumental variables suggested by the model to identify exogenous variations in cash. We then look at the role of liquid asset holdings in empirical default-predicting models, and present evidence that changes in credit risk cause firms to adjust their cash holdings.

### *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 documented previously can arise as a by-product of the precautionary motive for holding cash reserves by levered firms, which results in riskier firms having both more cash and higher credit spreads. 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 standard leverage and volatility measures do not fully account for the underlying credit risk in the presence of cash endogeneity. Empirical studies that use these explanatory variables generally explain only 30 to 40% of the variation in levels and changes in credit spreads (e.g., Collin-Dufresne, Goldstein, and Martin (2001)). Hence, in regressions of Tables I and II cash may be a proxy for the residual credit risk not fully accounted for by these factors. To investigate this possibility, in this subsection we look at how the correlation between cash and spreads is affected by alternative controls for differences in credit risk.

The results are presented in columns (1) to (5) of Table V. Univariate regression (1) is identical to

that in column (1) of Table I, and included in the table for the ease of comparison. Column (2) introduces standard controls for (quasi-market) leverage used in much of the literature, and the proxy for asset volatility suggested by Schaefer and Strebulaev (2007) (using equity volatility yields similar results). The correlation between cash and spreads falls slightly once these variables are introduced, but remains highly statistically significant. To control for credit risk more accurately, in regression (3) we add a full set of dummy variables for the firm’s credit rating from Moody’s, which conveniently summarizes the rating agency’s opinion about the firm’s creditworthiness. Ratings provide an admittedly crude summary of credit risk, as evidenced in regression (3) by the fact that leverage and volatility remain strongly significant determinants of spreads.<sup>20</sup> Nevertheless, column (3) shows that the introduction of rating dummies not only increases the regression’s explanatory power, but also dramatically affects the correlation between spreads and cash holdings, which becomes small and insignificant.

The disappearance of the significance of the cash coefficient is consistent with the conjecture that the positive correlation documented previously arises because cash holdings and credit spreads are both driven by factors subsumed by the credit rating. However, ratings in these regressions are treated as a black-box proxy for credit risk, and the role of cash in the rating agencies’ decision process is unclear. An alternative way to improve the regression specification is by constructing better proxies for credit risk. To this end, we estimate market leverage ratios and the volatility of assets *implied* by the time series of equity values, which incorporate expectations about default and cash policy. Specifically, we calibrate Merton’s (1974) structural model of credit risk using the KMV approach outlined in Crosbie and Bohn (2001) and first implemented in the academic literature by Vassalou and Xing (2004). Essentially, the procedure uses a year-long series of market equity values in conjunction with data on outstanding debt to yield estimates of the (unobserved) market value of the firm’s assets, as well as the volatility of assets and the market leverage ratio.<sup>21</sup> Once market-implied leverage and volatility estimates are obtained, we use them in regressions of spreads in the expectation that they should provide better controls for the fundamental credit risk factors that affect spreads.

Regressions that use these controls are reported in columns (4) and (5) of Table V. Compared to column (2) that uses standard leverage and volatility proxies, the regression in column (4) has higher explanatory power, with an  $R^2$  of 0.48 compared to 0.43. Consequently, with credit risk better accounted for by the market-implied variables, cash in this regression is not significantly related to spreads. The coefficient on cash, already less than a third of that in column (2), is further reduced when we add controls for firm size,

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<sup>20</sup>This is consistent with the fact that ratings are rarely adjusted immediately in response to changing credit conditions due to rating agencies’ desire to achieve a balance between “ratings stability” and accuracy (Cantor and Mann (2007)).

<sup>21</sup>The details of the estimation procedure can be found in Davydenko and Strebulaev (2007).

maturity, and systematic effects in regression (5), which is identical to that in column (4) of Table I but for the use of market-implied leverage and volatility proxies. Once again, as a result of using these variables,  $R^2$  is increased and cash is rendered insignificant.

[TABLE V HERE]

#### A.2. Exogenous variations in cash

The evidence so far suggests that the positive correlation between cash and spreads arises because endogenously determined cash holdings depend on credit risk factors, and disappears once those factors are accurately controlled for using ratings or market-based proxies. Our model further suggests that, consistent with the simple intuition, exogenous variations in cash holdings not induced by adjustments to changes in credit risk should be negatively related to spreads. The model suggests that future investment opportunities and measures of managerial self-interest can provide instruments for identifying such exogenous variations in cash. To proxy for growth options, we use the median ratio of R&D expenditures to sales in the firm's 3-digit SIC industry in each calendar year.<sup>22</sup> In addition to investment opportunities, the ratio of the manager's private costs of distress to the fraction of the firm's equity that she owns is another instrument that in the model induces variations in cash unrelated to credit risk. We assume that CEO's salary and bonus are at risk if the firm defaults. Accordingly, our *agency term* is constructed as the ratio of CEO's salary, bonus and other monetary compensation to the market value of her shares and options, estimated using the ExecuComp database.<sup>23</sup>

We employ these two instruments in IV regressions of spreads using specifications that mirror those in columns (1) to (5) of Table V. The results of these tests are shown in column (6) to (10) of the same table. The effect of control variables in IV and OLS regressions is similar, but the effect of cash holdings is not: The cash coefficient is negative throughout, and statistically significant, except for regression (7). Consistent with our predictions, IV regressions show that exogenous variations in cash are negatively correlated with spreads. However, although the simple intuition is confirmed in these regressions, our previous results show that in standard OLS specifications it is overturned by the effect of endogeneity, which is of first order

<sup>22</sup>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 in our setting it is also mechanically correlated with the market leverage ratio, which renders it unsuitable as a potential instrument.

<sup>23</sup>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.

importance in the interaction between cash and credit risk.

### *A.3. Robustness and extensions*

Table VI shows that the positive correlation between cash and spreads in base-case OLS regressions and the sign reversal in instrumental variable regressions in the presence of model-implied credit risk controls are robust to the inclusion of various factors that may potentially affect the firm's level of cash. Regressions (1) and (5) address the concern that different firms may have different liquidity needs due to the nature of their business, and these may be correlated with their 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. Differences in cash holdings across firms may be related to covenants that restrict minimum liquidity levels. To test this hypothesis, we collect data on bank covenants from the LPC DealScan database, and construct dummy variables summarizing the presence of such covenants. Regressions (2) and (6) show that controls for the presence of these covenants do not alter our conclusion regarding the relationship between cash and spreads in any way. Controls for covenants that restrict capital expenditures and thus can also affect cash (not shown) yield similar conclusions. Finally, to demonstrate that our results are not due to patterns of cash holdings and credit risk across different industries, in regressions (3) and (7) we control for industry effects by including dummy variables for the 49 Fama-French industries. These controls also have little effect on the cash coefficient in either OLS or IV regressions. Overall, the positive correlation between the two documented in Tables I and II is 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 not to squander existing cash, and may therefore face higher borrowing costs compared to 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. Therefore, it is natural to explore whether moral hazard is behind the effects we document by comparing the cash-spread coefficient for nonfinancial firms that we looked at previously with that for financial firms.

The base-case regression for financial firms is reported in column (4) of Table VI. In contrast to nonfi-

nancials, spreads of financial firms are *negatively* and significantly correlated with cash holdings, conforming to the simple intuition that higher solvency reduces the cost of debt due to the lower risk of default. 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 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 based on the precautionary motive for saving cash appears to be 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 studies so far have not accounted for this possibility. Because default is often thought of as being 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 model (1984) and Altman *et al.*'s (1977) ZETA-score model 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 proxies, Begley *et al.* (1996), Shumway (2001), and Hillegeist *et al.* (2004), as well as Ohlson (1980) and Zmijevski (1984), do not find that they are negatively and significantly associated with default. This has been a puzzling finding in the literature.

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 in order 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 should then result in a lower short-term probability of a liquidity crunch, but 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.<sup>24</sup> We estimate multiperiod logit regressions, equivalent to discrete hazard models (Shumway (2001)), using specifications suggested by Altman (1968) and Zmijevski (1984), and also separating cash from their liquidity measures.

The results of these tests are reported in Table VII. Regressions in columns (1) and (2) are estimated for the short-term prediction horizon. The dependent variable in these regressions is one if the firm defaults within the next fiscal quarter, and zero 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, although 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 short-term predictions, columns (3) to (6) show that these same measures of liquidity may be *positively* related to the probability of default in 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 cited above, 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, the results of these tests are consistent with the positive correlation between cash and spreads documented earlier, as well as with our explanation of that correlation based on the endogeneity of cash. They suggest that the effect of balance sheet liquidity on the probability of default for longer horizons cannot be adequately captured by the standard approach that treats liquid assets as an independent variable, and emphasize once again the importance of the endogenous cash policy in the presence of credit risk.

### *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

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<sup>24</sup>With the exception of Altman *et al.* (1977), all the papers cited above are restricted to predicting formal bankruptcy filings. Since failure does not necessarily involve bankruptcy, we use a wider definition of default adopted by rating agencies.

its cash policy. For example, we would expect firms that have been recently downgraded by credit rating agencies to increase the amount of cash they retain out of their cash flow in order to reduce the probability of a cash shortage in the face of the change in credit risk that triggered the downgrade. However, such adjustments in cash holdings may not be feasible if the firm is not generating enough cash flow, which is more likely in the case of unprofitable lower-rated firms that also need cash the most. 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 in “notches,” where the rating of AAA is coded as 1, AA+ as 2, AA as 3, etc.<sup>25</sup> We also use a set of control variables suggested by Almeida, Campello, and Weisbach (2004). The most important of these is the annual cash flow, which provides the firm with a means of increasing its cash reserve should it choose to do so.

Table VIII reports the results of estimating these regressions for the whole sample, and separately for different beginning-of-the-year credit ratings. The positive correlation between changes in cash and ratings means that decreases in the credit quality are associated with increases in cash reserves, as 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 indeed concave. For safest investment-grade ratings there is virtually no relationship between the firm’s rating and its cash policy, presumably because these firms still have ample access to short-term financing (indeed, most of these firms should have uninterrupted commercial paper programs). The effect is very different for firms rated BBB, for most of which a downgrade means falling either very close to or into the junk category, with access to financing becoming substantially more difficult. For example, these firms often have to cancel all their commercial paper programs. One reaction to the downgrade we see is an increase in cash holdings. We find similar results BB-rated firms as well. 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, as cash flows of these struggling firms are too low to allow them to increase their savings.

To summarize, the evidence on changes in cash holdings in response to a rating downgrade is consistent with and further corroborates our earlier evidence on the link between endogenously chosen cash holdings and the credit quality of the firm.

[TABLE VIII HERE]

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<sup>25</sup>An industry convention is that a change, say, from BBB- to BB+ is one notch. A change from AA+ to BBB+, for example, is then three notches down.

## V. Summary and conclusions

In this paper, we document a positive correlation between cash holdings and credit spreads, and argue that it can be explained by endogenous adjustments in cash holdings by firms that worry about the possibility of a liquidity shortage, which in the presence of restrictions on external financing can trigger costly default. Our model predicts such a spurious positive correlation when future cash flows are only partially pldedgeable and when the benefits of investment can only be realized if the firm does not default on its debt. At the same time, exogenous variations in the firm's cash holdings that are unrelated to credit risk factors are negatively related to spreads. The simple intuition that predicts that firms with high cash holdings should be safer accounts only for the direct effect of cash on spreads, and misses the indirect effect due to the endogeneity of cash, which our evidence suggests dominates in practice.

There are at least two important implications of our results for credit-risk studies. First, structural models starting with Merton (1974) focus primarily on leverage and volatility as determinants of credit spreads, and ignore the potential effect of cash. Some models assume that default is triggered by cash flow shortages, but nevertheless do not allow for an endogenous determination of the firm's cash holdings (Kim, Ramaswamy and Sundaresan (1993), Anderson and Sundaresan (1996)). Our model suggests that firm characteristics that determine credit spreads, such as leverage, volatility, profitability, and financing constraints, may also affect the firm's cash holdings, which in turn affect spreads. Embedding cash and its determinants in structural models of credit risk may be an important challenging question for future research. At the least, our results suggest that common empirical specifications in studies of credit spreads, which use credit risk variables suggested by extant structural debt-pricing models, may omit important variables that determine firm's cash holdings and spreads.

Second, our results suggest a more subtle approach to accounting for the role of balance sheet liquidity in empirical credit risk studies. For example, Altman (1968)'s  $z$ -score and other similar empirical models of default typically control for the firm's balance sheet liquidity, treating liquidity as an independent variable. We show that the correlation between endogenous liquidity and the probability of default may depend on the prediction horizon. While for short-term horizons cash holdings of firms with restricted access to external financing can be considered fixed, for longer horizons typical in such studies the endogeneity of cash and other liquid assets becomes a dominating factor that may result in perverse conclusions regarding their role in distress.

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 endogeneity of cash. Incorporating endogenous cash holdings into structural models of credit risk in a manner similar to recent models by Acharya et al. (2006), Anderson and Carverhill (2007), and Asvanunt, Broadie, and Sundaresan (2007) may be a promising avenue for improving their ability to explain empirically observed spreads.

## Appendix A: Proofs of propositions in the paper

**Proof of Proposition 1:** Define function  $m(I, B)$  as follows:

$$m(I, B) = (f'(I) - 1) - \frac{f(I)g(\delta_{1,B})}{1 - G(\delta_{1,B})}.$$

With the hazard rate  $h(x)$  defined as in the statement of proposition, we can rewrite this as

$$m(I, B) = (f'(I) - 1) - f(I)h(\delta_{1,B}).$$

From (8) it follows that  $m(I^*, B) = 0$ . Therefore,

$$\frac{dI^*}{dB} = -\frac{\frac{\partial m}{\partial B}}{\frac{\partial m}{\partial I^*}}.$$

Since  $I^*$  is the optimal solution of the maximization problem,  $\frac{\partial m}{\partial I^*} < 0$ . Thus, for  $\frac{dI^*}{dB}$  to be negative, it must be that

$$\frac{\partial m}{\partial B} = -f(I)h'(\delta_{1,B}) < 0,$$

where we have employed the fact that  $\frac{\partial \delta_{1,B}}{\partial B} = 1$ . Note that formally,

$$h'(\delta_{1,B}) = \frac{(1 - G(\delta_{1,B}))g'(\delta_{1,B}) + g(\delta_{1,B})^2}{(1 - G(\delta_{1,B}))^2}.$$

Requiring  $\frac{dI^*}{dB}$  to be negative is thus equivalent to requiring that  $h'(\delta_{1,B}) > 0$ .  $\diamond$

**Proof of Proposition 2:**

1. Recall that expected loss  $L$  is defined by (4) as

$$L = B - D = \int_{\delta_{\min}}^{\delta_{1,B}} [B - (c_1 + \delta_1)] g(\delta_1) d\delta_1.$$

Taking the derivative of  $L$  with respect to  $B$ , we get

$$\frac{\partial L}{\partial B} = \int_{\delta_{\min}}^{\delta_{1,B}} \left(1 - \frac{\partial c_1^*}{\partial B}\right) g(\delta_1) d(\delta_1) + (B - c_1^* - \delta_{1,B})g(\delta_{1,B}).$$

By noting that  $\delta_{1,B} = (B - c_1)$  we can now write the derivative of  $L$  with respect to  $B$  as

$$\frac{\partial L}{\partial B} = \left(1 - \frac{\partial c_1^*}{\partial B}\right) G(\delta_{1,B}).$$

It is sufficient to show that  $\frac{\partial c_1^*}{\partial B} < 1$ . From Proposition 1 we can write  $\frac{\partial c_1^*}{\partial B} = -\frac{\partial I^*}{\partial B}$  as

$$\frac{\partial c_1^*}{\partial B} = \frac{\frac{\partial m}{\partial B}}{\frac{\partial m}{\partial I^*}} = \frac{-f(I)h'(\delta_{1,B})}{f(I)h'(\delta_{1,B}) + f'(I)h(\delta_{1,B}) - f''(I)},$$

since the derivative of  $\delta_{1,B}$  with respect to  $I$  as well as  $B$  equal one. Given that  $h'(\cdot) > 0$ ,  $f'(\cdot) > 0$ , and  $f''(\cdot) < 0$ , the proposition follows.

2. Recall that

$$s = \frac{L}{B - L}.$$

By taking the derivative of  $s$  with respect to  $B$  we get

$$\frac{\partial s}{\partial B} = \frac{B \frac{\partial L}{\partial B} - L}{(B - L)^2}.$$

The above expression is positive when and only when the elasticity of  $L$  to  $B$ ,  $\frac{B}{L} \frac{\partial L}{\partial B}$ , is larger than 1.  $\diamond$

## Appendix B: Statements and proofs of discussed extensions

**Effect of partial pledgeability:** In this extension, we allow some of the date 2 cash flows to be pledgeable at date 1, thereby relaxing the financial constraint of the firm in states when there is a cash shortfall to pay off debtholders.

We assume that future cash flows  $f(I)$  are partially pledgeable to external finance markets at date 1. In particular, if a fraction  $\alpha$  of these cash flows are pledged to investors, then the firm can raise financing only up to  $\tau \alpha f(I)$ , where  $\tau \in [0, 1]$ . The parameter  $\tau$  can thus be interpreted as capturing the ease of raising external finance against unrealized future cash flows, or the dilution cost of external finance, or more broadly a metaphor for the mismatch between the maturity of debt (some upcoming short-term payments) and investments (possibly of longer term in nature).

With partial pledgeability of future cash flows, the firm has more than its slack  $S$  in order to pay down its debt at date 1. In particular, the default boundary is now given as  $\hat{\delta}_{1,B} = B - (c_0 - I) - \tau f(I) = \delta_{1,B} - \tau f(I)$ . In turn, equityholders' value can be expressed as:

$$\begin{aligned} \hat{E} &= \int_{\delta_{1,B}}^{\delta_{\max}} [f(I) + (c_0 - I + \delta_1 - B)]g(\delta_1)d\delta_1 \\ &+ \int_{\hat{\delta}_{1,B}}^{\delta_{1,B}} [f(I) - \frac{1}{\tau}(B - (c_0 - I) - \delta_1)]g(\delta_1)d\delta_1. \end{aligned} \quad (16)$$

In this expression, the first term is the same as equityholders' value  $E$  with  $\tau = 0$  (equation 3). The additional source of value arises from the fact that over the range  $\delta_1 \in [\hat{\delta}_{1,B}, \delta_{1,B}]$ , equityholders lose a fraction of the future investment returns. In particular, in order to cover the shortfall in debt payment of  $(B - (c_0 - I) - \delta_1)$ , equityholders "liquidate" their investment partly suffering a net outflow of  $\frac{1}{\tau}[B - (c_0 - I) - \delta_1]$ .

Equityholders find optimal investment  $\hat{I}^*$  by maximizing their value:

$$\frac{\partial \hat{E}}{\partial I} = \left( f'(I) - \frac{1}{\tau} \right) \left( 1 - G(\hat{\delta}_{1,B}) \right) + \left( \frac{1}{\tau} - 1 \right) \left( 1 - G(\delta_{1,B}) \right) = 0. \quad (17)$$

In particular, this first order condition implies that  $f'(I^*) \in [1, \frac{1}{\tau}]$ . That is, we still obtain underinvestment relative to the first-best investment which satisfies  $f'(I) = 1$ . Only in the extreme case when  $\tau = 1$  is the efficiency restored, and investment is at its first best level.<sup>26</sup>

<sup>26</sup>In particular, in this case, there is no relationship between cash and credit spreads, as the level of debt  $B$  varies. This illustrates that a crucial requirement for spreads to be positively related to cash (as we find in the data) is that firms face at least some financing constraints in the form of lack of full pledgeability of unrealized future cash flows.

The expected loss function for creditors is now given by

$$\hat{L} = \int_{\hat{\delta}_{\min}}^{\hat{\delta}_{1,B}} [B - (c_0 + \delta_1 + \tau f(I) - I)]g(\delta_1)d\delta_1 . \quad (18)$$

It can be shown that Propositions 1, 2, 3 and 4 of the benchmark model all hold for this general case with any pledgeability fraction  $\tau < 1$ . These proofs are available from authors upon request. Furthermore, we obtain the following relationship between cash holdings and pledgeability of future cash flows.

PROPOSITION 5. *The optimal cash holdings  $\hat{c}_1^*$  decline in pledgeability  $\tau$  for  $\tau$  sufficiently large.*

Proof of Proposition 5: Applying the implicit function theorem to the first order condition  $\hat{m}(I, \tau) = 0$  (equation 17) determining  $\hat{I}^*$ , we obtain that

$$\frac{d\hat{I}^*}{d\tau} = -\frac{\frac{\partial \hat{m}}{\partial \tau}}{\frac{\partial \hat{m}}{\partial \hat{I}^*}}.$$

Since  $\hat{I}^*$  is the optimal solution of the maximization problem,  $\frac{\partial \hat{m}}{\partial \hat{I}^*} < 0$ . Thus, for  $\frac{d\hat{I}^*}{d\tau}$  to be positive, it must be that

$$\frac{\partial \hat{m}}{\partial \tau} = \frac{1}{\tau^2} \left[ (1 - G(\hat{\delta}_{1,B})) - (1 - G(\delta_{1,B})) + (\tau f'(I) - 1) g(\hat{\delta}_{1,B})\tau f(I) \right] > 0, \quad (19)$$

where  $I$  equals  $\hat{I}^*$ .

Note that the first two terms on the right hand side together constitute a positive effect since  $\delta_{1,B} > \hat{\delta}_{1,B}$ . That is, as  $\tau$  increases, they lead investment to increase, because of the fact that when future cash flows are pledgeable, investment itself acquires a precautionary dimension and helps to reduce the likelihood of default. The third term constitutes a negative effect since  $f'(I) \leq \frac{1}{\tau}$ , and as  $\tau$  increases, this term causes investment to fall. This effect is similar to the effect in the benchmark model in that since future investments are not fully pledgeable, cash also has some precautionary role to play.

While in general, it is difficult to sign  $\frac{\partial \hat{m}}{\partial \tau}$ , the limiting case when  $\tau$  tends to one can be signed.

Note that as  $\tau$  goes to one, we obtain that  $f'(I) = 1$ , so that  $\frac{\partial \hat{m}}{\partial \tau}$  converges to  $[G(\delta_{1,B}) - G(\hat{\delta}_{1,B})]$ , which is positive since  $\hat{\delta}_{1,B} = [\delta_{1,B} - f(I)]$  when  $\tau = 1$ . In turn,  $\frac{d\hat{I}^*}{d\tau} > 0$  and  $\frac{d\hat{c}_1^*}{d\tau} < 0$ . Intuitively, with sufficiently high pledgeability, only investment plays a precautionary role and cash holdings decline as pledgeability rises even further.<sup>27</sup>  $\diamond$

**Effect of profitability:** We introduce variation in firm profitability by assuming that cash flow at date 1 is  $\hat{\delta}_1 = (\delta_1 + p)$ , where  $p$  is the known profitability constant. As can easily be shown, cash holdings of the firm decline in the profitability parameter  $p$ . Although the direct effect of profitability on spreads is also negative (as the firm becomes more profitable, it is easier to cover debt payments), the indirect effect through cash holdings is positive since lower cash leads to higher spreads. The next proposition shows that in the case of profitability, the direct effect dominates:

PROPOSITION 6. *Assume the hazard rate condition of Proposition 1 is satisfied.*

*Then, optimal cash holdings  $\hat{c}_1^*$  decrease in profitability  $p$ .*

*Nevertheless, creditors' expected loss  $L$  and credit spread  $s$  are decreasing in the profitability parameter  $p$ .*

Sketch of proof of Proposition 6: We denote the benchmark distribution analyzed so far as  $\bar{g}(\delta)$  over  $[\delta_{\min}, \delta_{\max}]$  and the more profitable distribution as  $g(\delta, p)$  over  $[\delta_{\min} + p, \delta_{\max} + p]$  such that  $g(\delta, p) = \bar{g}(\delta - p)$  for  $p > 0$  and  $p$

<sup>27</sup> However, as  $\tau$  goes to zero, in general it is not possible to sign  $\frac{\partial \hat{m}}{\partial \tau}$ . On the one hand, investment no longer plays a precautionary role since  $\hat{\delta}_{1,B} = \delta_{1,B}$ . On the other hand, the last term in the expression for  $\frac{\partial \hat{m}}{\partial \tau}$  which captures the precautionary role of cash, also goes to zero. Hence, in this case, both the numerator and the denominator in  $\frac{\partial \hat{m}}{\partial \tau}$  converge to zero, so that the limit must be calculated using the L'Hospital rule to be the limit as  $\tau$  goes to zero of

$$\frac{1}{2\tau} \left[ f(I)g(\hat{\delta}_{1,B}) + (2\tau f'(I) - 1)g(\hat{\delta}_{1,B})f(I) - (\tau f'(I) - 1) g'(\hat{\delta}_{1,B})\tau f(I)^2 \right]. \quad (20)$$

This, in turn, converges to

$$f'(I)g(\delta_{1,B})f(I) - \frac{1}{2}g'(\delta_{1,B})f(I)^2,$$

which cannot be signed in general.

small enough such that the default point  $\delta_{1,B}$  remains above  $(\delta_{\min} + p)$ . Then, it is straightforward to show that by substituting  $\hat{\delta} = \delta - p$ , one obtains an almost identical first-order condition as in equation (8) with the important difference that the default point  $\delta_{1,B}$  is replaced by  $(\delta_{1,B} - p)$ .

The rest of the proof follows along the lines of that of Propositions 1 and 2. In particular, we obtain that (i)  $\frac{dI^*}{dp} > 0$  under the hazard rate condition of Proposition 1; (ii) In turn,  $\frac{dc_1^*}{dp} < 0$ , but it can be shown that  $\frac{dc_1^*}{dp} > -1$ ; (iii)  $\frac{\partial L}{\partial p} = \frac{\partial L}{\partial c_1} < 0$ ; (iv) From (ii) and (iii),  $\frac{dL}{dp} = \frac{\partial L}{\partial p} + \frac{\partial L}{\partial c_1} \cdot \frac{dc_1}{dp} < 0$ ; (v) And, finally, since the spread  $s$  is monotone in the loss  $L$ , we also obtain that  $\frac{ds}{dp} < 0$ .  $\diamond$

**Effect of volatility:** Suppose that  $\delta_1 \sim N(\bar{\delta}_1, \sigma^2)$ .<sup>28</sup> The next proposition states the condition under which an increase in volatility leads to an increase in the precautionary cash savings.

**PROPOSITION 7.** *Optimal cash holdings  $c_1^*$  increase in volatility  $\sigma$  if the default point  $\delta_{1,B}$  is below the mean interim cash-flow level  $\bar{\delta}_1$ .*

Proof of Proposition 7 : As in the proof of Proposition 1, the sign of  $\frac{dI^*}{d\sigma}$  is the same as the sign of  $\frac{\partial m}{\partial \sigma}$ . With the normality assumption, we have

$$g(\delta_{1,B}, \sigma) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(\delta_{1,B} - \bar{\delta}_1)^2}{2\sigma^2}}, \text{ and } G(\delta_{1,B}, \sigma) = \int_{-\infty}^{\delta_{1,B}} g(\delta_1, \sigma) d\delta_1.$$

Then, we obtain that

$$\frac{\partial g(\delta_{1,B}, \sigma)}{\partial \sigma} = g(\delta_{1,B}, \sigma) \frac{(\delta_{1,B} - \bar{\delta}_1)^2}{\sigma^3}, \text{ and } \frac{\partial G(\delta_{1,B}, \sigma)}{\partial \sigma} = \int_{-\infty}^{\delta_{1,B}} \frac{(\delta_1 - \bar{\delta}_1)^2}{\sigma^3} g(\delta_1, \sigma) d\delta_1.$$

Then, some algebra (details available upon request) leads to the following expression for  $\frac{\partial m}{\partial \sigma}$ :

$$\frac{\partial m}{\partial \sigma} = \frac{-f(I)g(\delta_{1,B}, \sigma)}{[1 - G(\delta_{1,B}, \sigma)]^2 \sigma^3} [(\delta_{1,B} - \bar{\delta}_1)^2 (1 - G(\delta_{1,B}, \sigma)) + \int_{-\infty}^{\delta_{1,B}} (\delta_1 - \bar{\delta}_1)^2 g(\delta_1) d\delta_1].$$

What matters for the sign of  $\frac{\partial m}{\partial \sigma}$  is thus the term inside  $[\cdot]$  on the right hand side. By writing  $(\delta_1 - \bar{\delta}_1)^2$  as  $(\delta_1 - \delta_{1,B} + \delta_{1,B} - \bar{\delta}_1)^2$ , and expanding, we obtain that this term can be expressed as

$$(\delta_{1,B} - \bar{\delta}_1)^2 + \int_{-\infty}^{\delta_{1,B}} [(\delta_1 - \delta_{1,B})^2 + 2(\delta_1 - \delta_{1,B})(\delta_{1,B} - \bar{\delta}_1)] g(\delta_1) d\delta_1.$$

Now, note that  $\int_{-\infty}^{\delta_{1,B}} (\delta_1 - \delta_{1,B}) g(\delta_1) d\delta_1$  is always negative. Therefore, if  $\delta_{1,B} < \bar{\delta}_1$ , then the entire term inside  $[\cdot]$  in the expression for  $\frac{\partial m}{\partial \sigma}$  is positive, and, in turn,  $\frac{\partial m}{\partial \sigma}$  is negative. This implies that under the condition that default risk of the firm is not too high, investment  $I^*$  declines with volatility and cash holdings  $c_1^*$  increase in volatility.  $\diamond$

**Effect of growth options:** Consider the benchmark model with growth option  $z$ , as described in Section C. We obtain the following result showing the effect of growth options on credit spreads:

**PROPOSITION 8.** *The equilibrium level of cash holdings,  $c_1^*$  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 8: At the optimal level of investment  $m(I^*, z) = 0$ , where  $m(I, z)$  is as defined in the proof of Proposition 1 but with  $f(I)$  replaced by  $[f(I) + z]$ . Then it follows that

$$\frac{dI^*}{dz} = -\frac{\frac{\partial m}{\partial z}}{\frac{\partial m}{\partial I^*}}$$

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<sup>28</sup> While this introduces the possibility of a negative cash flow to creditors, we assume that the parameters are such that this likelihood is tiny.

But  $\frac{\partial m}{\partial I^*} < 0$  because  $I^*$  is the optimal investment level, and so the sign depends on the sign of  $\frac{\partial m}{\partial z}$ . Taking the derivative of  $m(I^*, z)$  with respect to  $z$ , we obtain that this cross-partial derivative equals  $[-zh(\delta_{1,B})]$ , which is negative. It follows thus that  $\frac{dc_1^*}{dz} = -\frac{dI^*}{dz} > 0$ .

Next, note that  $\frac{ds}{dz} = \frac{B}{(B-L)^2} \frac{dL}{dz}$ , and from the expression for expected loss in equation (4), we obtain that  $\frac{dL}{dz} = -\frac{dc_1}{dz} Pr[\delta_1 < \delta_{1,B}] < 0$ .  $\diamond$

**Effect of agency costs:** Again, consider the benchmark model with private managerial costs upon distress  $\gamma$  and managerial ownership share of  $\theta$ , as described in Section C. Then, the following result which is analogous to that for growth options is obtained:

PROPOSITION 9. *The equilibrium level of cash holdings,  $c_1^*$  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 9: The proof is identical to the one above since it involves only replacing growth options  $z$  by the agency parameter  $\frac{\gamma}{\theta}$ .  $\diamond$

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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 calculated as 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 leverage-weighted average of the firm's one-year historic equity volatility and average bond volatility for the same rating. *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 nonfinancial 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 level, respectively.

	OLS (1)	CS (2)	FMB (3)	OLS (4)	CS (5)	FMB (6)
<i>Cash/Assets</i>	3.14** (2.57)	6.27*** (3.76)	1.96*** (3.58)	3.34*** (3.88)	3.05*** (2.73)	3.70*** (8.57)
<i>Leverage</i>				5.81*** (14.41)	5.17*** (18.27)	5.94*** (10.44)
<i>Asset volatility</i>				6.18*** (9.12)	7.59*** (10.33)	6.33*** (12.03)
<i>Log(Assets)</i>				-0.27*** (5.99)	-0.24*** (5.11)	-0.309*** (9.94)
<i>Maturity</i>				0.01 (1.10)	0.01 (0.66)	0.002 (0.12)
<i>Const.</i>	1.82*** (26.29)	1.78*** (16.59)	2.01*** (12.14)	0.33 (0.70)	13.45* (1.73)	1.05*** (3.59)
<i>Monthly dummies</i>	No	No		Yes	Yes	
<i>N</i>	24,258	24,258	24,258	21,527	21,527	21,527
<i>Adj. R<sup>2</sup></i>	0.01	0.03	0.01	0.49	0.78	0.43
<i>No. of months</i>			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 calculated as 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 leverage-weighted average of the firm's one-year historic equity volatility and average bond volatility for the same rating. *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 nonfinancial 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 level, respectively.

	AAA-AA (1)	A (2)	BBB (3)	BB (4)	B-CCC (5)
<i>Cash/Assets</i>	0.16 (0.44)	1.20* (1.86)	3.20*** (2.95)	4.52** (2.13)	8.34** (2.08)
<i>Leverage</i>	0.93*** (3.61)	1.27*** (4.89)	2.28*** (7.40)	6.27*** (6.94)	14.19*** (5.51)
<i>Asset volatility</i>	0.24 (0.78)	1.11*** (3.90)	1.78*** (3.37)	3.29** (2.02)	4.08 (1.34)
<i>Log(Assets)</i>	-0.03** (2.05)	-0.12*** (5.36)	-0.21*** (4.88)	-0.07 (0.57)	-0.86** (2.30)
<i>Maturity</i>	0.01*** (5.58)	0.01*** (5.86)	0.02*** (2.80)	0.02 (0.81)	0.11* (1.98)
<i>Const.</i>	0.50*** (3.34)	1.09*** (6.10)	1.36*** (3.26)	-1.30 (1.17)	-0.66 (0.19)
<i>Monthly dummies</i>	Yes	Yes	Yes	Yes	Yes
<i>N</i>	1,860	7,105	9,138	2,567	839
<i>Adj. R<sup>2</sup></i>	0.75	0.58	0.41	0.45	0.55

**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 first column of Panel A report the senior unsecured rating as of the first date the firm appears in the data set. 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 and 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 calculated as 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 leverage-weighted average of the firm's one-year historic equity volatility and average bond volatility for the same rating. *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 nonfinancial 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	0.233	0.220	0.173	0.276	0.090	22,457
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 3-digit SIC industry each year, as well as the *Agency term*, defined as the ratio of 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 leverage-weighted average of the firm's one-year historic equity volatility and average bond volatility for the same rating. Regressions (3) and (8) include a set of dummy variables for rating gradations from AA to CCC, by notch. *Model leverage* and *model volatility* are, respectively, the market value of debt divided by the market value of total assets, and the standard deviation of market asset returns, estimated from the series of equity prices and book debt values using the Merton (1974) model. The sample consists of monthly observations for nonfinancial 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 level, respectively.

	OLS					IV				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>Cash/Assets</i>	3.14** (2.57)	2.57*** (2.82)	0.48 (0.57)	0.82 (0.95)	0.69 (0.86)	-6.31*** (3.06)	-1.52 (0.69)	-3.40** (2.05)	-4.69** (2.25)	-4.34*** (2.69)
<i>Leverage</i>		6.54*** (16.47)	4.06*** (13.00)				6.00*** (11.50)	4.01*** (10.89)		
<i>Asset volatility</i>		8.81*** (14.21)	5.41*** (12.62)				9.30*** (12.35)	6.56*** (14.00)		
<i>Model leverage</i>				6.86*** (15.49)	6.43*** (14.53)				6.52*** (12.12)	6.10*** (11.86)
<i>Model volatility</i>				8.53*** (15.98)	7.92*** (12.93)				8.60*** (13.03)	7.86*** (10.49)
<i>Log(Assets)</i>					-0.29*** (7.90)					-0.25*** (6.23)
<i>Maturity</i>					0.02*** (3.40)					0.02*** (4.37)
<i>Rating dummies</i>	No	No	Yes	No	No	No	No	Yes	No	No
<i>Monthly dummies</i>	No	No	No	No	Yes	No	No	No	No	Yes
<i>Const.</i>	1.82*** (26.29)	-2.36*** (10.90)	-0.73*** (4.30)	-2.20*** (10.84)	0.35 (0.91)	1.99*** (18.59)	-2.17*** (8.09)	-0.51*** (2.63)	-1.95*** (8.06)	0.25 (0.63)
<i>N</i>	24258	21527	21527	23990	23990	17703	16112	16112	17654	17654
<i>Adj. R<sup>2</sup></i>	0.01	0.43	0.54	0.48	0.54	0.01	0.39	0.51	0.44	0.51

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. Regressions (1) to (4) are estimated using OLS. Regressions (5) to (7) are instrumental variable regressions that use the *R&D/Sales* ratio of the median firm in the same 3-digit SIC industry each year, as well as the *Agency term*, defined as the ratio of 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 leverage-weighted average of the firm's one-year historic equity volatility and average bond volatility for the same rating. *Model leverage* and *model volatility* are, respectively, the market value of debt divided by the market value of total assets, and the standard deviation of market asset returns, estimated from the series of equity prices and book debt values using the Merton (1974) model. *Current ratio* is the ratio of current assets to current liabilities. *Cash covenant* is a dummy variable that equals one if the firm's bank debt covenants restrict liquidity levels. Regressions (3) and (7) include a set of dummy variables for the 49 Fama-French industries. Except for regression (4), the sample consists of monthly observations for nonfinancial U.S. firms between December 1996 and December 2003. In regression (4), 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 level, respectively.

	OLS				IV		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Cash/Net assets</i>	3.24*** (3.68)	3.33*** (3.87)	3.08*** (3.60)	-1.34*** (3.45)	-3.70** (2.05)	-4.34*** (2.69)	-7.83** (2.38)
<i>Leverage</i>	6.15*** (14.80)	5.80*** (14.18)	6.15*** (14.79)	2.76*** (4.84)			
<i>Asset volatility</i>	6.36*** (9.26)	6.17*** (9.10)	4.88*** (8.02)	6.46*** (4.09)			
<i>Model leverage</i>					6.53*** (11.35)	6.11*** (11.75)	6.19*** (12.21)
<i>Model volatility</i>					7.73*** (10.25)	7.87*** (10.41)	7.73*** (10.27)
<i>Log(Assets)</i>	-0.24*** (4.87)	-0.27*** (5.88)	-0.31*** (6.63)	-0.29*** (5.75)	-0.22*** (4.68)	-0.25*** (6.22)	-0.25*** (5.66)
<i>Maturity</i>	0.01 (0.98)	0.01 (1.08)	0.01 (1.38)	0.04*** (3.13)	0.03*** (4.60)	0.02*** (4.31)	0.03*** (4.54)
<i>Current ratio</i>	0.03 (0.39)				0.04 (0.43)		
<i>Cash covenant</i>		0.15 (0.34)				-0.09 (0.26)	
<i>Industry dummies</i>			Yes				Yes
<i>Monthly dummies</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Const.</i>	-0.04 (0.08)	0.33 (0.69)	0.96** (2.14)	1.50*** (3.09)	-0.13 (0.29)	0.25 (0.65)	0.83* (1.96)
<i>N</i>	20596	21527	21346	5384	16801	17654	17508
<i>Adj. R<sup>2</sup></i>	0.50	0.49	0.54	0.45	0.53	0.51	0.51

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 one if the firm defaults within the following fiscal quarter, and zero otherwise. In regressions (3) and (4) the dependent variable equals one if the firm defaults in 12 to 15 months, and zero otherwise. In regressions (5) and (6) the dependent variable equals one if the firm defaults in 36 to 39 months, and zero 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, *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 level, respectively.

	1 quarter		1 year		3 years	
	(1)	(2)	(3)	(4)	(5)	(6)
Altman's (1968) z-score						
<i>WC/TA</i>	-1.66*** (3.72)		2.01*** (3.74)		3.87*** (5.51)	
<i>Cash/TA</i>		-0.84 (0.47)		2.21** (2.50)		5.01*** (7.03)
<i>(WC-Cash)/TA</i>		-1.69*** (3.73)		1.91*** (2.89)		2.87*** (2.97)
<i>RE/TA</i>	-0.12 (1.13)	-0.10 (0.99)	-0.30** (2.11)	-0.28* (1.86)	-0.50*** (4.28)	-0.37*** (2.72)
<i>EBIT/TA</i>	-2.52** (2.10)	-2.45** (2.02)	-1.93*** (4.38)	-1.90*** (4.20)	-0.88 (1.48)	-0.54 (0.73)
<i>ME/TL</i>	-5.22** (2.51)	-5.19** (2.49)	-1.38*** (2.62)	-1.39*** (2.63)	-0.28 (1.44)	-0.34 (1.59)
<i>S/TA</i>	0.19 (0.39)	0.22 (0.47)	-2.67*** (2.77)	-2.60** (2.53)	-0.80 (0.96)	-0.28 (0.39)
<i>Const.</i>	-2.78*** (6.23)	-2.83*** (5.79)	-3.49*** (10.89)	-3.51*** (10.42)	-4.91*** (17.24)	-5.01*** (18.38)
<i>N</i>	17950	17945	17950	17945	17950	17945
<i>Adj R</i> <sup>2</sup>	0.32	0.32	0.09	0.09	0.045	0.049
Zmijewski's (1984) model						
<i>CA/CL</i>	-0.05 (0.76)		0.03* (1.68)		0.08*** (4.00)	
<i>Cash/CL</i>		-0.21 (1.28)		0.04* (1.84)		0.08*** (3.86)
<i>(CA-Cash)/CL</i>		-0.00 (0.06)		0.02 (0.32)		0.11 (1.42)
<i>NI/TA</i>	-4.33*** (4.06)	-4.33*** (4.04)	-1.71*** (3.15)	-1.73*** (3.12)	-0.00 (0.00)	0.24 (0.25)
<i>TL/TA</i>	1.71*** (3.38)	1.71*** (3.37)	1.03*** (4.61)	1.03*** (4.59)	1.16*** (4.53)	1.17*** (4.59)
<i>Const.</i>	-6.36*** (15.51)	-6.35*** (15.68)	-5.79*** (30.02)	-5.77*** (28.02)	-6.09*** (27.83)	-6.13*** (25.62)
<i>N</i>	21627	21568	21627	21568	21627	21568
<i>Adj R</i> <sup>2</sup>	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 as 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 difference between current assets net of cash and current liabilities. *Short-term debt* is debt in current liabilities over total book assets. All these variables are measured at year-end  $t$ . 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 level, respectively.

	All firms		AAA-AA	A	BBB	BB	B-CCC
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rating change	0.10** (2.38)	0.11** (2.51)	-0.03 (0.08)	0.22 (1.13)	0.35*** (3.25)	0.32*** (3.17)	0.06 (0.98)
Cash flow	11.30*** (10.14)	14.91*** (11.32)	18.99* (1.91)	12.42*** (3.75)	9.68*** (3.23)	19.37*** (5.26)	15.61*** (9.21)
Market to book	0.16 (1.31)	0.45*** (4.39)	0.32 (1.21)	0.36* (1.75)	0.56*** (4.25)	0.62*** (2.84)	0.72*** (2.83)
Firm size	0.17*** (5.37)	0.10*** (2.83)	0.27 (1.28)	0.04 (0.83)	0.12** (2.52)	0.09 (1.54)	0.56*** (5.68)
Expenditures		-6.64*** (6.17)	-11.58 (1.63)	-8.94** (2.39)	-5.35*** (3.00)	-9.55*** (5.19)	-5.77*** (3.54)
Acquisitions		-7.93*** (8.39)	-7.34 (0.81)	-4.30** (2.01)	-8.56*** (5.06)	-8.24*** (6.04)	-9.25*** (5.25)
$\Delta$ NWC		-12.18*** (9.91)	-35.65 (1.08)	-15.67*** (4.32)	-8.71*** (3.21)	-13.27*** (5.48)	-12.28*** (6.91)
$\Delta$ Short debt		0.00** (2.48)	0.00 (0.78)	0.00* (1.71)	0.00** (2.01)	0.00*** (2.84)	0.00*** (2.96)
Const.	-1.89*** (6.19)	-1.20*** (4.00)	-3.08 (1.15)	-0.89 (1.35)	-1.44*** (2.99)	-1.37** (2.27)	-4.48*** (5.96)
N.	19227	17038	355	1976	4312	4065	6175
$R^2$	0.03	0.06	0.08	0.06	0.04	0.09	0.07

**Figure 1. Cash holdings by rating**

This graph shows 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.). *Cash/Net assets* is cash divided by total book assets net of cash.

