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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 positive correlation between cash and spreads. In contrast, spreads are negatively related to the "exogenous" component of cash holdings that is independent of credit risk factors. Similarly, although firms with higher cash reserves are less likely to default over short horizons, endogenously determined liquidity may be related positively to the longer-term probability of default. Our empirical analysis confirms these predictions, suggesting that precautionary savings are central to understanding the effects of cash on credit risk.

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1. Introduction

A firm's holdings of liquid assets, such as cash, affects the probability of corporate default and bankruptcy. This observation may in turn affect the firm's decision to retain a cash reserve that could otherwise be invested or paid out to shareholders. Standard econometric techniques commonly used in empirical studies of credit spreads and default probabilities ignore the interaction between the possibility of default and the firm's optimal cash policy, and may produce counter-intuitive and misleading results. This paper shows that the effect of cash holdings on credit risk is more subtle than traditional studies have implicitly assumed, and highlights the importance of adopting the corporate finance prospective of the firm in credit risk and other areas of asset pricing studies.

Since Black and Scholes (1973) and Merton (1974), a vast majority of theoretical models of risky debt pricing have ignored the role of cash. According to the standard view of the levered firm adopted by traditional "structural" models, should the firm find itself in a temporary cash shortage, it will always be able to avoid default by selling new equity at no cost, as long as the share price remains positive. As a result, the firm's cash holdings are irrelevant in most prominent credit risk models, including Black and Cox (1976), Leland (1994), Longstaff and Schwartz (1995), Leland and Toft (1996), Collin-Dufresne and Goldstein (2001), and others.[1] This view is mirrored in empirical studies of credit spreads and corporate bond returns, which also do not consider the role of cash holdings (e.g., Collin-Dufresne, Goldstein, and Martin (2001), Duffee (1998), and Schaefer and Strebulaev (2008)).

By contrast, since Altman's (1968) z-score model, most empirical default-predicting models have used various controls for balance sheet liquidity (e.g., Ohlson (1980), Zmijewski (1984), Shumway (2001), and Chava and Jarrow (2004)). Such studies select a set of accounting- or equity-based variables, and, taking them as given, estimate logit or hazard models of default or bankruptcy. With few exceptions, they typically control for corporate liquidity by using one or more liquidity proxies on the right-hand side. The results regarding the role of liquidity in these studies are mixed and often puzzling: For example, the coefficient for the current ratio is positive in Zmijewski (1984) and negative in Shumway (2001), whereas working capital is negative and significant in Ohlson

[1] Prominent exceptions include recently developed models by Acharya, Huang, Subrahmanyam, and Sundaram (2006), Anderson and Carverhill (2007), Gamba and Triantis (2008), Asvanunt, Broadie, and Sundaresan (2010), and Gryglewicz (2011), which allow for optimal cash holdings in the presence of costly external financing.

(1980) but positive and significant in Hillegeist *et al.* (2004). Yet such proxies continue to be used in this way in default-predicting studies due to their intuitive appeal.

Liquidity is expected to play a role in distress because, contrary to the assumption of perfect capital markets adopted by structural models, in reality firms' access to external financing may be restricted (e.g., Fazzari, Hubbard, and Petersen (1988)). As a result of market frictions, cash reserves affect the timing of default after controlling for the firm's economic prospects (Davydenko (2010)). Ceteris paribus, firms with larger liquid asset reserves are expected to be safer and thus have lower credit spreads and smaller default probabilities.

Yet the standard reduced-form empirical approach commonly used to study spreads and the probability of default appears to lead to an opposite conclusion, that firms with larger liquid assets exhibit higher degree of credit risk. OLS regressions of bond spreads for non-financial firms reveal that spreads are positively, not negatively, correlated with cash holdings. This result holds true with and without controls for standard credit risk factors used in empirical studies, such as leverage, volatility, and credit rating. The effect is robust, persistent, and significant, both statistically and economically. A one standard deviation increase in the cash-to-asset ratio is associated with a 20 basis point increase in credit spreads. Furthermore, intuition suggests that even if for most firms default triggered by a cash shortage is a remote 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 lower-rated firms. Yet once again this intuition appears in conflict with the data. Figure 1 shows the point estimate and the 95% confidence interval for the coefficient for cash holdings (normalized by book assets) in a panel regression that controls for leverage, asset volatility, firm size, debt maturity, and time effects.[2] The spread-cash coefficient is positive for all ratings, and increases monotonically as the rating deteriorates. The correlation between cash and spreads is almost 25 times as high for the lowest ratings (B–CCC) as for the AAA–AA-rated bonds – and positive.

Similar relationships are found in predictive regressions of the long-term probability of default. These tests are closely related to a series of classic empirical default-predicting models, including Altman's (1968) Z-score, Ohlson's (1980) O-score, Shumway (2001), Chava and Jarrow (2004), and

[2]Specifically, this is the coefficient for *Cash/Assets* obtained from regression (3) of Table 4, estimated separately for different ratings. A detailed description of the data and the empirical methodology is provided in Section 4.

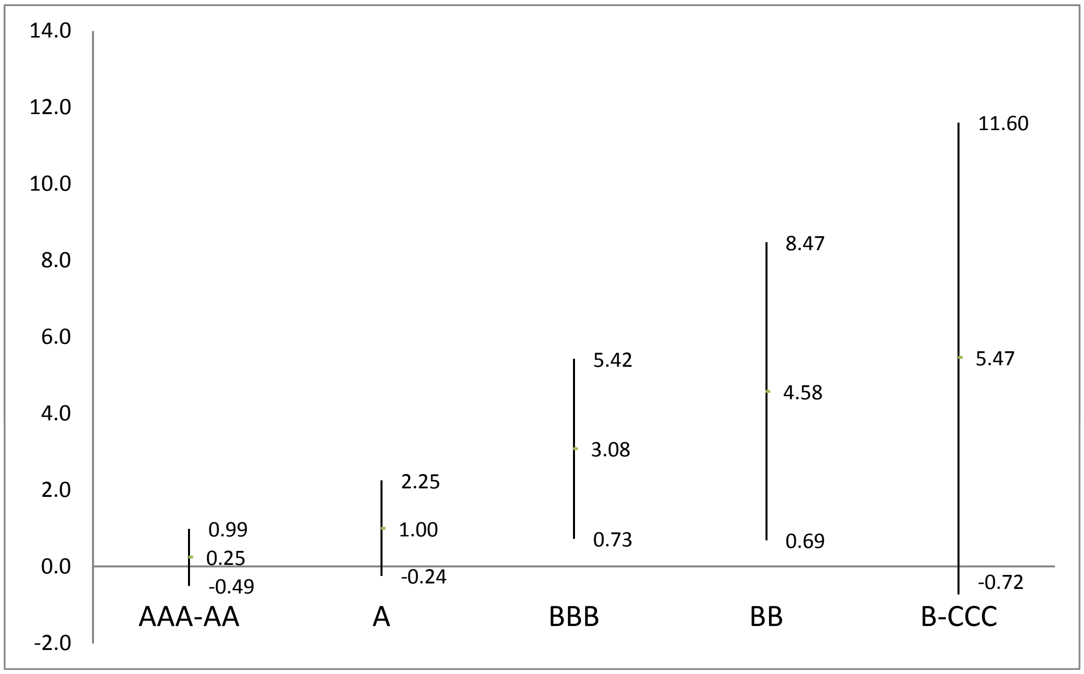

Fig. 1. The correlation between credit spreads of cash holdings by rating. This graph shows the point estimate and the 95% confidence interval for the coefficient for *Cash/TA* in regression (3) of Table 4, estimated separately for each rating group.

many others. For illustration, we use the model suggested by Zmijewski (1984), although many other specifications work similarly. Zmijewski regresses the one-year probability of bankruptcy on the current ratio (current assets over current liabilities), which is a commonly used measure of liquidity, and two other accounting ratios. Surprisingly, he finds liquidity to be positively (albeit insignificantly) associated with default in most subsamples. We re-estimate his model for prediction horizons between one quarter and three years, and find that the correlation of liquidity with default depends on the horizon, as shown in Figure 2. The short-term probability of default is lower when liquid asset reserves are high, consistent with intuition and the findings of Davydenko (2010). However, for horizons of one year and more, the correlation between cash and default reverses sign, as in Zmijewski (1984), and soon becomes strongly statistically significant – again with the wrong sign.

The positive correlation between corporate liquidity and both credit spreads and the long-term default probability is a robust phenomenon, observed for other data sets and time periods. Thus, standard tests used in empirical studies of spreads and default probabilities seem to suggest that higher liquidity results in higher credit risk.

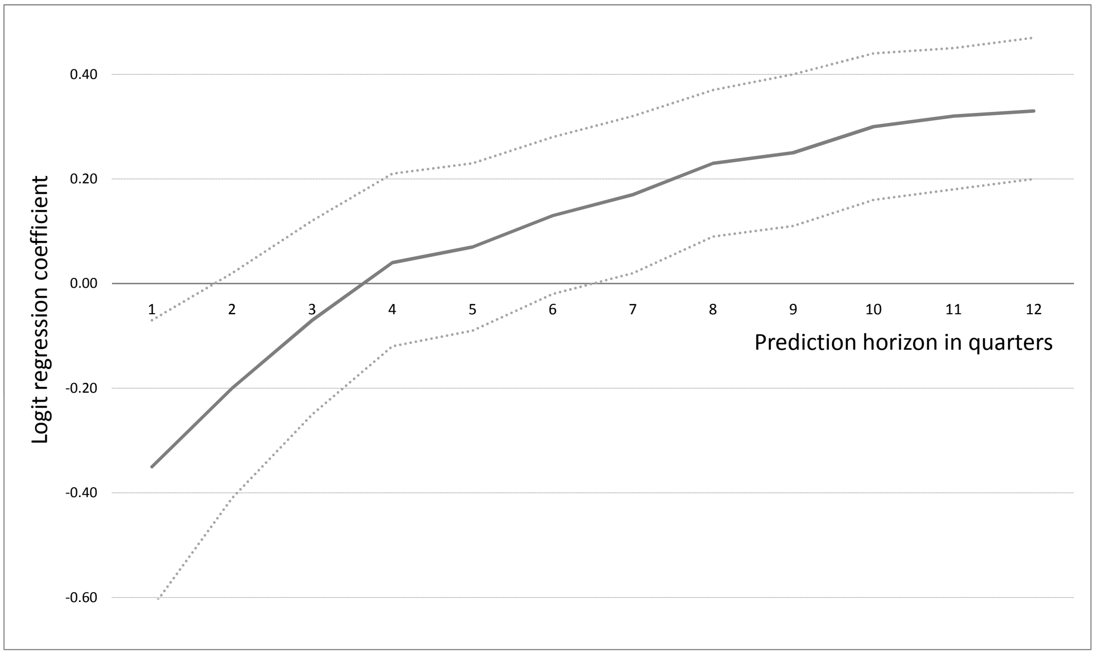

Fig. 2. Liquid assets and the probability of default at different horizons. This graph shows the point estimate and the 95% confidence interval for the coefficient for the current ratio QA/CL in regression (2) of Table 6 for different prediction horizons. For a horizon of m quarters, the dependent variable equals one if the firm defaults no more than in m quarters from the observation date.

How can these puzzling empirical findings be reconciled with the simple economic intuition that cash makes firms safer? We suggest an explanation based on the endogeneity of cash holdings. Although endogeneity is recognized as a major issue in empirical corporate finance and many other areas of economic research (Roberts and Whited (2011)), it has attracted less attention than it warrants in credit risk studies and many other the fields of asset pricing.

We argue that the endogeneity of cash holdings is of first-order importance for understanding the role of cash in credit risk. In the presence of financing constraints, riskier firms may choose to maintain higher cash reserves as a buffer against the possible cash flow shortfall. Such endogenous adjustments in cash holdings can induce a spurious positive correlation between credit spreads and cash holdings in equilibrium. This effect means that standard OLS and logit regressions common in empirical credit risk research may yield misleading results. To show how a positive correlation between cash and credit spreads can arise under endogenous cash policy, we first construct a simple model of cash in the presence of credit risk. We then present evidence that the positive correlation between cash and spreads is spurious rather that causal, and that it is reversed when we control for the endogeneity of cash holdings.

Our model features a levered firm that can either invest its cash in a long-term project or retain it as a cash buffer against a possible shortfall that can occur when the firm's debt comes due. Future cash flows cannot be pledged fully as collateral because of market frictions, and default is costly. In this setting, higher investment implies higher cash flows in the future, provided the firm does not default in the interim period. At the same time, higher cash reserves mean a lower probability of a cash shortage when the debt payment is due.

An exogenous change in factors that affect firm's credit risk affect its credit spreads not only directly but also indirectly as the firm adjusts its cash reserve in response. For example, if the expected future cash flows decline exogenously, the probability of default rises, causing credit spreads to increase. At the same time, the firm optimally increases its cash holdings, which reduces the probability of a cash shortfall when the debt comes due, implying lower spreads. We show that the direct effect dominates as long as constraints on external financing are binding, so that riskier firms have both higher optimal cash reserves *and* higher credit spreads, inducing a positive correlation between the two, which we empirically find is the case in the cross-section of firms.

However, "exogenous" variation in cash holdings unrelated to credit risk factors, for instance, due to managerial self-interest, is *negatively* correlated with spreads, in line with the simple intuition. Empirically, we find that the correlation between cash and spreads turns negative when we use instrument variations in cash by variables implied by the model (proxies for managerial self-interest and firm's long-term investment opportunities).

The model also shows that the correlation between liquid assets and the probability of default depends on the prediction horizon, consistent with Figure 2. Higher cash reserves reduce the probability of default in the short term, but may increase it over a longer period. This happens because in order to save more cash the constrained firm reduces investment, which results in lower future cash flows and a higher probability of a long-term cash flow shortfall. Empirically, we find that for prediction horizons of one year or more, which most researchers focus on, the positive correlation between liquidity and default reverses sign in instrumental variable regressions.

The main implication of our results is that empirical studies of credit risk (and potentially other areas of asset pricing) should devote more attention to the potential endogeneity of some of the variables that are often taken as given. Otherwise, using some of the most common variables, such as corporate liquidity proxies, in some of the most standard tests, such as predictive regressions of default, may yield grossly misleading results.

Theoretical and empirical research in corporate finance has focused increasingly on the fact that corporate cash holdings are endogenously determined.[3] The primary focus of this literature is on financial constraints, which create a precautionary motive for hoarding cash. However, extant studies do not explicitly link cash holdings to credit risk or credit spreads. Moreover, empirical corporate finance studies focusing on constraints and cash holdings classify firms as constrained when they are small, do not have a credit rating, and have no access to the public bond market. In contrast, our focus in this paper is on explaining the linkage between cash holdings and credit risks for large firms with rated public bonds, which would be considered unconstrained according to the standard corporate finance classification. Our model derives a relationship between cash holdings and credit risk, holding constant the difficulty of accessing external finance. The model thus lends itself naturally to studying cross-sectional variations within firms that are publicly rated but differing in their credit risk levels.

The remainder of this paper is organized as follows: Section 2 presents the model. Section 3 describes the data set. Section 4 studies the relationship between cash and credit spreads, and Section 5 look at the role of liquidity in empirical default-predicting models. Section 6 concludes. Proofs are provided in the Appendices.

2. The model

This section develops a simple stylized model of the firm's endogenous cash policy in the presence of costly default and restricted access to outside financing. Our main goal is to show that cash holdings in equilibrium can be positively correlated with credit spreads and default risk, and to disentangle the intuitive prediction that cash-rich firms should be 'safer' from the confounding effects of endogeneity.

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

2.1. Base case model setup

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

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

In what follows, we assume the hazard rate $h(\psi)$ to be weakly monotonic.[4]

At $t = 0$, the firm has a cash endowment of c_0, which can be fully or partially invested in the long-term project, or retained within the firm as a buffer carried over from date 0 to date 1 to meet a future cash shortfall. We denote the investment amount as I and the cash buffer as c, equal to $(c_0 - I)$. The shortfall in future can arise as the firm needs to make a debt repayment at date 1 and has uncertain cash flows arriving at date 1 from assets in place. In particular, at $t = 1$, the firm receives a random cash inflow of $\hat{\delta} = \delta + \psi$ but owes a fixed amount B in debt. In the model, debt level is predetermined (a legacy of the past), whereas retained cash reserves can be chosen by the firm at $t = 0$.[5] We also assume that debt cannot be renegotiated due to high bargaining costs; for example, it might be held by dispersed bondholders prone to co-ordination problems.

If the firm has insufficient funds to repay the debt in full at $t = 1$, it defaults and is liquidated, in which case future cash flows from the long-term investment, $f(I)$, are lost. We model a financing

[4] This assumption is unrestrictive and often appears in economic applications, such as game theory and auctions (e.g., Fudenberg and Tirole (1991, p. 267)). Bagnoli and Bergstrom (2005) show that the hazard rate is weakly monotonic if function $(1 - G(\psi))$ is log-concave, which holds for uniform, normal, logistic, exponential, and many other probability distributions.

[5] Although firms can choose not only cash holdings but also debt levels, observed variations in cash holdings are much larger than those in leverage ratios. For the median non-financial firm in Compustat with a non-trivial amount of debt in the capital structure, the coefficient of variation (standard deviation divided by the mean) for cash as a proportion of total assets is 0.80, compared with 0.36 for total debt over total assets and only 0.27 for book equity over total assets, with differences significant at the 1% level. Thus, cash policy is likely to be more easily adjusted than debt levels. We therefore treat debt as exogenous in our analysis of the optimal cash policy.

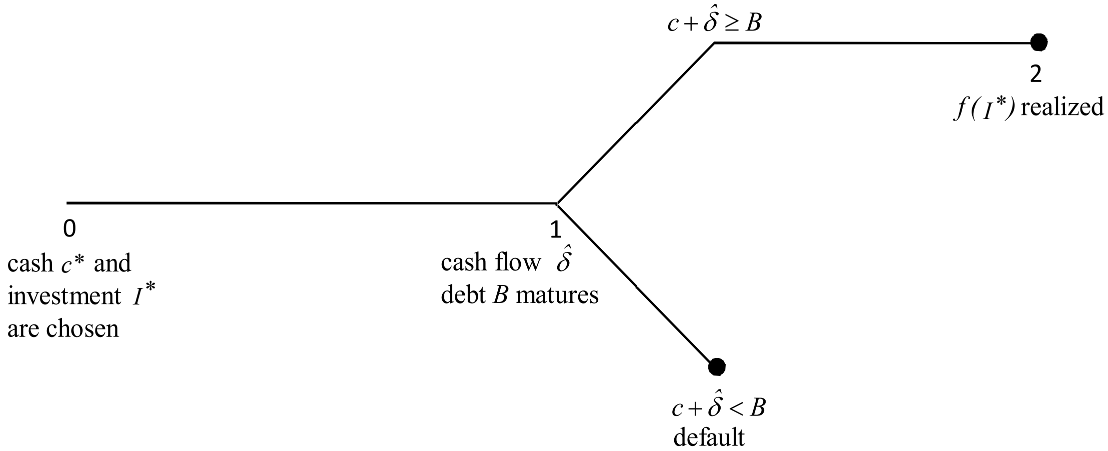

Fig. 3. Timeline of the model

friction at $t = 1$ by assuming that the firm can use only a fraction τ of its future cash flows as collateral for new financing, where $0 \leq \tau < 1$ and $\tau = 0$ corresponds to the case of extreme financing frictions, when the firm cannot raise *any* external financing against its future cash flows.[6] The firm's equityholders maximize the final period return. The risk-free rate of interest is normalized to zero, and in the base case, managers act in the best interest of shareholders. Figure 3 illustrates the model's timeline.

The maximum amount of cash available for debt service at date 1 is $c + \delta + \psi + \tau f(I)$, which is the sum of the cash reserve c, the random cash flow $\hat{\delta} = \delta + \psi$, and the newly borrowed amount $\tau f(I)$. The "default boundary," or the minimum cash flow shock that allows the firm to repay B in full and avoid default, is:

$$\psi_B = B - c_0 - \delta + I - \tau f(I). \tag{2}$$

The total payoff to equityholders is the sum of the initial cash endowment, the period 1 cash flow, and the payoff from long-term investment, less the invested amount and debt payment, provided that the firm does not default on its debt. The market value of equity is therefore

$$E = \int_{\psi_B}^{\infty} [-I + c_0 + \delta + \psi - B + f(I)] g(\psi) d\psi. \tag{3}$$

Conditional on survival, raising new financing at $t = 1$ in this setting is value neutral, so we assume

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

without loss of generality that the firm always raises the maximum available amount, $\tau f(I)$. The equity value in Equation (3) can be rewritten as

$$E = \int_{\psi_B}^{\infty} [(\psi - \psi_B) + (1 - \tau) f(I)] g(\psi) d\psi, \tag{4}$$

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

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

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

$$D = B - \int_{-\infty}^{\psi_B} [B - (c + \hat{\delta})] g(\psi) d\psi, \tag{5}$$

which can be interpreted as the face value of debt B, adjusted for the loss that creditors expect to incur in default states $[-\infty, \psi_B]$. Note that creditors recover the amount $(c + \hat{\delta})$ in case of default. Because interest rates are zero, the credit spread, denoted s, equals the total debt yield, given by

$$s = \frac{B}{D} - 1. \tag{6}$$

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

$$\frac{ds}{dx} = \frac{\partial s}{\partial x} + \frac{\partial s}{\partial c} \times \frac{dc}{dx}. \tag{7}$$

It is easy to show that $\frac{\partial s}{\partial c} < 0$, which is the intuitive result that higher cash holdings result in lower credit spreads *provided everything else is held constant*. At the same time, the direct effect of x on the spread, $\frac{\partial s}{\partial x}$, and on cash holdings, $\frac{dc}{dx}$, depends on the nature of x. As the next subsection shows, these two effects can work in opposite directions and yield a positive overall correlation between credit spreads and cash.

2.2. Endogenous cash policy and credit risk

In this subsection, we show that variations in the firm's expected cash flow δ may result in a positive correlation between credit spreads and optimal cash holdings.

Let I^* denote the firm's optimal investment and c^* the optimally chosen cash reserve: $c^* = c_0 - I^*$. Let s^* represent its credit spread in equilibrium, $s^* = s(c^*)$. The following proposition summarizes the effect of the expected interim cash flow δ on equilibrium cash holdings, as well as its net effect on the credit spread (see the Appendices for all proofs).

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

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

The first part of Proposition 1 states that if the hazard rate $h(\cdot)$ is non-decreasingand external financing is restricted ($\tau < 1$), then "riskier" firms with lower expected interim cash flow, which face a higher risk of a cash flow shortage at the time when debt is due, optimally choose a higher cash reserve. Empirical evidence in support of this prediction appears in Figure 4b, which shows that for firms with low interest coverage ratios for which our effects are relevant, cash holdings are decreasing with the size of the cash flow (scaled by debt service).

The second part of Proposition 1 states that despite their larger cash buffer, firms with lower expected cash flows have higher credit spreads, provided that restrictions on external financing are binding (that is, the pledgeability of assets is sufficiently low). Thus, the direct effect of the lower cash flow is to increase spreads by more than the indirect effect decreases them through the rise in precautionary savings. Formally, in Equation (7) with $x = \delta$, we have $\frac{\partial s}{\partial \delta} < 0$ (other things being equal, an increase in the cash flow reduces spreads), $\frac{dc^*}{d\delta} \leq 0$ (higher cash flow means lower precautionary savings), and even though $\frac{\partial s}{\partial c^*} < 0$ (lower savings mean higher spreads), the first effect dominates, so that $\frac{ds}{d\delta} < 0$ (overall, spreads and cash flows are negatively correlated). Hence, both the spread s^* and the cash reserve c^* increase when expected cash flows fall. In practice, this means that when cash flow levels are allowed to vary over time or in the cross-section, this variation is likely to induce a positive correlation between endogenously chosen cash reserves and credit spreads.

It should be noted that the same effect may arise due to variation in firm characteristics other than cash flow, if they affect both spreads and optimal cash holdings. For example, consider variations in debt levels across firms. Suppose that the firm's debt level increases. The direct effect of this increase is to raise spreads. However, at the same, time optimal cash holdings also rise, which dampens the effect of higher debt levels on spreads. It can be shown that the direct effect dominates, much as in the case of varying cash flows in Proposition 1. As a result, more indebted firms have both higher cash levels and higher spreads, implying a positive cross-sectional correlation between the two.

2.3. Exogenous variations in cash

In this subsection, we look at the effect of "exogenous" variations in cash, which are not induced by variations in credit risk factors. Suppose that cash holdings also depend on a variable x that does not affect spreads directly, so that in Equation (7), $\frac{\partial s}{\partial x} = 0$, implying that x can be correlated with spreads only through its effect on cash. Then, variations in cash induced by variations in x are negatively correlated with spreads. This dependence is consistent with the simple intuition that firms with more cash should be "safer" and have lower credit spreads.

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

What economic factors might affect cash holdings but not the value of debt, other than indirectly through their effect on cash? As an illustration, we augment the model to allow managers' optimally chosen cash holdings to depend on growth options (future investment opportunities) and the structure of managerial compensation.[7]

Growth options: We model the firm's growth options as an investment opportunity that will be open to the firm at the interim date $t = 1$ and will yield a cash flow at date 2. If this investment is

[7] Other examples include cash windfalls or losses unrelated to managers' cash policy decisions. For instance, the firm may win a lawsuit, resulting in a cash inflow from the defendant.

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

Formally, equityholders' value can be written as:

$$E = \int_{\psi_B}^{\infty} [-I + c_0 + \delta + \psi - B + f(I) + z] g(\psi) d\psi \ . \tag{8}$$

We show in Appendix B that the presence of growth options decreases initial investment, because the incentive to survive is now stronger. In particular, the total effect of the change in growth options on credit spreads consists of only the indirect effect through the optimal cash balance. Hence, the cross-sectional variation in optimal cash holdings induced by growth options should be *negatively* correlated with credit spreads.

Managerial losses in distress: Default involves private costs for the management. Gilson (1989) notes that such costs may arise because of the loss of future income, firm-specific human capital, or non-pecuniary benefits, such as power and prestige, and because of adverse reputation effects. He finds empirically that the top management of distressed firms is almost three times as likely to be replaced as that of non-distressed firms. Managers' private costs of distress likely depend on the structure of their compensation contracts. Differences in managerial compensation across firms should thus result in different incentives for managers to avoid default, because the private costs differ. That is, for managers of two firms with the same underlying credit risk, the precautionary motive for saving cash may be weaker or stronger, depending on their compensation structure. In this way, differences in managerial compensation induce an exogenous variation in cash holdings.

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

$$M = \theta \times E - \gamma G(\psi_B). \tag{9}$$

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

2.4. Cash and the probability of default

Another important aspect of credit risk that we investigate is the correlation of cash with the probability of default. We show that the correlation between the two depends on the horizon over which we measure the likelihood of default. In choosing the optimal cash reserve, the firm's managers trade off the reduction in the risk of default at date 1 (short-term effect) against investment returns realized only at date 2 (long-term effect). We extend our model to show that higher cash reserves reduce the likelihood of default in the short run, but smay increase it in the long run.

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

Next, consider the risk of default at date 2. Suppose that the firm has not defaulted at date 1, so that $\psi > \psi_B$. Then, the firm's available resources for debt payment at date 2 are the surplus cash reserve carried over from period 1, which is equal to $\delta + \psi + c - B_1$, and the investment cash flow $f(I)$.[8] Default occurs at date 2 whenever $(\delta + \psi + c - B_1) + f(I) < B_2$, which implies a default

[8] For simplicity, we assume that the firm carries its surplus cash reserve to date 2. In general, if B_2 due is very high,

boundary below which the firm defaults at date 2, expressed in terms of date 1 cash flow shock, as $\psi_{B_2} = \psi_{B_1} + B_2 - f(I)$. Because we assume that cash flows at date 2 are known with certainty, if the firm survives at date 1 and its outstanding debt B_2 is lower than the investment return $f(I)$, then its conditional likelihood of default at date 2 is zero. If B_2 is higher than the investment return $f(I)$, there is a positive probability of default at date 2 as well. To avoid default in future, the firm's remaining cash after date 1 debt repayment must be sufficiently high.[9]

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

$$\frac{d\psi_{B_2}}{dI} = \frac{d\psi_{B_1}}{dI} - f'(I) = 1 - f'(I). \tag{10}$$

Because the probability of default in period 2 is increasing in ψ_{B_2}, this equation formalizes the following trade-off: Higher cash reserves decrease the probability of default at date 1, $\frac{d\psi_{B_1}}{dI} > 0$. However, since $1 - f'(I) < 0$ whenever there is a financing friction, the probability of default in the longer-term increases as the firm increases its cash reserve at the expense of long-term investment:

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

3. Data description

In our empirical analysis, we use a sample of firms with observed bond spreads to study how liquid asset holdings are related to spreads and the probability of default.

3.1. Data sources and sample composition

We study yield spreads on bonds included in the Merrill Lynch U.S. Investment Grade Index and High Yield Master II Index between December 1996 and December 2003. The Merrill Lynch indices include corporate bonds with a par amount of at least 100 million dollars and remaining maturity of at least one year. The bond pricing database consists of monthly bid quotes from Merrill Lynch's

equityholders may have a strategic motive to pay out the cash reserves as dividends in earlier periods, as otherwise all this cash would simply accrue to creditors (Acharya, Huang, Subrahmanyam, and Sundaram (2006)). We assume that covenants restrict such strategic dividends, as is typically the case.

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

bond trading desks. We augment these data with descriptive bond information from the Fixed Income Securities Database (FISD) provided by Mergent. We merge the data with quarterly Compustat and CRSP, and also use expected default frequencies (EDFs) and estimates of the volatility of assets supplied by Moody's/KMV. Also, 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.

During the sample period, the two Merrill Lynch indices include 429,420 monthly corporate bond quotes. We exclude observations that we cannot reliably merge with FISD and Compustat, and in most of our tests, unless specifically stated otherwise, we also exclude bonds issued by financial companies (SIC codes 6000–6999). We eliminate non-fixed coupon bonds; asset-backed issues; bonds with embedded optionalities, such as callable, puttable, exchangeable, and convertible securities; and bonds with sinking fund provisions. Finally, we exclude bonds with remaining time to maturity of less than one year or more than thirty years, because the data on the risk-free rate that we use to estimate spreads are not available for these maturities. The final sample includes 82,676 bond spreads for 485 different firms.

Table 1 shows the composition of our sample by rating and by industry. Most of our regressions include one firm observation per month; we have 24,496 such observations. Three quarters of the sample are concentrated in the two lowest investment-grade categories, A and BBB. Junk firms (those rated BB and lower) represent 16.4% of the sample. This composition is similar to that documented in other corporate bond and credit default swap data sets (e.g., Collin-Dufresne, Goldstein, and Martin (2001), Davydenko and Strebulaev (2007), Schaefer and Strebulaev (2008)).[10] Panel B of Table 1 shows the composition of the sample by industry. The highest proportion of firms are in manufacturing, followed by utilities and transportation, and then consumer goods.

[TABLE 1 HERE]

[10] The number of firms in each rating class does not stay constant throughout the sample period, because ratings can change over time. Statistics reported in the first column of Table 1 show ratings for the 485 firms as of the date when they first appear in the sample. During our sample period, more firms were downgraded than upgraded. As a result, for junk ratings, the proportion of firm-months in the sample is higher than the proportion of junk firms firms in the second column of the table.

3.2. Statistics on spreads and liquidity ratios

We measure the credit spread as the difference between the bond's promised yield implied by its price, and the yield on a portfolio of risk-free zero-coupon securities (STRIPS) with the same promised cash flow, as suggested by Davydenko and Strebulaev (2007). This estimation method controls accurately for the shape of the term structure. Our initial data set is an unbalanced panel of monthly observations of spreads. A potential issue with this data structure is that large firms with many outstanding bonds may be overrepresented in any given month. Because we are interested in the relationship between credit risk and liquid assets, which are firm– rather than bond-specific, using all bond-month observations may bias the results toward large firms. We address this issue by computing the average spreads across bonds for a given firm in a given month, and using one observation per firm-month in our analysis. We also 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.

Panel A of Table 2 reports descriptive statistics on the spreads. The mean spread in the sample is 192 basis points, and the median is 135 basis points. Unsurprisingly, 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 (372 basis points) is more than twice as high as that for BBB bonds (181 basis points). This jump in the spread is likely attributable to not only the increase in the probability of default but also the lower liquidity of speculative-grade bonds (BB and below) compared with investment-grade bonds.

Panel B summarizes various measures of balance sheet liquidity. To measure liquid asset reserves, we use the Cash/Assets ratio popular in empirical corporate finance studies, as well as liquidity ratios employed in empirical default-predicting models. 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; Zmijewski's (1984) model and the ZETA-score model of Altman, Haldeman, and Narayanan (1977) use the current ratio CA/CL (current assets over current liabilities); and Ohlson (1980) and Chava and Roberts (2004) use both WC/TA and CL/CA to proxy for liquidity. Davydenko (2010) uses the quick ratio, QA/CL, equal to current assets less inventories, over current liabilities. The quick ratio is similar to the current ratio, but does not consider inventories to be part of liquid asset holdings, because distressed firms may find it difficult to convert their inventories into cash. Panel B shows that, our firms have substantially lower cash reserves on average than those in the broader Compustat samples typically used in empirical studies of cash holdings. For instance, in Opler, Pinkowitz, Stulz, and Williamson (1999), the mean (median) ratio of cash to assets is 17% (6.5%), compared with 3.9% (2.0%) in our sample.[11]

[TABLE 2 HERE]

The potentially ambiguous nature of the spread-cash relationship is illustrated by Figure 4a, which summarizes cash holdings by credit rating and by the interest coverage ratio. The graph shows that cash is roughly U-shaped in the firm's credit quality. Safe AAA and AA firms have higher-than-average cash holdings and low debt levels. Their high balance sheet liquidity and low net leverage are likely important reasons for why rating agencies rate them so highly in the first place. For such firms, the risk of default is unlikely to be a leading factor shaping their cash policy. However, at the other end of the ratings spectrum, speculative-grade (junk) firms (those rated below BBB–) also have higher-than-average cash holdings, and lower grades of junk generally correspond to higher cash reserves. We argue that this pattern is due to levered firms' precautionary motives for saving cash. Despite their relatively high cash reserves, these firms remain riskier than A- or BBB-rated firms because of their much higher levels of debt relative to their cash flows. Indeed, even relatively high cash holdings of 5.8% of net assets for B-rated firms fade to insignificance next to their leverage ratios, which on average exceed 66%. As a result of these pattern of cash holdings, cash turns out to be positively associated with spreads in cross-section, with a stronger relationship for riskier firms.

Figure 4b shows a similar U-shaped relationship between cash and the interest coverage ratio, defined as cash flow over interest payments. Firms with lower coverage ratios face a higher risk of a cash flow shortage, so that, in contrast to Figure 4a, riskier firms are represented by the left part of this graph. Our model predicts that equilibrium cash holdings are non-increasing in cash flow. Figure 4b demonstrates that in the region where credit risk is likely to be a concern (i.e., in the left part of the graph), cash holdings increase as the cash flow (normalized by debt payments) decreases, as predicted by the model.

[11]These differences arise in part because our sample does not include firms with zero or near-zero leverage, which tend to hold significant amounts of cash (Strebulaev and Yang (2006)), and in part because bond issuers are likely to be less financially constrained and value cash holdings less than an average Compustat firm (which should work against our finding of any effects related to the optimally chosen cash policy).

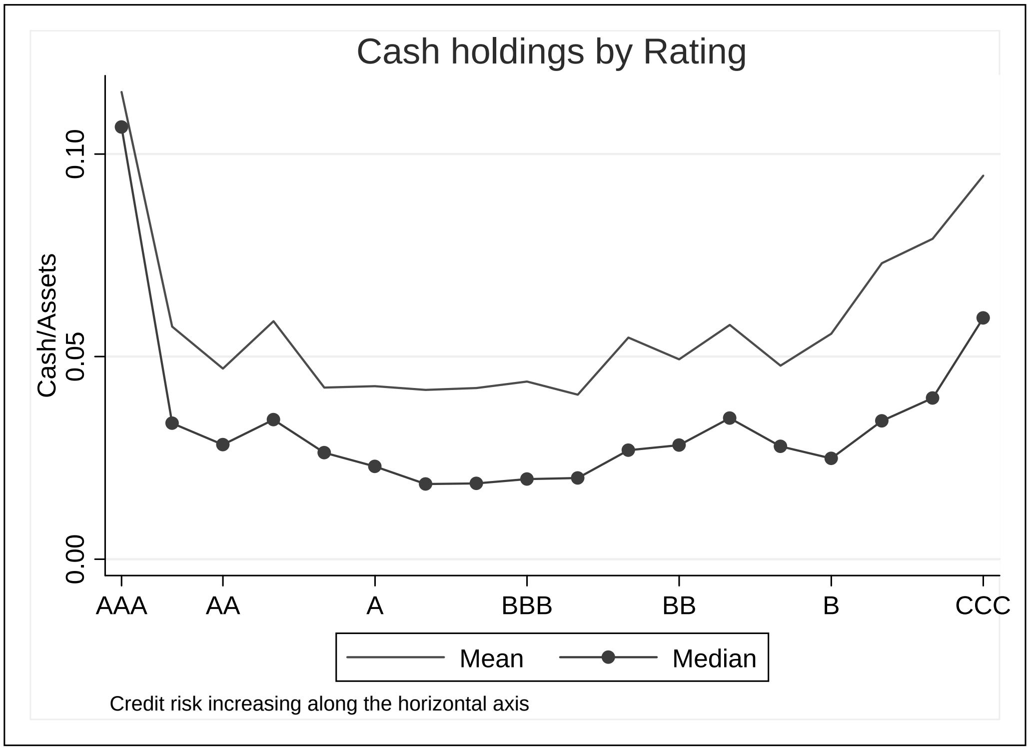

Fig. 4a. Cash holdings by rating. This graph shows means and medians of the ratio of cash to total assets by the firm's senior unsecured rating.

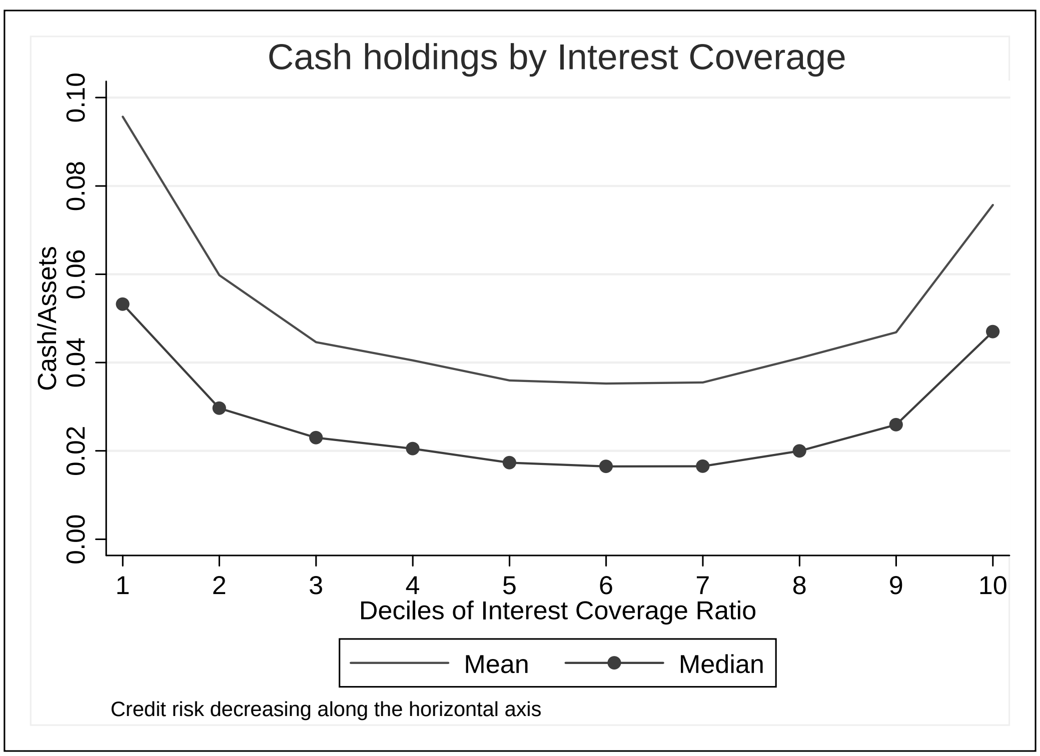

Fig. 4b. Cash holdings by interest coverage. This graph shows means and medians of the ratio of cash to total assets by deciles of the *interest coverage ratio*, computed as EBITDA divided by interest expense.

3.3. Control variables

Table 3 presents descriptive statistics on the control variables used in regressions of spreads and default probabilities, which we borrow from extant empirical research.

Based on insights from structural models of credit risk, empirical studies of spreads control for leverage, volatility, debt maturity, and various macroeconomic factors, in particularly those related to the term structure of the risk-free rate of interest (e.g., Collin-Dufresne, Goldstein, and Martin (2001)). We estimate the (quasi-market) *leverage ratio* as the book value of total debt divided by the sum of the book value of debt and the market value of equity at the end of the previous fiscal quarter. Another factor featuring prominently in credit risk models, the volatility of assets, is not directly observable. We use estimates of *firm asset volatility* supplied by Moody's/KMV, which employs a proprietary algorithm based on the Merton (1974) model to infer volatility from the time series of equity prices. To control for the term premium in corporate bond yields, we use the average remaining *time to maturity* of all sample bonds outstanding for the firm at each observation date. We include the logarithm of total book assets to control for all influences that the firm's size may exert on debt spreads. In some of the regressions we also use the firm's senior unsecured credit ratings by notch from Standard and Poor's (AAA, AA+, AA, AA–, ..., C), which summarizes the credit agency's opinion of the firm's creditworthiness and incorporates not only its financial characteristics but also industry conditions and other, frequently soft, information. Finally, Collin-Dufresne, Goldstein, and Martin (2001) find that a significant part of monthly changes in spreads is driven by unidentified systematic factors. To control for all economy-wide factors, including the risk-free rate of interest, we use monthly dummies in our regressions of spreads.

Default-predicting models have identified a large number of accounting- and market-based variables related to default. We re-estimate two of the best-known models, those of Altman (1968) and Zmijewski (1984), as well as one that uses the Expected Default Frequency (EDF) from Moody's/KMV. Altman's z-score includes WC/TA (the liquidity proxy), as well as RE/TA (Retained Earnings over Total Assets), $EBIT/TA$ (Earnings Before Interest and Tax over Total Assets), ME/TL (equity market capitalization over Total Liabilities), and S/TA (Sales over Total Assets). Zmijewski's model includes the current ratio CA/CL as the liquidity proxy, NI/TA (net income over Total Assets), and TL/TA (Total Liabilities over Total Assets). Finally, we estimate a simple model that uses the quick ratio QA/QL as the liquidity proxy and the *EDF* from Moody's/KMV as a summary measure of credit risk. MKMV estimates the EDF based on the firm's equity prices and liability structure using a version of the Merton (1974) model in conjunction with a proprietary data set of defaults (Crosbie and Bohn (2002)). Hillegeist *et al.* (2004) and Bharath and Shumway (2008) show that variants of this variable are strong predictors of default.

Table 3 shows that our firms are relatively large in size, with median total book assets of almost $6.5Bn. This is to be expected, given that all of them issue public bonds. They also have relatively high leverage ratios compared with broad Compustat samples not conditioned on the presence of public bonds in the capital structure. Statistics on leverage and asset volatility are similar to those in other credit risk studies. Looking at firm characteristics by rating (not reported), we find that firms with higher ratings are larger, less levered, and more profitable; have slightly larger capital expenditures; and return substantially more cash to shareholders via dividends and repurchases than do riskier firms. Comparing the values of Altman's and Zmijewski's default factors with those reported in Shumway (2001), our firms appear more distressed than the average Compustat firm – again, likely because of the presence of bonds, which implies higher-than-average leverage ratios.

[TABLE 3 HERE]

4. Cash holdings and credit spreads

This section studies the relationship between balance sheet liquidity and bond spreads. First, we show that standard OLS regressions used in empirical studies of spreads appear to suggest that higher cash holdings result in higher spreads. Then, we use instrumental variables suggested by the model, and demonstrate that in IV regressions, higher cash holdings correspond to lower spreads.

In these tests, the dependent variable is the bond spread relative to a cash flow-matched portfolio of Treasuries, averaged across all of the firm's outstanding bonds for each date. To proxy for balance sheet liquidity, we use the ratio of cash to total assets, as well as working capital over total assets (as in Altman's (1968) z-score), and the current ratio, equal to current assets over current liabilities (as in Zmijewski (1984)), although many other proxies yield similar results. We include standard controls for leverage, volatility, bond maturity, firm size, and credit rating, and also use monthly dummies to abstract from the effect of all macroeconomic variables.

The regressions results are presented in Table 4. The effect of standard credit risk factors is in line with economic intuition and corroborates evidence from other studies of spreads (e.g., Davydenko and Strebulaev (2007)): More levered, more volatile, and smaller firms are riskier and consequently have higher credit spreads. Adding monthly and rating dummies substantially increases the R^2 in regressions (3) and (4), from 49% to 55% and 68%, even though the regression in column (2) already controls for credit risk by using leverage and volatility proxies. Thus, though ratings provide an admittedly crude summary of credit risk (as evidenced by the strong significance of leverage and volatility in column (4)), they clearly have significant incremental explanatory power.

But the results concerning the effect of liquid assets on spreads contradict the simple intuition that firms with more liquid assets are "safer" and thus should have lower spreads. Both in univariate regressions and in the presence of standard credit risk controls, the correlation between credit spreads and liquidity is positive and strongly statistically significant, typically at the 1% level. The implied economic effect is also considerable: In columns (1)–(3), a one standard deviation increase in the cash-to-asset ratio corresponds to an increase in the bond spread of about 16 basis points. The positive relationship between credit spreads and liquidity proxies persists even after controlling for the credit rating. Moreover, in untabulated tests, we estimate specification (3) separately for different ratings groups, and find that the coefficient for cash is increasing monotonically as the rating deteriorates (see Figure 1).

These results are robust in the data and insensitive to the way the control variables are constructed. They are nearly identical if cash is measured as a fraction of assets net of cash, rather than total assets, or if, instead of the MKMV asset volatility estimate, we use equity volatility or the proxy suggested by Schaefer and Strebulaev (2008). They are strengthened if we use book instead of market leverage, or if, instead of monthly dummies, we use macro variables, such as the risk-free rate (Duffee (1998)) or VIX (Schaefer and Strebulaev (2008)). One could hypothesize that cash holdings are affected by covenants restricting liquidity levels, which in turn are correlated with the underlying credit risk. However, such covenants are infrequent in practice (Dichev and Skinner (2002)). Using data on bank loans from DealScan, we find that only 1.6% of our firms have covenants specifying minimum liquidity ratios (current or quick ratio). In addition, for 2.9% of firms covenants restrict capital expenditures, which also may affect cash reserves. Controlling for the presence of such covenants has no impact on our results.[12]

[TABLE 4 HERE]

Our model suggests that the positive correlation of spreads with liquid assets is due to the endogenous nature of cash holdings in credit-risky firms. Thus, standard OLS regressions used in empirical studies of spreads may be inadequate for studying the role of factors such as cash, which are subject to endogenous corporate financing decisions. The model also predicts that exogenous variations in cash (those not induced by differences in credit risk factors) should be negatively related to spreads.

We test this prediction using instrumental variable regressions. Instruments are factors that induce cross-sectional variation in cash holdings unrelated to the underlying credit risk. The model suggests two potential instruments. First, more profitable future investment opportunities (growth options) should result in the firm's retaining more cash for the future, regardless of its level of credit risk. Yet once the higher cash reserve is in place, it provides a safety cushion for creditors, decreasing credit spreads. To proxy for *growth options*, we use the median ratio of R&D expenditures to sales in the firm's three-digit SIC industry in each calendar year.[13]

Second, the model suggests the ratio of managerial private costs of financial distress to the fraction of the firm's equity that the manager owns as another instrument. The higher this fraction, the higher is the manager's incentive to hoard cash (above the level that maximizes the value of equity) to avoid default and the associated private costs. We assume that the CEO's salary and bonus are at risk if the firm defaults. Accordingly, our *agency term* is the ratio of the CEO's salary, bonus, and other monetary compensation to the market value of her shares and options, estimated using the ExecuComp database.[14]

We employ these two instruments in IV of spreads that mirror the regressions of Table 4, with the same proxies for liquid asset reserves and the same standard control variables. The results are presented in Table 5. As expected, exogenous variations in liquid asset reserves are negatively and

[12]The robustness tests are available on request.

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

[14]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.

significantly related to bond spreads. Thus, the simple intuition that higher cash holdings make firms safer, implying a negative relationship between cash and spreads, is correct. However, to uncover this intuitive result, the empiricist must overturn the effect of endogeneity of cash, which strongly dominates in standard OLS regressions that are commonly used in empirical studies of credit risk. These findings show that accounting for the fact that firms can choose their cash holdings optimally is of first-order importance for understanding the role of liquid assets in credit risk.

[TABLE 5 HERE]

5. Balance sheet liquidity and the probability of default

Most empirical default-predicting models include some proxies for balance sheet liquidity, treating them as independent variables expected to reduce the probability of default. However, despite the intuitive appeal and the widespread use of liquidity ratios in this context, Begley, Ming, and Watts (1996), Shumway (2001), and Hillegeist *et al.* (2004), as well as Ohlson (1980) and Zmijewski (1984) in their original work, find them unrelated or even positively associated with default. In this section, we look at how the endogeneity of cash affects the correlation between liquid asset reserves and the probability of default.

The standard approach in the literature is to identify a set of factors expected to affect the probability of default, and, taking them as given, estimate some variant of a hazard model of default or bankruptcy. Logit models, equivalent to discrete-time hazard models (Shumway (2001)) are used most frequently. We first estimate a set of logit regressions of default using different model over the three-year horizon. Using the definition of default adopted by rating agencies, default events include missed bond payments, bankruptcy filings, and distressed bond renegotiations. (Similar results obtain when firm failures are restricted to bankruptcies.) The results are presented in Table 6. Column (1) uses the variables that enter Altman's (1968) z-score model as predictors of default. While the effect of most variables conforms to expectations, the ratio of working capital to total assets, which is Altman's proxy for liquidity, is positively correlated with the 3-year default probability, and is highly statistically significant. Column (2) employs predictors used by Zmijewski (1984), and also finds a positive coefficient for liquidity, measured by the current ratio. Regression (3) uses another proxy for liquidity, the quick ratio (Davydenko (2010)), and controls for other credit risk factors by including the Expected Default Frequency (EDF) from Moody's/KMV, variations of which have been frequently used in recent empirical studies (e.g., Bharath and Shumway (2008)). Once again, liquidity is positively correlated with the probability of default. Columns (4)–(6) show that this basic result persists after the EDF is added to the models of Altman (1968) and Zmijewski (1984), and even when all the control variables are included simultaneously.

[TABLE 6 HERE]

According to our model, the correlation between liquidity and the probability of default is driven by the firm's incentive to conserve cash to survive a liquidity shortfall in the short run, which reduces investment and results in lower expected cash flows in the long run. Thus, we expect the correlation to be negative over short horizons, but positive over long horizons.

To test this hypothesis, we re-estimate the same predictive models for different horizons, one quarter, one year, and three years. We also use the instrumental variables previously employed in regressions of spreads (Section 4) to isolate the effect of exogenous increases in cash holdings on long-term default probabilities. The results of these tests are reported in Table 7.

The regressions in column (1) are for the short-term probability of default, so that the dependent variable is 1 if the firm defaults within the next fiscal quarter, and 0 otherwise. As expected, proxies for balance sheet liquidity are negatively correlated with the short-term probability of default in all three models. This result is consistent with Davydenko (2010), who finds that firms with restricted access to external financing are more likely to default over the next quarter when their liquid assets fall short of current liabilities.

In contrast to the short-term results, columns (2) and (4) show that liquidity is *positively* related to the probability of default at the one and three year horizons, which are typical in empirical default-predicting studies. This result is illustrated in Figure 2, which shows the sign reversal for CA/CL in the Zmijweski model as the horizon increases from one quarter to one year and beyond.

At the same time, instrumental-variable logit regressions in columns (3) and (5) suggest that the relationship between cash and the long-term probability of default is negative when the endogeneity of cash is controlled for, and that it becomes stronger as the prediction horizon increases: The liquidity coefficient is negative but insignificant in 2 of the 3 one-year regressions in column (3), but it is negative and strongly significant in all 3 models for the three-year prediction in column (5).

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

[TABLE 7 HERE]

6. Concluding remarks

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

The severe credit crisis caused by the subprime debacle highlights the relation between cash policy and corporate debt pricing. The subsequent recession implies lower future expected cash flows. At the same time, the unwillingness of banks to extend credit means that firms cannot rely on external sources of financing should a liquidity crisis occur. Both factors increase the value of a marginal dollar of cash and elevate the importance of cash management policies to a new level. The perception of market practitioners becomes that "In a period in which credit is being rationed, the price of leveraged assets declines and cash is king."[15] Disentangling the various effects that such shocks in the economic environment have on cash policy and credit risk provides an important avenue for further research.

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

Appendix A: The first-order condition and proofs of Propositions

Investment first-order condition. Managers maximize the value of equity by choosing the appropriate level of investment I. From Equation (3), equityholders' optimization problem yields the following first order condition:[16]

$$\frac{\partial E}{\partial I} = \int_{\psi_B}^{\infty} [-1 + f'(I)]g(\psi)d\delta_1 - [-I + (c_0 + \delta + \psi_B - B) + f(I)]g(\psi_B)\frac{d\psi_B}{dI} = 0. \tag{A1}$$

Substituting the expression for ψ_B from Equation (2) and rearranging, we can rewrite this first-order condition as

$$f'(I) = \frac{1 + (1-\tau)f(I)h(\psi_B)}{1 + \tau(1-\tau)f(I)h(\psi_B)}. \tag{A2}$$

In the first-best case of unrestricted investment, the standard maximization solution would yield $f'(I) = 1$. In our model, the right-hand side in Equation (A2) is greater than 1 as long as there are financing frictions (i.e., $\tau < 1$) and the firm's ability to repay the debt at the chosen investment level is uncertain (i.e., $g(\psi_B) > 0$). It follows that the firm's optimal investment in our model, I^*, is lower than the first-best level.[17]

To understand the intuition behind the optimal investment and cash policies, note that we can re-write the first-order condition as follows:

$$(f'(I) - 1) \times (1 - G(\psi_B))\, dI = (1-\tau)f(I) \times g(\psi_B)d\psi_B. \tag{A3}$$

The left-hand side in Equation (A3) is the net value gain from increasing investment by dI, equal to $(f'(I) - 1)dI$, conditional on survival in the interim period, the probability of which is $1 - G(\psi_B)$. The right-hand side gives shareholders' expected marginal loss from default, equal to the value of equity at the default boundary $(1-\tau)f(I)$ multiplied by $g(\psi_B)d\psi_B$, which is the marginal increase in the probability of default due to the shift in the default boundary by $d\psi_B$.

Proof of Proposition 1. Define function $m(I^*, \delta)$, where I^* is the optimal investment level from the first-order condition (A2), as

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

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

$$\frac{dc^*}{d\delta}\frac{\partial c^*}{\partial \delta} = -\frac{\partial I^*}{\partial \delta} = -\Big(-\frac{\frac{\partial m}{\partial \delta}}{\frac{\partial m}{\partial I^*}}\Big). \tag{A5}$$

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

$$\frac{\partial m}{\partial I^*} = f''(I^*) - \frac{(1-\tau)^2(f'(I^*)h(\psi_B) + f(I^*)h'(\psi_B)(1 - \tau f'(I^*)))}{(1 + \tau(1-\tau)f(I^*)h(\psi_B))^2}, \tag{A6}$$

which is non-positive because $f'' < 0$, $h' > 0$, and $f'(I^*) < \frac{1}{\tau}$ (the latter holds from the first-order condition (A2)). Also,

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

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

$$\frac{\partial m}{\partial \delta} = -\frac{(1-\tau)^2 f(I^*) h'(\psi_B) \frac{\partial \psi_B}{\partial \delta}}{(1+\tau(1-\tau) f(I^*) h(\psi_B))^2} > 0, \tag{A7}$$

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

Part 2. From definitions of D and s (Equations (5) and (6)), it follows that

$$\frac{\partial s}{\partial \delta} = -\frac{B}{D^2}\frac{\partial D}{\partial \delta} = -\frac{B}{D^2}(G(\psi_B) + g(\psi_B)\tau f(I^*)), \tag{A8}$$

and

$$\frac{\partial s}{\partial c^*} = -\frac{B}{D^2}\frac{\partial D}{\partial c^*} = -\frac{B}{D^2}(G(\psi_B) + g(\psi_B)\tau f(I^*) - \tau^2 f(I^*) f'(I^*) g(\psi_B)). \tag{A9}$$

Therefore,

$$\frac{ds}{d\delta} = \frac{\partial s}{\partial \delta} + \frac{\partial s}{\partial c^*}\frac{\partial c^*}{\partial \delta} = -\frac{B}{D^2}\Big(G(\psi_B) + g(\psi_B)\tau f(I^*)\Big)\Big(1 + \frac{\partial c^*}{\partial \delta}\Big) + \frac{B}{D^2}\tau^2 f(I^*) f'(I^*) g(\psi_B)\frac{\partial c^*}{\partial \delta}. \tag{A10}$$

Because $\frac{\partial c^*}{\partial \delta} \leq 0$, for this quantity to be negative, it is sufficient to establish that $\frac{\partial c^*}{\partial \delta} > -1$. From Equation (A5)

$$\frac{\partial c^*}{\partial \delta} = -\frac{-\frac{(1-\tau)^2 f(I^*) h'(\psi_B) \frac{\partial \psi_B}{\partial \delta}}{(1+\tau(1-\tau) f(I^*) h(\psi_B))^2}}{f''(I^*) - \frac{(1-\tau)^2 (f'(I^*) h(\psi_B) + f(I^*) h'(\psi_B)(1-\tau f'(I^*)))}{(1+\tau(1-\tau) f(I^*) h(\psi_B))^2}}. \tag{A11}$$

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

$$Z(\tau) \equiv f''(I^*) - f'(I^*)\left(1 - \tau f'(I^*)\right)^2 \left(h(\psi_B) - \tau f(I^*) h'(\psi_B)\right) < 0. \tag{A12}$$

Note that when $\tau = 0$,

$$Z(0) = f''(I^*) - f'(I^*) h(\psi_B) < 0. \tag{A13}$$

Because $Z(\tau)$ is continuous in τ, there exist such $\bar{\tau} > 0$ that for all $\tau < \bar{\tau}$, the condition (A12) is satisfied. □

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

$$\frac{ds}{dx} = \frac{\partial s}{\partial c}\frac{\partial c}{\partial x}. \tag{A14}$$

In the proof of Proposition 1, we showed that

$$\frac{\partial s}{\partial c^*} = -\frac{B}{D^2}\frac{\partial D}{\partial c^*} = -\frac{B}{D^2}(G(\psi_B) + g(\psi_B)\tau f(I^*)\Big(1 - \tau f'(I^*)\Big). \tag{A15}$$

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

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

Appendix B: Growth options and managerial losses

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

PROPOSITION B1. *The equilibrium level of cash holdings c^* is positively related to the growth option z. Credit spread s is negatively related to the growth option z only through the change in optimal cash balance.*

Proof of Proposition B1. With growth option z, the first-order condition that determines the firm's investment policy takes the following form:

$$f'(I) = \frac{1 + [(1-\tau)f(I) + z]\, h(\psi_B)}{1 + \tau\, [(1-\tau)f(I) + z]\, h(\psi_B)}. \tag{B1}$$

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

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

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

$$\frac{\partial m}{\partial z} = -\frac{1}{(1 + \tau\, [(1-\tau)f(I) + z]\, h(\psi_B))^2} h^2(\psi_B)(1-\tau) < 0, \tag{B2}$$

and therefore, $\frac{\partial c}{\partial z} > 0$. The result on credit spread follows because $\frac{\partial s}{\partial z} = 0$ by assumption, and $\frac{\partial s}{\partial c} < 0$ (for the reasons established in (A8)). □

PROPOSITION B2. *The equilibrium level of cash holdings c^* is positively related to the agency parameter $\frac{\gamma}{\theta}$. Credit spread s is negatively related to the agency parameter $\frac{\gamma}{\theta}$ only through the change in optimal cash balance.*

Proof of Proposition B2. The first-order condition of the manager's objective function (9) can be written as

$$\frac{\partial M}{\partial I} = \theta \int_{\psi_B}^{\infty} [-1 + f'(I)] g(\psi) d\delta_1 - [-I + (c_0 + \delta + \psi_B - B) + f(I)] g(\psi_B) \frac{\partial \psi_B}{\partial I} - \gamma g(\psi_B) \frac{\partial \psi_B}{\partial I} = 0, \tag{B3}$$

which results in a condition identical to (B1), with z replaced by $\frac{\gamma}{\theta}$. The result then follows from applying the proof of Proposition B1.□

References

Acharya, Viral V., Jing-zhi Huang, Marti G. Subrahmanyam, and Rangarajan K. Sundaram, 2006, When does strategic debt-service matter? *Economic Theory* 29, 363-378.

Almeida, Heitor, Murillo Campello, and Michael S. Weisbach, 2004, The cash flow sensitivity of cash, *Journal of Finance*, 59, 1777–1804.

Altman, Edward I., 1968, Financial ratios, discriminant analysis and the prediction of corporate bankruptcy, *Journal of Finance*, 23, 589-609.

Altman, Edward I., R. Haldeman, and P. Narayanan, 1977, ZETA analysis: A new model to identify bankruptcy risk of corporations, *Journal of Banking and Finance*, 1, 29–54.

Anderson, Ronald W., and Andrew Carverhill, 2007, Liquidity and capital structure, Centre for Economic Policy Research Working paper No. 6044.

Asvanunt, Attakrit, Mark Broadie, and Suresh Sundaresan, 2010, Managing corporate liquidity: Strategies and pricing implications, Working paper, Columbia University.

Bagnoli, Mark, and Ted Bergstrom, 2005, Log-concave probability and its applications, *Economic Theory* 25, 445–469.

Bates, Thomas W., Kathleen M. Kahle, and René M. Stulz, 2009, Why do U.S. firms hold so much more cash than they used to? *Journal of Finance* 64, 1985–2021.

Begley, Joy, Jin Ming, and Susan Watts, 1996, Bankruptcy classification errors in the 1980s: An empirical analysis of Altman's and Ohlson's models, *Review of Accounting Studies*, 1, 267–284.

Bharath, Sreedhar T., and Tyler Shumway, 2008, Forecasting default with the Merton Distance to Default model, *Review of Financial Studies* 21, 1339–1369.

Black, Fischer, and John C. Cox, 1976, Valuing corporate securities: Some effects of bond indenture provisions, *Journal of Finance* 31, 351–367.

Black, Fischer, and Myron Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy* 81, 637–654.

Campbell, John Y., Jens Hilscher, and Jan Szilagyi, 2008, In search of distress risk, *Journal of Finance* 63, 2899–2939.

Chava, Sudheer, and Robert A. Jarrow, 2004, Bankruptcy prediction with industry effects, *Review of Finance* 8, 537–569.

Collin-Dufresne, Pierre, and Robert S. Goldstein, 2001, Do credit spreads reflect stationary leverage ratios? *Journal of Finance* 56, 1929–1957.

Collin-Dufresne, Pierre, Robert S. Goldstein, and J. Spencer Martin, 2001, The determinants of credit spread changes, *Journal of Finance* 56, 2177–2207.

Crosbie, Peter J., and Jeffrey R. Bohn, 2001, Modeling default risk, KMV LLC.

Davydenko, Sergei A., 2010, What triggers default? A Study of the default boundary, Working paper, University of Toronto.

Davydenko, Sergei A., and Ilya A. Strebulaev, 2007, Strategic actions and credit spreads: An empirical investigation, *Journal of Finance*, 62, 2633–2671.

Dichev, Ilia D., and Douglas J. Skinner, 2002, Large-sample evidence on the debt covenant hypothesis, *Journal of Accounting Research* 40, 1091–1123.

Dittmar, Amy, and Jan Mahrt-Smith, 2007, Corporate governance and the value of cash, *Journal of Financial Economics* 83, 599–634.

Duffee, Gregorie R., 1998, The relation between Treasury yields and corporate bond yield spreads, *Journal of Finance* 53, 2225–2241.

Erickson, Timothy, and Toni M. Whited, 2000, Measurement rrror and the relationship between investment and q, *Journal of Political Economy*, 108, 1027-1057.

Fudeberg, Drew, and Jean Tirole, 1991, Game theory, MIT Press.

Fazzari, Steven M., R. Glenn Hubbard, and Bruce C. Petersen, 1988, Financing constraints and corporate investment, *Brookings Papers on Economic Activity* 1988:1, 141–206.

Gamba, Andrea, and Alexander Triantis, 2008, The value of financial flexibility, *Journal of Finance*, 63, 2263–2296.

Gilson, Stuart, 1989, Management turnover and financial distress, *Journal of Financial Economics*, 25, 241–262.

Graham, John, 2000, How big are the tax benefits of debt?, *Journal of Finance*, 55, 1901–1941.

Gryglewicz, Sebastian, 2011, A theory of corporate financial decisions with liquidity and solvency concerns, *Journal of Financial Economics* 99, 365–384.

Hillegeist, Stephen A., Elizabeth K. Keating, Donald P. Cram, and Kyle G. Lundstedt, 2004, Assessing the probability of bankruptcy, *Review of Accounting Studies*, 9, 5–34.

Himmelberg, Charles P., and R. Glenn Hubbard, 2000, Incentive pay and the market for CEOs: An analysis of pay-for-performance sensitivity, Working Paper, Columbia University.

Kim, Chang-Jin, David C. Mauer, and Ann E. Sherman, 1998, The determinants of corporate liquidity: Theory and evidence, *Journal of Financial and Quantitative Analysis* 33, 335-359.

Leland, Hayne E., 1994, Corporate debt value, bond covenants, and optimal capital structure, *Journal of Finance* 49, 1213–1252.

Leland, Hayne E., and Claus Bjerre Toft, 1996, Optimal capital structure, endogenous bankruptcy, and the term structure of credit spreads, *Journal of Finance* 51, 987–1019.

Longstaff, Francis A., and Eduardo S. Schwartz, 1995, A simple approach to valuing risky fixed and floating rate debt, *Journal of Finance* 50, 789–819.

Merton, Robert C., 1974, On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance* 29, 449–470.

Myers, Stewart C., 1977, Determinants of corporate borrowing, *Journal of Financial Economics*, 5,147-175.

Myers, Stewart C., and Raghuram G. Rajan, 1998, The paradox of liquidity, *Quarterly Journal Economics*, 113, 733-771.

Ohlson, James A., 1980, Financial ratios and the probabilistic prediction of bankruptcy, *Journal of Accounting Research*, 18, 109–31.

Opler, Tim, Lee Pinkowitz, René Stulz, and Rohan Williamson, 1999, The determinants and implications of corporate cash holdings, *Journal of Financial Economics*, 52, 3–46.

Roberts, Michael R., and Toni M. Whited, 2011, Endogeneity in Empirical Corporate Finance, Working paper, University of Pennsylvania.

Schaefer, Stephen M., and Ilya A. Strebulaev, 2008, Structural models of credit risk are useful: Evidence from hedge ratios on corporate bonds, *Journal of Financial Economics* 90, 1–19.

Shumway, Tyler, 2001, Forecasting bankruptcy more accurately: A simple hazard model, *Journal of Business*, 74, 101–24.

Strebulaev, Ilya A., and Baozhong Yang, 2006, The mystery of zero-leverage firms, Working paper, Stanford University.

Zmijewski, Mark E., 1984, Methodological issues related to the sstimation of financial distress prediction models, *Journal of Accounting Research* (Supplement), 59–86.

Table 1
Sample size and industry composition

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

	Firms	Spreads	Firm-months	Firm-quarters
Panel A: Observations by rating				
AAA	7	1,224	447	155
AA	38	6,090	1,622	559
A	164	30,627	8,075	2,780
BBB	191	33,281	10,420	3,600
BB	60	8,364	2,842	1,007
B	24	2,444	942	343
CCC and below	1	646	148	60
Panel B: Observations by industry				
Consumer goods	66	14,167	3,686	1,284
Manufacturing	92	12,505	4,515	1,565
High Tech & Telecoms	49	8,884	2,347	819
Wholesale and retail trade	61	12,478	3,521	1,218
Oil & Chemicals	56	9,324	3,220	1,108
Utilities & Transportation	80	14,439	3,942	1,368
Other industries	81	10,879	3,265	1,142
Total	485	82,676	24,496	8,504

Table 2

Statistics on spreads and liquidity ratios

This table reports summary statistics on credit spreads and measures of balance sheet liquidity, by firm-month observation. Panel A reports the annualized bond spread in basis points, averaged over all outstanding straight bonds for each firm-month, for all firms and separately by senior unsecured rating. 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 liquidity ratios for the sample of firm-months, as of the end of the previous fiscal quarter. *TA* is the total book assets of the issuing firm. *Cash* is cash and marketable securities; *WC* is working capital, *CA* is current assets, *QA* is current assets less inventories, and *CL* is current liabilities.

	Mean	Median	25%	75%	St. dev.	N
			Panel A: Credit spreads			
All	191.5	135.2	87.5	214.8	178.4	24,496
AAA	80.0	74.2	57.7	95.8	26.8	447
AA	78.7	69.3	54.0	94.0	36.3	1,622
A	114.9	100.7	72.9	142.3	60.0	8,075
BBB	180.5	152.5	104.0	210.3	119.5	10,420
BB	371.7	321.7	220.7	452.5	227.1	2,842
B	583.8	512.6	349.5	759.6	287.2	942
CCC and below	757.6	740.8	470.0	1,139.6	322.4	148
			Panel B: Liquidity ratios			
Cash/TA	0.039	0.020	0.009	0.048	0.049	24,258
WC/TA	0.073	0.056	-0.012	0.146	0.123	22,741
CA/CL (current ratio)	1.342	1.252	0.935	1.637	0.579	22,741
QA/CL (quick ratio)	0.745	0.687	0.497	0.925	0.383	22,424

Table 3
Statistics on control variables

This table reports summary statistics on control variables used in regressions of spreads and default. *Total assets* is the total book assets of the issuing firm in billions of dollars. *Cash/Assets* is cash and near-cash divided by total book assets. *Cash/Net assets* is cash and near-cash divided by total book assets minus cash. *Leverage* is the book value of total debt divided by the sum of the book value of debt and the market value of equity. *Asset volatility* is the annualized standard deviation of asset returns estimated by Moody's/KMV. *Bond 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. *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, *NI* is net income, and *EDF* is the Expected Default Frequency provided by Moody's/KMV.

	Mean	Median	25%	75%	St. dev.	N
Total assets, $Bn	13.37	6.46	2.95	16.47	20.04	24,315
Leverage	0.325	0.298	0.164	0.461	0.196	23,021
Asset volatility	0.187	0.179	0.146	0.217	0.060	21,962
Bond maturity	8.979	7.250	4.549	12.145	6.009	24,496
RE/TA	0.218	0.207	0.084	0.345	0.227	22,738
EBIT/TA	0.023	0.022	0.012	0.034	0.022	21,473
ME/TL	1.796	1.161	0.629	2.198	1.917	23,770
S/TA	0.256	0.218	0.137	0.314	0.180	24,252
NI/TA	0.010	0.011	0.004	0.019	0.018	24,258
TL/TA	0.682	0.671	0.592	0.760	0.139	24,294
EDF, %	0.712	0.200	0.069	0.578	1.661	21,962

Table 4

OLS regressions of bond spreads

The dependent variable is the annualized yield spread in basis points relative to a cash flow-matched portfolio of STRIPS, averaged over all outstanding bonds for each firm-month observation in the sample. *TA* is the book value of total assets, *WC* is working capital, *CA* is current assets, and *CL* is current liabilities. *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 volatility of assets as estimated by Moody's/KMV. *Maturity* is the weighted-average remaining bond maturity in years for all bonds with available spreads for each firm-month observation in the sample. The values of t-statistics adjusted for clustering at the firm level are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cash/TA	3.26***	3.12***	3.25***	1.25*				
	(2.64)	(3.48)	(3.83)	(1.73)				
WC/TA					0.93**	0.96***		
					(2.09)	(3.36)		
CA/CL							0.23***	0.15***
(current ratio)							(2.67)	(2.71)
Leverage		6.45***	5.72***	2.92***		3.04***		3.02***
		(18.6)	(16.1)	(9.63)		(9.52)		(9.45)
Asset volatility		12.5***	9.19***	4.06***		3.97***		4.12***
		(14.3)	(9.09)	(5.53)		(5.50)		(5.68)
Log(TA)		-0.12***	-0.25***	-0.15***		-0.12***		-0.13***
		(-3.22)	(-5.88)	(-4.55)		(-3.60)		(-3.68)
Maturity		0.0021	0.0048	0.015***		0.015***		0.014***
		(0.35)	(0.80)	(3.60)		(3.45)		(3.35)
Rating dummies				Yes		Yes		Yes
Monthly dummies			Yes	Yes		Yes		Yes
Const.	1.79***	-1.59***	-0.16	0.30	1.84***	0.075	1.59***	-0.0035
	(27.5)	(-3.72)	(-0.33)	(0.71)	(27.7)	(0.17)	(12.0)	(-0.0077)
N	24,258	21,110	21,110	21,110	22,741	20,178	22,741	20,178
Adj. R^2	0.8%	49.2%	54.8%	67.7%	0.4%	68.5%	0.6%	68.4%

Table 5
Instrumental variable regressions of credit spreads

The dependent variable is the annualized yield spread in basis points relative to a cash flow-matched portfolio of STRIPS, averaged over all outstanding bonds for each firm-month observation in the sample. The proxies for balance sheet liquidity (*Cash/TA*, *WC/TA*, and *CA/CL*) are instrumented with the *R&D/Sales* ratio of the median firm in the same three-digit SIC industry each year and with the *Agency term*, defined as the ratio of the CEO's salary and bonus to the value of her equity holdings and options in the firm. *TA* is the book value of total assets, *WC* is working capital, *CA* is current assets, and *CL* is current liabilities. *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 volatility of assets as estimated by Moody's/KMV. *Maturity* is the weighted-average remaining bond maturity in years for all bonds with available spreads for each firm-month observation in the sample. The values of t-statistics adjusted for clustering at the firm level are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cash/TA	-6.46***	-4.42**	-2.64*	-4.57***				
	(-3.11)	(-2.31)	(-1.71)	(-2.63)				
WC/TA					-5.06***	-4.51**		
					(-2.76)	(-2.12)		
CA/CL							-1.28**	-1.18*
(current ratio)							(-2.39)	(-1.71)
Leverage		5.84***	4.98***	2.71***		2.79***		2.93***
		(14.2)	(12.1)	(8.06)		(6.01)		(5.96)
Asset volatility		13.8***	9.40***	5.85***		7.75***		8.37***
		(12.1)	(7.51)	(6.00)		(4.26)		(3.28)
Log(TA)		-0.072*	-0.21***	-0.12***		-0.26***		-0.31***
		(-1.89)	(-4.93)	(-3.52)		(-3.61)		(-2.85)
Maturity		0.0076	0.011*	0.015***		0.020***		0.025***
		(1.19)	(1.79)	(3.81)		(2.88)		(2.82)
Rating dummies				Yes		Yes		Yes
Monthly dummies			Yes	Yes		Yes		Yes
Const.	1.96***	-1.91***	-0.12	0.39	2.15***	1.45*	3.49***	2.95*
	(19.2)	(-4.46)	(-0.24)	(0.92)	(11.9)	(1.88)	(4.65)	(1.79)
N	17,703	16,497	16,497	16,497	16,839	15,864	16,839	15,864
Adj. R^2	.%	41.6%	50.3%	63.5%	.%	53.3%	.%	49.3%

Table 6
Liquid assets in long-term default-predicting models

This table reports quarterly logit regressions of public bond defaults over the 3-year horizon. The dependent variable equals 1 if the firm defaults within 3 years from the observation date, and 0 otherwise. *WC* is working capital, *TA* is the book value of total assets, *CA* is current assets, *CL* is current liabilities, *QA* is current assets less inventories, *RE* is retained earnings, *ME* is the market value of equity, *TL* is the book value of total liabilities, *S* is sales, *NI* is net income, and *EDF* is the Expected Default Frequency provided by Moody's/KMV. Absolute values of z-statistics adjusted for clustering at the firm level are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
WC/TA	1.72***			2.08***		
	(3.13)			(3.29)		
CA/CL		0.33***			0.43***	
(current ratio)		(4.81)			(5.39)	
QA/CL			0.10**			0.09**
(quick ratio)			(2.17)			(2.07)
RE/TA	-1.32***			0.16	0.30	0.13
	(5.63)			(0.39)	(0.73)	(0.33)
EBIT/TA	-14.74***			-13.53***	-14.48***	-13.66***
	(11.12)			(4.55)	(4.73)	(4.63)
ME/TL	-0.56***			-0.10	-0.13	-0.09
	(3.00)			(1.05)	(1.38)	(0.90)
S/TA	-0.98			-1.12	-0.54	-0.41
	(1.63)			(1.43)	(0.75)	(0.58)
NI/TA		-16.03***		0.19	1.44	0.78
		(13.30)		(0.07)	(0.51)	(0.29)
TL/TA		2.42***		1.20*	1.50**	0.82
		(7.07)		(1.77)	(2.23)	(1.20)
EDF			0.19***	0.14***	0.14***	0.15***
			(20.04)	(12.08)	(11.83)	(12.25)
const.	-1.80***	-5.00***	-3.52***	-3.83***	-4.65***	-3.63***
	(9.14)	(15.68)	(28.65)	(7.29)	(8.13)	(6.98)
N	17,925	21,625	16,944	14,966	14,965	14,777
R^2	15.9%	13.3%	24.0%	26.5%	27.5%	26.4%

Table 7

Liquid assets and the probability of default at different horizons

This table reports quarterly logit regressions (columns (1), (2), and (4)) and instrumental-variable logit regressions (columns (3) and (5)) of public bond defaults at different prediction horizons. In regression (1), the dependent variable equals 1 if the firm defaults within the following fiscal quarter, and 0 otherwise. In regressions (3) and (4), the dependent variable equals 1 if the firm defaults between 9 to 12 months from the observation date, and 0 otherwise. In regressions (5) and (6), the dependent variable equals 1 if the firm defaults between 33 to 36 months from the observation date, and 0 otherwise. *WC* is working capital, *TA* is the book value of total assets, *CA* is current assets, *CL* is current liabilities, *QA* is current assets less inventories, *RE* is retained earnings, *ME* is the market value of equity, *TL* is the book value of total liabilities, *S* is sales, *NI* is net income, and *EDF* is the Expected Default Frequency provided by Moody's/KMV. Absolute values of z-statistics adjusted for clustering at the firm level are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

	1 quarter	1 year		3 years	
	Logit	Logit	IV	Logit	IV
	(1)	(2)	(3)	(4)	(5)
Altman's (1968) z-score					
WC/TA	-1.05***	2.28***	1.82	2.92***	-73.09***
	(2.62)	(4.24)	(0.35)	(3.70)	(3.40)
RE/TA	-0.16	-0.79***	-0.92*	-0.82***	2.48
	(0.96)	(3.14)	(1.74)	(3.40)	(1.41)
EBIT/TA	-0.83	-11.50***	-9.50**	-5.07**	-40.07***
	(1.23)	(6.59)	(2.18)	(2.09)	(2.76)
ME/TL	-11.08***	-0.92**	-1.59**	-0.29	-0.10
	(10.28)	(2.36)	(2.04)	(1.55)	(0.13)
S/TA	0.28	-1.53**	-1.00	-1.09	16.48***
	(0.58)	(2.33)	(0.72)	(1.21)	(3.07)
const.	-1.94***	-4.00***	-3.58***	-5.01***	-3.81***
	(9.78)	(13.60)	(6.09)	(19.18)	(5.10)
N	17,922	17,922	8,363	17,922	8,363
Zmijewski's (1984) model					
CA/CL	-0.35**	0.27***	-1.53	0.42***	-11.45***
(current ratio)	(2.46)	(4.09)	(1.05)	(4.91)	(3.83)
NI/TA	-18.10***	-11.99***	-16.96***	-5.20***	-26.70***
	(12.36)	(9.48)	(4.28)	(2.77)	(2.89)
TL/TA	2.77***	1.87***	0.32	1.90***	-14.61***
	(7.22)	(5.64)	(0.14)	(4.98)	(2.78)
const.	-7.12***	-6.91***	-3.38	-7.60***	20.77***
	(18.70)	(23.27)	(0.93)	(20.52)	(2.66)
N	21,625	21,625	9,826	21,625	9,826
EDF-based model					
QA/CL	-0.73***	0.26***	-0.82	0.43***	-5.72***
(quick ratio)	(2.75)	(2.89)	(0.58)	(4.06)	(3.41)
EDF	0.31***	0.17***	0.21***	0.07***	0.13***
	(12.58)	(17.25)	(11.19)	(5.00)	(3.69)
const.	-7.57***	-6.21***	-5.54***	-6.11***	-1.31
	(14.21)	(35.11)	(4.60)	(31.55)	(0.94)
N	16,944	16,944	9,139	16,944	9,139