Abstract

Intuition suggests that firms with higher cash holdings should be “safer” and 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. In contrast, spreads are negatively related to the part 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.

Keywords: Credit spreads; Default; Liquidity; Precautionary savings

JEL Classification Numbers: G32, G33
1. Introduction

Common intuition suggests that firms that have larger cash holdings in their asset and investment portfolio should be “safer”. In particular, cash-rich firms should have lower probability of default and lower credit spreads, other things equal. In this paper, we argue that in general other things are not equal, and that this intuitive, but naïve, prediction falls prey to the confounding effects of endogeneity. We show empirically that a conservative cash policy is more likely to be pursued by a firm that finds itself in distress. As a result, larger cash holdings are empirically associated with higher, not lower, credit spreads.

In a nutshell, our theoretical argument can be summarized as follows: The firm is a portfolio of assets, of which cash is one, and the composition of assets in the portfolio is endogenous to firm’s liability structure, and in particular, the implied credit risk. Hence, a higher level of cash reflects other changes across the firm’s assets and doesn’t necessarily imply a safer overall portfolio. We take predictions from this simple theoretical argument to the data to explore complex interactions between cash policy and the onset of default.

An important implication of our study is that studies of corporate securities’ pricing should more readily adopt the corporate-finance view of the firm, as standard asset-pricing analysis based on common intuition may be inadequate. Two of our empirical results are particularly striking and go counter to such intuition. First, when we replicate the reduced-form empirical approach commonly used in these studies, we find that a one standard deviation increase in the cash-to-asset ratio is associated with an economically significant 20 basis point increase in credit spreads, after controlling for firm-specific characteristics such as leverage, volatility, and credit rating. The cash effect is robust and persistent.

Second, we explore the role of liquid assets in studies that predict default and bankruptcy, such as Altman’s (1968), Ohlson (1980), Zmijewski (1984), Shumway (2001), and Chava and Jarrow (2004). While almost all such studies control for balance sheet liquidity, their findings concerning the effect of liquidity on the probability of default are inconclusive and often puzzling.\footnote{For example, in regressions of the probability of default, the coefficient for the current ratio is positive in Zmijewski (1984) and negative in Shumway (2001), whereas that on working capital is negative in Ohlson (1980) and positive in Hillegeist et al. (2004).} When we re-estimate such default-predicting models, we find that the correlation of liquidity with default depends on the...
horizon over which default of the firm is being considered. The short-term probability of default is lower when liquid asset reserves are large, consistent with the common intuition. However, for horizons of one year and more, the correlation between cash and default reverses sign and becomes strongly statistically significant. Further, the positive correlation between firm’s liquidity and long-term default probability is a robust phenomenon.

What can explain these puzzling empirical findings? We propose an explanation based on the endogeneity of firm’s cash policy. In the presence of financing constraints, riskier firms (for example, those facing larger default probability) may optimally choose to maintain higher cash reserves as a buffer against the possible cash flow shortfall in the future. We model a levered firm that can either invest its cash in a long-term project or retain it as a cash buffer when the firm’s debt comes due. Market frictions lead to partial lack of pledgability of future cash flows as collateral, which makes default costly. The firm faces a trade-off between investing more now (and getting higher cash flows in the future, conditional on not defaulting) and keeping more cash now (implying a lower probability of a cash shortage and thus a higher chance of survival).

In this model, an exogenous change in factors that affect the firm’s credit risk influences credit spreads and default probability through two channels: by affecting spreads directly (the “direct” channel), and through the adjustment of the firm’s cash policy (the “indirect” channel). For example, a decline in expected future cash flows leads to an increase in default probability and a corresponding rise in credit spreads. At the same time, the firm responds by optimally increasing its cash holdings, which reduces the probability of a cash shortfall and leads to lower spreads. The model’s main insight is that the direct channel dominates as long as constraints on external financing are binding, so that riskier firms have both higher optimal cash reserves and higher credit spreads and higher long-term default probability.

Conversely, the model implies that variation in cash holdings that is unrelated to credit risk factors (so that there is no direct effect on spreads) should be negatively correlated with spreads, in line with the standard intuition. Indeed, we find empirically that the correlation between cash and spreads, as well as that between cash and longer-term default probability, turns negative when we “instrument” the variations in cash by such variables as proxies for managerial self-interest and firm’s long-term investment opportunities.
Finally, the model also predicts that over a short horizon, higher cash reserves reduce the probability of default (consistent with the findings of Davydenko (2010)), but may increase it over a longer period, reconciling the seemingly conflicting evidence of the effect of cash holdings in default-predicting models.

Importantly, the intuition illustrated by the paper is very general and that empirical studies of credit risk (and likely other areas of asset pricing) should account for endogeneity of corporate financial and investment. Otherwise, using most common variables, such as corporate liquidity proxies, in some of the most standard tests, such as predictive regressions of default, may yield misleading results due to spurious correlations. 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 in asset pricing studies.

Our paper is related to the increasingly rich literature in corporate finance on the endogenous determination of corporate cash holdings. The primary focus of this literature is on financial constraints, which create a precautionary motive for hoarding cash (that access to external financing may be restricted has been known at least since the study of Fazzari, Hubbard, and Petersen (1988)). However, extant studies do not explicitly link cash holdings to credit risk or credit spreads, as we do.

Our paper highlights the importance of adopting the corporate finance prospective in asset pricing research. Consider, for instance, the extant credit risk research. A typical assumption made is that should the firm find itself in a temporary cash shortage, it avoids default by selling new equity, as long as the share price remains positive, rendering cash policy irrelevant. This approach is mirrored in empirical credit risk studies, which also do not consider the role of cash holdings. Our results suggest that theoretical and empirical studies of credit risk (and likely other areas of asset pricing) should account for the endogeneity of corporate financial and investment policies. Otherwise, employing the most common balance-sheet “control” variables (such as proxies for cor-

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3This assumption is made in in most prominent credit risk models such as Black and Cox (1976), Leland (1994), Longstaff and Schwartz (1995), Collin-Dufresne and Goldstein (2001), and others. Notable 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.

4See, for example, Collin-Dufresne, Goldstein, and Martin (2001), Duffee (1998), and Schaefer and Strebulaev (2008).
porate liquidity) in standard tests (such as predictive regressions of default) may yield economically misleading results.

2. The model

This section develops a model of a firm’s optimal cash policy in the presence of costly default and restricted access to external financing. Our main goal is to show that cash holdings in equilibrium can be positively correlated with credit spreads and default risk, and to discuss the economic mechanisms behind this counter-intuitive relationship. We disentangle the intuitive, but naïve, prediction that cash-rich firms should be ‘safer’ from the confounding effects of endogeneity. As discussed in Section 2.2, although the model is stylized, our conclusions are quite general.

2.1. Model setup

The model features a single levered firm in a three-period investment economy. The firm has both assets in place and growth opportunities. In each period \( t \) from 0 to 2, its assets in place produce a cash flow \( x_t \). For our purposes, it is important that the interim-period cash flow \( x_1 \) is random and unknown at date 0. We can write \( x_1 \) as \( x_1 = \bar{x}_1 + u \), where \( \bar{x}_1 \) is a known constant and \( u \) is a zero-mean random cash flow shock. The probability distribution of \( u \) is described by the density function \( g(u) \) with support \([u, \infty)\), and with the associated cumulative distribution function \( G(u) \) and the hazard rate \( h(u) \), defined as:

\[
h(u) = \frac{g(u)}{1 - G(u)}. \tag{1}
\]

We assume the hazard rate \( h(u) \) to be weakly monotonically increasing.\(^6\) For our results it is sufficient that the cash-flow shock \( u \) is the only source of randomness in the model, and so we assume that the cash flows at dates 0 and 2 are known. As will become clear below, the timing in the model is such that allowing for a random component in these cash flows would neither alter shareholders’ incentives nor affect our results in any way.

\(^5\)Although firm’s cash flows can be negative, they are bounded from below by investors’ limited liability. We assume that the minimum cash flow shock, \( \underline{u} \), is large enough for the limited liability to be satisfied.

\(^6\)This assumption is unrestricted 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 the function \((1 - G(u))\) is log-concave, which holds for uniform, normal, logistic, exponential, and many other probability distributions.
At date $t = 0$, the assets in place generate a positive cash flow of $x_0 > 0$. At this time, the firm has access to a long-term project, which in return for investment $I$ at $t = 0$ yields a deterministic cash flow of $f(I)$ at $t = 2$, where $f(I)$ is a standard increasing concave production function. Market frictions preclude the firm from accessing outside financing, so that the firm’s disposable cash comes entirely from its internal cash flow, $x_0$. This cash can be invested, either partially or fully, in the long-term project, or retained within the firm as a cash reserve, carried over from date 0 to date 1. We denote the cash reserve as $c$, so that $c = x_0 - I$.

At date $t = 1$, the firm needs to make a debt payment of $B$, whose level is assumed to be predetermined (a legacy of the past). 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. Failure to repay the debt in full at $t = 1$ results in default and liquidation, in which future cash flows both from the long-term investment, $f(I)$, and from assets in place, $x_2$, are lost. As the period-1 cash flow, $x_1$, is random, there is no assurance that it will be sufficient to repay the debt in full. Moreover, due to market frictions, external financing is unavailable, and hence the debt payment must be made out of the firm’s internal funds. This gives rise to incentives for the firm to

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7 Although firms can choose not only cash holdings but also debt levels, variations in cash holdings are likely to be much larger than those in leverage ratios. To test this conjecture, we use annual Compustat data between 1980 and 2006, focusing on non-financial firms with non-trivial debt amounts (specifically, book leverage above 5%). We find that for the median firm, 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. Therefore, in our analysis of the optimal cash policy we treat debt as exogenous.
retain part of its cash between periods 0 and 1 as a buffer against a possible future cash shortfall, to reduce the probability of default.

The firm’s equityholders maximize the final-period payoff. The risk-free rate of interest is normalized to zero, and, in the base case, managers act in the best interest of shareholders. Figure 1 illustrates the model’s timeline.

2.2. Discussion

Before proceeding further, we want to stress that the exact specification of the model can vary substantially without affecting the results qualitatively, as long as two assumptions are satisfied. First, default involves deadweight costs. (Although we assume that all future cash flows are lost in default, an extension to a partial loss is straightforward.) Second, external financing cannot be raised against the full value of future cash flows, meaning that there must be some financing frictions at date 1. If the firm can pledge a large enough fraction of its future cash flows as collateral, then current and future cash holdings can be viewed as time substitutes, and there is no role for precautionary savings of cash. In reality, the condition of partial pledgeability, which we model in an extreme form, is likely to be universally met. In Subsection 2.6 we extend the model by allowing the firm to borrow up to a certain fraction of its future cash flows at $t = 1$, and show that our main results continue to hold as long as financing constraints are sufficiently binding.

A related feature in our model is that a non-trivial part of the cash flow from the current investment will be realized only after a portion of the outstanding debt is due, giving rise to a time mismatch between cash flows and liabilities. Effectively, the expected long-term cash flow can neither be pledged nor used as cash to cover debt obligations. In practice, most capital expenditure items are likely to satisfy this requirement, because they usually generate cash flows after some non-trivial debt payments is made. In the base case model, we assume that the investment outcome is realized in full only at date 2. This assumption can be relaxed so that the investment also can generate a cash flow at date 1. What is needed is a non-trivial fraction of cash flows expected after the debt payment is due, so that firm survival at the intermediate stage is a worthy option.

In general, firms can distribute some of the cash to their shareholders. Fixed, pre-committed dividends at $t = 0$ amount to a reduction in the net cash flow $x_0$, and can be easily incorporated in the model. Although modeling an optimal dividend policy at $t = 0$ would complicate the analysis
considerably by introducing a second choice variable, the intuition is straightforward. Most firms would choose not to pay any dividend, because the cash can be profitably invested in the long-term project. However, if the firm is very risky, the precautionary motive for saving cash can be dominated by the incentives to engage in “asset substitution”, i.e., to pay out a large immediate dividend at the expense of making the firm even riskier. To prevent such behavior, when credit risk is a concern, discretionary dividends and share repurchases are likely to be prohibited by covenants.8

[SSS Serg: I don’t know if the following makes sense or if it’s enough to answer to ref’s q.3. I’ll try to think more if I ever get a minute for it.]

If the firm has access to external capital at \( t = 0 \), it can choose to raise additional capital at that time to increase its investment and/or cash holdings. Raising equity in this situation can be viewed as making a negative dividend payment. By the same logic as above, in our model a firm should normally find it desirable to raise equity, as long as the marginal value of an additional dollar of investment is greater than one. However, if the firm is very risky, instead of investing, shareholders would have incentives to pay themselves a dividend rather than contribute additional equity. By contrast, raising debt maturing at \( t = 1 \) that is more senior than the existing debt solely in order to increase the cash reserve is value-neutral in this setting, as the increase in the cash holding is exactly offset by the increase in the required debt repayment (i.e., such cash is negative debt in our model). In our base-case model, we assume that financing constraints at \( t = 0 \) result in the firm’s inability to raise any additional financing. Allowing for optimally chosen financing and/or for an endogenous dividend policy could be an interesting extension of our model.

Reverting to our model, note that cash reserves are costly to the firm because they are financed by reductions in long-term investment. This way of modeling the opportunity cost of cash holdings is convenient, but by no means unique.9 Forgone investment in the model should be understood more broadly as the opportunity cost of cash.

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8 We have analyzed a continuous-time version of our model in which investment levels were fixed, and the firm could choose to retain its cash flow in a reserve or pay it out as dividends. The main predictions of this continuous-time endogenous-dividend model were the same as those of the model that we are discussing here.

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

At date 0, the firm faces the following trade-off between investing its cash in the long-term project and retaining it until the next period. On one hand, larger retained cash holdings imply lower investment. This results in lower future cash flows generated by the long-term investment conditional on survival in the interim period. On the other hand, an increase in cash holdings reduces the probability of a cash shortage at date 1, and thus increases the likelihood that the firm survives until date 2 to reap the benefits of the long-term investment. The firm’s optimal cash and investment policies balance these costs and benefits of cash.\(^1\)

The maximum amount of cash available for debt service at date 1 is \(c + x_1\), where \(c = x_0 - I\) is the cash reserve and \(x_1 = \pi_1 + u\) is the interim-period cash flow from assets. The “default boundary,” or the minimum cash flow shock that allows the firm to repay \(B\) in full and avoid default, is:\(^2\)

\[
\begin{align*}
    u_B &= B - x_0 + I - \pi_1. \\
\end{align*}
\]

The default boundary increases in the level of debt and sunk investment, and decreases in realized date-0 and expected date-1 cash flows. For all realizations of \(u\) between \(u\) and \(u_B\), the firm defaults and equityholders are left with nothing. The total payoff to equityholders is the sum of the cash flows from assets in place and the payoff from the long-term investment, less the invested amount and the debt repayment, provided that the firm does not default on its debt in the interim. The market value of equity is therefore:

\[
E = \int_{u_B}^{\infty} [x_0 - I + \pi_1 + u - B + f(I) + x_2] g(u) \, du. \tag{3}
\]

The equity value in Equation (3) can also be intuitively rewritten as:

\[
E = \int_{u_B}^{\infty} [(u - u_B) + f(I) + x_2] g(u) \, du, \tag{4}
\]

where \(u - u_B\) is the amount of cash left in the firm after \(B\) is repaid, and \(f(I) + x_2\) is shareholders’

\(^{10}\)Covenant restrictions may prevent the firm from investing at the optimum. Should this be the case, the firm may end up with excessive cash reserves (from equityholders’ point of view) and our results are likely to be strengthened.

\(^{11}\)Without loss of generality, we assume that \(u_B \geq u\).
Managers maximize the value of equity by choosing the optimal level of investment. From Equation (3), equityholders’ optimization problem yields the following first-order condition:\footnote{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.}

\[
\frac{\partial E}{\partial I} = \int_{u_B}^{\infty} \left[-1 + f'(I)\right]g(u) du - \left[x_0 - I + \bar{\pi}_1 + u_B - B + f(I) + x_2\right]g(u_B) \frac{du_B}{dI} = 0. \tag{5}
\]

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

\[
f'(I) = 1 + (f(I) + x_2) h(u_B). \tag{6}
\]

In the first-best case of unrestricted investment, the standard maximization solution would yield \(f'(I) = 1\). In the presence of costly default and restricted access to outside financing, investment is below its first-best level. This follows from Equation (6), given that the right-hand side is greater than one. To understand the intuition behind the optimal investment and cash policies, notice that the first-order condition (5) can be re-written as follows:

\[
(f'(I) - 1) \times (1 - G(u_B)) \, dI = (f(I) + x_2) \times g(u_B) \, du_B. \tag{7}
\]

The left-hand side in Equation (7) is the net value gain from increasing investment by \(dI\), which is equal to \((f'(I) - 1) \, dI\), multiplied by \(1 - G(u_B)\) to condition on the probability of survival. The right-hand side gives shareholders’ marginal expected loss from default, equal to the value of equity at the default boundary, \(f(I) + x_2\), multiplied by the marginal increase in the probability of default due to the shift in the default boundary, \(g(u_B) \, du_B\).

The market value of the firm’s debt, \(D\), is:

\[
D = B - \int_{u}^{u_B} \left[B - (c + \bar{\pi}_1 + u)\right]g(u) \, du, \tag{8}
\]

equal to the face value of debt \(B\), adjusted for the loss that creditors expect to incur in default states \([u, u_B]\). Note that creditors recover \(c + x_1\) in case of default.

With the riskless interest rate at zero, the credit spread, denoted \(s\), coincides with the total debt
yield, given by
\[ s = \frac{B}{D} - 1. \]
\[ (9) \]

2.4. Cash holdings and credit spreads

In this subsection, we study the correlation between credit spreads and cash reserves when they both adjust in response to changes in model parameters.

The effect of any variable \( y \) on the credit spread can be decomposed into two components, which we call direct and indirect effects. First, the spread may depend on \( y \) directly, for example, because \( y \) affects the default boundary and hence the likelihood of default. Second, a change in \( y \) may induce a change in the optimal cash reserve \( c \), which in turn alters the default boundary and thus affects spreads (an indirect effect through cash).

It is convenient to introduce a special term for variations in cash not induced by changes in credit risk factors. Formally, suppose that cash holdings depend on a variable \( y \) that does not affect spreads directly, so that \( \partial s / \partial y = 0 \). In particular, within our model this condition implies that \( y \) does not enter the expression for the default boundary \( u_B \), nor does it affect the distribution of the time-1 cash flow, \( g(u) \). When all other variables are fixed, \( y \) can affect spreads only indirectly, through its effect on cash. We will refer to changes in cash holdings induced by changes in variables that do not affect spreads directly as “exogenous” (to credit risk). By contrast, variations in cash are “endogenous” (to credit risk) if they are induced by changes in credit risk factors. It should be emphasized that an “exogenous” variation in cash need not be due to factors outside the firm’s control. Instead, it can arise as the firm optimally adjusts its cash policy in response to changes in firm characteristics that have no direct effect on credit spreads.

2.4.1. Endogenous variations in cash

A change in many variables that affect spreads directly may also cause cash to adjust in the same direction, so as to undo the direct effect partially. For example, a direct effect of a drop in the expected cash flow is to raise the yield spread. However, optimal cash holdings also increase, which in turn decreases the spread (the indirect effect of the drop in cash flow). Other variables, such as the level of debt and the volatility of cash flow, may produce similar effects. This subsection shows
that such adjustments in cash can result in a positive correlation between cash holdings and credit spreads in the cross-section.

Let $^*$ denote the equilibrium values of the variables, so that $I^*$ and $c^* = x_0 - I^*$ are the equilibrium levels of investment and cash holdings, and $s^* = s(c^*)$ is the credit spread when $I = I^*$. The following Proposition summarizes the effect of changes in the expected date-1 cash flow, $\bar{x}_1$, on cash holdings and spreads (see the Appendix for all proofs):

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

1. The equilibrium cash reserve $c^*$ is a decreasing function of $\bar{x}_1$;
2. The equilibrium credit spread $s^*$ is a decreasing function of $\bar{x}_1$.*

When the expected cash flow decreases, the probability of a cash flow shortage at the time of debt repayment increases, so that the direct effect is to make the firm riskier and to raise the credit spread. The first part of Proposition 1 states that the firm’s optimal response is to alleviate the increase in risk by increasing its precautionary savings. This gives rise to the indirect effect of the decrease in cash flow, which is to reduce spreads. The second part of Proposition 1 states that the direct effect dominates, so that despite their larger cash buffer, firms with lower expected cash flows have higher credit spreads. In practice, this means that when cash flow levels are allowed to vary over time or in the cross-section, this variation can induce a positive correlation between endogenously chosen cash reserves and credit spreads.

To understand why the direct effect dominates, notice that for each dollar of decline in the expected cash flow, the firm increases its cash reserves by less than a dollar. This can be seen from the first-order condition (6), which balances the marginal cost of cash due to lower investment with its marginal benefit due to lower probability of default. Suppose that the expected cash flow decreases by $1, so that without any adjustments, the default boundary would drop by $1. In response, the firm reduces investment and increases the cash reserve, so that the boundary does not drop as much. However, since the production function is concave and the hazard function $h(\cdot)$ is non-decreasing, for the Equation (6) to be satisfied again, investment has to drop by less than $1. Thus, the concavity of the production function makes one-for-one reductions in investment prohibitively costly. As a result, cash holdings increase by less than $1, so that the net effect of the
drop in the expected cash flow is to reduce the default boundary and thus to increase the credit spread. The intuition behind this economic mechanism is quite general: If the cost of increasing cash levels to offset higher default risk is convex, the firm offsets default risk only partially, and the direct effect on spreads dominates.\footnote{This discussion illustrates the importance of financing constraints. If the firm can pledge a sufficiently high proportion of its long-term cash flow to creditors as collateral, long-term income can play only a secondary role as a cash substitute. The marginal cost of cash holdings is then effectively reduced and Proposition 1 may not hold. We discuss the case of partially pledgability in Subsection 2.6.}

As noted above, similar effects can arise due to variations in firm characteristics other than its 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, 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 expected cash flow 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. Similar effects may also arise when the initial cash flow, $x_0$, is allowed to vary, or when the firm pays a fixed dividend that reduces its net cash flow (see Subsection 2.2).

2.4.2. Exogenous variations in cash

This subsection considers the effect of “exogenous” variations in cash, which are not induced by changes in credit risk factors. It is easy to show that such cash variations are negatively correlated with credit spreads, consistent with the simple intuition that firms with more cash should be “safer” and have lower spreads.

\textbf{Proposition 2.} If $\frac{\partial s}{\partial y} = 0$, then $\text{sign} \left( \frac{ds}{dy} \right) = -\text{sign} \left( \frac{dc}{dy} \right)$.

Proposition 2 states that when some factor that is unrelated to credit risk causes cash holdings to increase, credit spreads fall in response. In other words, spreads are negatively related to exogenous changes in cash.

In our empirical analysis, we refer to factors $y$ that induce an exogenous variation in cash as \textit{instruments}. To be an instrument, a variable must affect cash holdings without altering creditors’ payoffs or the probability of default other than through changes in cash. Put differently, an instrument would not affect spreads if cash were held constant. Formally, instruments in our model are
variables that enter the first-order condition (Equation (6)), but not the expression for the value of debt (Equation (8)). Assuming that external financing cannot be raised against any part of period-2 cash flow, both the cash flow from assets in place, $x_2$, and any parameters that affect the shape of the production function, $f(\cdot)$, satisfy these requirements. Variations in cash induced by changes in these variables would be negatively related to spreads.

**Example 1: Growth options.** The long-term cash flow from assets in place, $x_2$, can be interpreted as the value of the firm’s growth options. An increase in the growth option increases the value of equity conditional on survival, and hence enhances shareholders’ incentives to conserve cash to avoid default. At the same time, as this cash flow is not collateralizable, it does not benefit short-term creditors directly. Since the growth option does not enter the expression for the value of debt, it affects spreads only indirectly, through the induced variation in cash holdings. It follows from Proposition 2 that the resulting cross-sectional variation in cash is negatively correlated with credit spreads.

More generally, when external financing is not fully prohibited, a fraction of the long-term cash flow can be used as collateral in order to raise external financing. Anticipating this at $t = 0$, the firm would substitute some of its cash reserve with future external financing, which would enter the expression for the default boundary and thus affect the probability of default directly. Thus, not every long-term cash flow can provide an instrument. Only variations in the levels of those assets that the firm does not anticipate using as collateral at the time when it chooses its cash holdings (i.e., at $t = 0$) can play this role.\(^{14}\) One example of an instrument would be any unanticipated shock to the firm’s cash that occurs between $t = 0$ and debt maturity.\(^{15}\) As discussed above, non-collateralizable long-term growth options also induce exogenous variations in cash. There can be also other non-collateralizable assets that affect the firm’s incentives to save cash, such as human capital.\(^{16}\)

\(^{14}\)We would like to thank the referee for pointing out this property of instruments.

\(^{15}\)For example, if the firm obtains an unexpected settlement in a lawsuit (see Blanchard et al (1994)), its cash reserve increases exogenously and its debt becomes safer as a result of the change in cash.

\(^{16}\)It is worth emphasizing that in a more general settings with multiple classes of debt, some variables can be used as an instrument for some debt obligations, but not for others. For example, if at time $t$ a firm has two bonds outstanding with different maturities, $T_1 < T_2$, then non-collateralizable assets that produce a cash flow between $T_1$ and $T_2$ do not affect the value of short-term debt but can affect the cash reserve at $t$, and hence can be used as an instrument for analyzing the relationship between cash and the short-term credit risk. However, the cash flow from the same assets affect the value of the long-term debt directly (by increasing the amount of cash available at $T_2$), and hence cannot be...
Alternatively, factors outside of the base-case model, such as managers’ self-interest, may affect the firm’s cash policy and serve as an instrument.

**Example 2: Managerial losses in distress.** Another example of a non-collateralizable “asset” is the private benefit that managers derive from avoiding default. Gilson (1989), Baird and Rasmussen (2006) and Ozelge (2007) find that upon distress, there is a significantly higher probability of top-management dismissal, especially due to direct intervention by lending banks, and that managers dismissed in distress suffer a significant private cost in the form of diminished future employment opportunities. Eckbo and Thorburn (2003) find that in Sweden, where creditor rights include automatic firing of the manager in default, managers of bankrupt companies suffer a median (abnormal) income loss of 47%. 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 save cash in order to avoid default, because the private costs differ. As a result, differences in managerial compensation can induce an exogenous variation in cash holdings.17

Consider the following extension of the base-case model. Assume 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 $\theta$, the manager’s incentives to retain cash increases with the private cost of distress $\gamma$. Conversely, given $\gamma$, the manager’s incentives to hold cash declines with her ownership of the firm $\theta$. 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:

$$M = \theta \times E - \gamma G(u_B).$$

As Appendix B shows, technically this case is very similar to that of the variation in $x_2$, and the used as a long-term instrument. [SSS Serg: is this f/n enough of a response to ref’s question about asset maturity?]

17Managerial incentives have also been shown to be important in studies of capital structure (Carlson and Lazrak (2010)) and corporate takeovers (Pinkowitz and Williamson (2011)).
cross-sectional correlation between cash holdings and spreads induced by variations in the agency factor $\gamma$ is thus negative.

2.5. Cash policy and the probability of default

Another important question concerns the relationship between cash and the probability of default. In this subsection, we show that the correlation between the two depends on the horizon over which the likelihood of default is measured. Managers choose the optimal cash policy taking into account the probability of default over the long term. By contrast, in the presence of market frictions it is difficult for a distressed firm to adjust its cash balances to desired levels over short horizons. Therefore, the relationship between cash and default in the short term should be studied conditional on past cash and investment choices.

In our discrete-time model, the instantaneous probability of default is zero almost everywhere, except for the moment just before the scheduled debt repayment at $t = 1$, that is, after the random cash flow $x_1$ is realized. Whether the firm defaults on the debt payment at that moment depends on the total amount of cash available at that time, which is equal to the sum of the firm’s cash reserve $c$ chosen earlier and the realization of the random cash flow $x_1$. The firm defaults if the total cash amount is smaller than the required debt payment. Thus, ceteris paribus, the instantaneous probability of default is inversely related to the firm’s total cash holdings.

By contrast, for long horizons the endogeneity of cash holdings is crucial. In our model, the long-term probability of default evaluated at date 0, $q$, is given by:

$$q = \int_{u_B}^{u} g(u)du = G(u_B).$$

(11)

To study how cash reserves are related to the probability of default at this point, consider the effect of variation in the date-1 expected cash flow, $\overline{x}_1$. According to Proposition 1, as $\overline{x}_1$ increases, shareholders optimally decrease the cash reserve $c^*$ chosen at date 0. Similar to the effect on credit spreads, there are two effects on the probability of default $q$, direct and indirect. On the one hand, a higher expected cash flow results in a lower default probability (the direct effect). On the other hand, a smaller chosen cash reserve means a larger probability of default (the indirect effect). As
the next proposition shows, the direct effect dominates:

**Proposition 3.** The probability of default evaluated at $t = 0$, $q$, is a decreasing function of $\overline{x_1}$.

The intuition for why the direct effect dominates is similar to that for the relationship between cash and spreads. As the expected date-1 cash flow increases by $\$1$, optimal cash reserves decrease by less than $\$1$ due to the concavity of the production function, so that shareholders are indifferent at the margin between higher investment returns and lower probability of realizing them due to the interim probability of default. Note that, as with the relationship between cash and credit spreads, other parameters (such as the level of debt) can induce the same result.

At the same time, *exogenous* variations in cash holdings are negatively correlated with the long-term probability of default. Once again, this relationship mirrors that for credit spreads, which is discussed in detail in Section 2.4.2.

### 2.6. The effect of partial pledgability

In our base-case model, the firm has no access to external financing. In this subsection, we extend the model to consider the effect of partial pledgability of future cash flows. Suppose that at $t = 1$ the firm can use a fraction $\tau$ of its future cash flow (which equals $f(I) + x_2$) as collateral for new financing, where $0 \leq \tau < 1$. Here, $\tau = 0$ corresponds to our base case of extreme financing frictions, when the firm cannot raise *any* external financing against its future cash flows, whereas $\tau = 1$ means the absence of financing frictions.\(^{18}\)

Conditional on survival, raising new financing at $t = 1$ in this setting is value-neutral. Therefore, we can assume without loss of generality that the firm always raises the maximum available amount, $\tau (f(I) + x_2)$. Thus, cash available for debt service at date 1 is $c + x_1 + \tau (f(I) + x_2)$, which is the sum of the cash reserve $c$, the random cash flow $x_1 = \overline{x_1} + u$, and the newly borrowed amount $\tau (f(I) + x_2)$. The “default boundary,” or the minimum cash flow shock that allows the firm to repay $B$ in full and avoid default, is:

$$u_B = B - c_0 - \overline{x_1} + I - \tau (f(I) + x_2).$$  \((12)\)

\(^{18}\) One economic interpretation of $\tau$ is that it represents the extent to which future cash flows are verifiable at date 1. Low values of $\tau$ correspond to unverifiable cash flows that are difficult to pledge as collateral to providers of outside finance.
The value of equity can be written as:

\[ E = \int_{u_B}^{\infty} [(u - u_B) + (1 - \tau) (f(I) + x_2)] g(u) \, du, \]

(13)

where \( u - u_B \) is the amount of cash left in the firm after \( B \) is repaid, and \( (1 - \tau) (f(I) + x_2) \) is shareholders’ claim on period-2 cash flow, conditional on the firm not defaulting in the interim.

As previously, variations in model parameters may affect spreads directly and indirectly. The following Proposition states that variations in the expected cash flow produce a positive correlation between equilibrium cash holdings and credit spreads, provided that financing frictions are sufficiently binding:

**Proposition 4.** If the hazard rate \( h(\cdot) \) is non-decreasing, then

1. The equilibrium cash reserve \( c^* \) is a non-increasing function of \( x_1 \) for any \( \tau < 1 \);

2. There exists a threshold level of pledgeability \( \bar{\tau} \), such that the equilibrium credit spread \( s^* \) is decreasing in \( x_1 \) for any \( \tau < \bar{\tau} \).

The first part of Proposition 4 is a generalization of the result obtained earlier for \( \tau = 0 \). The second part states that there exists a minimum level of financing constraints above which the direct effect of the variation in \( x_1 \) dominates, so that cash and spreads change in the same direction. Thus, Proposition 1 is a special case of Proposition 4, corresponding to \( \tau = 0 \). We conclude that our main prediction holds in situations when access to external financing is possible, provided that market frictions are strong enough.

It is worth noting that when asset pledgeability \( \tau \) is high, an increase in expected cash flow \( x_1 \) may for some combinations of functions \( f \) and \( h \) result in higher credit spreads because of the following asset shifting problem. When investment cash flows are highly pledgeable, and when investment productivity is declining only slowly, an increase in the interim cash flow by one dollar can induce an increase in investment by more than a dollar, as shareholders expect to be able to borrow more against a larger pool of collateral at \( t = 1 \). Thus, the composition of funds available for debt service shifts toward a lower precautionary cash reserve in combination with higher new borrowing. Even though in the new equilibrium the probability of default is lower, in default states
creditors’ recovery rates are disproportionately lower, because there is less cash in the firm, and long-term investment has no value in default. Thus, under such scenarios the overall effect of the increase in expected interim cash flow may be to increase spreads.\textsuperscript{19}

3. Data description

In this section we describe our data and discuss the construction of variables used in the empirical tests.

3.1. Data sources and sample composition

Our empirical tests focus on the probability of default and on credit spreads. We restrict our attention to firms that have issued public bonds, both because defaults on private debt are difficult to observe, and also because we only observe credit spreads for public bond issuers. Information on bonds is from the Fixed Income Securities Database (FISD) provided by Mergent. Default data are from Moody’s Default & Recovery Database (DRD), which provides comprehensive information about defaults on rated bonds, including omitted payments, bankruptcy filings, and distressed bond renegotiations. Financial data are from Compustat, executive compensation data are from ExecuComp, and estimates of the expected default frequencies (EDFs) are from Moody’s/KMV (MKMV). Finally, to estimate yield spreads, we use prices of bonds included in the Merrill Lynch U.S. Investment Grade Index and High Yield Master II Index between December 1996 (the month when the indices were created) and September 2010. The bond pricing database consists of monthly bid quotes from Merrill Lynch’s bond trading desks, which are only available for a subset of bond issuers.

We construct our sample as follows. First, we merge data on non-financial U.S. firms in Compustat with information on bond issuers in FISD, taking account of mergers, acquisitions, name changes, and parent-subsidiary relationships between different bond issuers, and excluding firms which we cannot merge reliably. We thus obtain 2,247 unique firms that had at least one bond outstanding between 1996 and 2010. We use quarterly Compustat data to study the probability of

\textsuperscript{19}Note that asset shifting ceases to be a problem when financing frictions are very low. Indeed, in the limiting case of $\tau = 1$, cash holdings and investment cash flows are perfect time substitutes, so that investment is at its first-best level, and precautionary savings play no role. In this case, higher expected interim cash flow simply enlarges the total pool of assets without affecting cash holdings, and thus results in lower credit spreads.
default for these firms. To this end, we search for these firms in the DRD, and find that 541 of them defaulted during the sample period. Finally, for 1,595 of our firms monthly bond pricing information is available from the Merrill Lynch indices. To be able to estimate credit spreads accurately, we eliminate non-fixed coupon bonds; asset-backed issues; bonds with embedded options, such as callable, puttable, exchangeable, and convertible securities; and bonds with sinking fund provisions. We also 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. This leaves us with 530 firms, 35,206 firm-months, and 103,691 bond-month observations. To summarize, our final data set consists of 79,932 firm-quarter observations for 2,247 bond issuers at risk of default, for 530 of which we have monthly credit spread observations.

Table 1 shows the composition of our sample, as well as that of the subsample for which spreads are available. As can be seen from column (2), B-rated firms are the most common in the sample. In total, junk firms (those rated BB+ and lower) comprise 58% of all firm-quarters. This proportion is substantially smaller for the subsample of firms for which we have spreads: In column (3), junk firms add up to 23% of the spread subsample, while 68% of it are concentrated in the two lowest investment-grade categories, A and BBB. The reason why junk firms are under-represented in the subsample with spreads is because they are more likely to issue callable bonds, which we exclude for the purposes of spread analysis. As we explain below, our main results are driven primarily by risky firms, for which the possibility of a cash shortage looms large. Thus, they would be strengthened if more junk firms issued straight bonds. Overall, the composition of spreads by rating in our subsample 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)).

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20 The indices include corporate bonds with a par amount of at least 100 million dollars ($250 million for investment-grade bonds after December 2004) and remaining maturity of at least one year.
21 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 columns (1) and (3) of Table 1 show ratings for each firm 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 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.\textsuperscript{22} 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. Because spreads are observed at the monthly frequency, but balance sheet information is only available quarterly, in our regressions each observation of a liquidity ratio is used in three different months. This introduces correlation in regression residuals. We account for it by clustering regression residuals at the firm level (see Petersen (2008)).

Panel A of Table 2 reports descriptive statistics on credit spreads. The mean spread is 224 basis points, and the median is 153 basis points. Unsurprisingly, spreads are higher for lower-rated bonds. Untabulated comparisons suggest that for a given rating, spreads typically increase with maturity. It is interesting to note that the average BB spread (361 basis points) is almost twice as high as that for BBB bonds (196 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.\textsuperscript{23}

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

\textsuperscript{22}In robustness tests, we estimate spreads relative to the swap curve computed using the Nelson-Siegel (1987) algorithm. The spreads estimated in this way are lower, but our qualitative results are not affected in any way. Another alternative would be to use CDS instead of bond spreads. We do not pursue this possibility due to the lack of access to CDS data, which in any case have only been available since 2006.

\textsuperscript{23}Potentially, the lower liquidity of speculative-grade bonds may be a concern in our analysis. However, if the illiquidity component in the credit spread is not highly varying within each rating group, its effect on our regression estimates should be minimal. See Schaefer and Strebulaev (2008) for a discussion of the impact of illiquidity.
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 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 7.1% (3.1%) in our sample. 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 (2012)), 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). Our tests on a broad set of Compustat firms (see Fig. 2b below and the discussion therein) confirm that our main results are likely to be even stronger for them, as they are more financially constrained and thus more concerned about internal cash reserves. [SSS Serg: last sent new]

Figure 2a summarizes cash holdings by credit rating; we obtain similar results when we use other measures of credit risk (e.g., 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
3.6% of net assets for the median B-rated firm fade to insignificance next to its debt level, which is close to 50% of assets. 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.

To confirm that these results are not limited to public bond issuers, we look at cash holdings of all non-financial firms in the annual Compustat file since 1950 (341,954 firm-year observations for 24,825 firms). Because most of these firms lack a credit rating, we use the interest coverage ratio (EBIDTA divided by the interest expense) as a proxy for credit risk. Figure 2b plots the means of the cash-to-asset ratio for each decile of the interest coverage ratio, separately for firms with total assets above and below the median.

Several results stand out. First, the U-shaped relationship between cash and credit risk holds beyond our sample of bond issuers. In particular, cash holdings are increasing sharply as firms become very risky. Second, for a given level of credit risk, small firms hold more cash than large firms. This finding is consistent with larger firms having better access to external financing, and thus less of a need for precautionary savings of cash. Third, the levels of cash for an average Compustat firm is substantially higher than that for our sample of bond-issuing firms, consistent with lower financing constraints for bond issuers making internal cash reserves less crucial. Many corporate finance studies classify firms that issue bonds and have a credit rating as unconstrained (e.g., Almeida, Campello, and Weisbach (2004)). By focusing on these firms, we are biasing ourselves against finding a role for an endogenous cash policy. Nonetheless, our results show that even for bond issuers the precautionary motive for saving cash is the first-order determinant of the relationship between liquid assets and credit risk.
Fig. 2a. Cash holdings by rating: Bond issuers. This graph shows means and medians of the ratio of cash to total assets by the firm’s senior unsecured rating. The sample consists of all firm-quarters for non-financial U.S. firms that had bonds outstanding between December 1996 and September 2011.

Fig. 2b. Cash holdings by interest coverage: All Compustat firms. For each decile of the interest coverage ratio, this graph plots the mean of the cash-to-asset ratio among small and large firms. The sample consists of all firm-years for non-financial U.S. firms in annual Compustat between 1950 and 2011. The interest coverage ratio is the sum of Pretax Income, Depreciation & Amortization, and Interest Expense, divided by Interest Expense. In each year, firms are classified as small (large) if their total assets are below (above) the median for that year.
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 particular those related to the term structure of interest rates (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 is the volatility of assets, which we estimate as a weighted average of the 3-year volatility of equity and the volatility of debt by rating, as suggested by Schaefer and Strebulaev (2008). To control for the effects of volatility and leverage beyond the simple linear dependence, we include the distance to default, which is a volatility-adjusted measure of leverage based on the Merton (1974) model of credit risk. Specifically, we use the simplified (‘naïve’) distance to default measure suggested by Bharath and Shumway (2008), which they find to outperform other, more sophisticated proxies. 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 systematic factors. We follow them in controlling for the risk-free interest rate (using the 10-year constant-maturity Treasury rate), the slope of the yield curve (the difference between 10- and 2-year Treasury rates), the VIX index to control for market-wide volatility, the monthly S&P-500 return, and Jump, an option-implied proxy for the probability and magnitude of a large negative jump in firm value.\textsuperscript{24}

\textsuperscript{24}Following Collin-Dufresne, Goldstein, and Martin (2001), we construct the variable Jump as follows. First, from the OptionMetrics database, we obtain Black-Scholes volatility estimates for at- and out-of-the-money puts and at- and in-the-money calls on S&P 500 futures with shortest maturities. Second, we estimate the regression
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 MKMV. 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 MKMV 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. As is common in such studies, we winsorize all variables at at the first and 99th percentiles.

Table 3 shows that our firms are relatively large in size, with median total book assets of almost $7.7Bn. 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.

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

$$\sigma(K) = a + bK + cK^2,$$

where $K$ is the strike price. Third, for each month-end, we compute $Jump = [\sigma(0.9F) - \sigma(F)]$, where $F$ is the current futures price.
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.

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. Similar to Collin-Dufresne, Goldstein, and Martin (2001), we also find the macroeconomic controls to be robustly significant and consistent with expectations. Interestingly, adding rating dummies increases the $R^2$ noticeably even when we control for firm-specific credit risk using leverage and volatility proxies (from 54%–55% to 64%–65%). 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.

The results on the effect of liquid assets 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), (4), and (7), a one standard deviation increase in the three liquidity ratios corresponds to an increase in the bond spread of 18, 15, and 20 basis points, respectively. The positive relationship between credit spreads and liquidity proxies persists even after controlling for the credit rating. Moreover, in untabulated tests, we estimate specification (2) separately for different ratings groups, and find that the coefficient for cash is increasing monotonically as the rating deteriorates.

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 Schaefer and Strebulaev’s (2008) proxy for asset volatility we use
the asset volatility estimate provided by MKMV. They are strengthened if we use book instead of market leverage. 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. In unreported tests we find that controlling for the presence of such covenants has no impact on our results.\(^{25}\)

Our model suggests that the positive correlation of spreads with liquid assets arises 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 spread. In essence, cash reserves act as another proxy for credit risk. Thus, our theory would predict that as we introduce more credit risk controls, the positive coefficient should decrease. This is what we observe in Table 4. For example, compared with column (1), the coefficient for Cash/TA is lower in column (2), which controls for leverage, volatility, and other factors. In column (3), which also controls for ratings, it is reduced further. Nonetheless, it retains strong statistical significance. 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. Our model suggests two potential instruments. First, profitable future investment opportunities (growth options) increase the value of the firm in the absence of default, and hence strengthen the precautionary motive for saving cash. Yet once the higher cash reserve is in place, it provides a safety cushion for creditors, decreasing credit spreads. The discussion of growth options in Section 2.4.2 suggests that it is variations in non-collateralizable assets that can serve as an instrument for cash in our model. Accordingly, to proxy for growth options, we use the median ratio of intangible to total assets in the firm’s three-digit SIC industry in each calendar year.\(^{26}\)

\(^{25}\)See Murfin (2012) for a recent study of the determinants of bank loan covenants.

\(^{26}\)We prefer intangibles 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
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 incentives 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.\textsuperscript{27}

We employ these two instruments in IV regressions 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. The last row shows the \textit{p}-value of the \textit{F}-test of the instruments’ relevance. It shows that our two instruments are jointly strongly significant determinants of the three liquidity ratios.\textsuperscript{28} The table shows that, as expected, exogenous variations in liquid asset reserves are negatively and significantly related to bond spreads. Moreover, the economic effect of higher liquid reserves is substantial: In fulls-specification regressions (3), (6), and (9), a one standard deviation increase in the instrumented liquidity ratios decreases spreads by between 37 and 53 basis points.

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.

\textsuperscript{27} To be precise, the agency term is defined as \((\text{salary + bonus + other annual compensation + long-term incentive plan + all other compensation})/(\text{value of the equity stake + value of all unexercised options owned})\) for the CEO. As ExecuComp reports the Black-Scholes value of new option grants but not the current value of previously granted options, we employ the algorithm suggested by Himmelberg and Hubbard (2000) to estimate the market value of old options.

\textsuperscript{28} Staiger and Stock (1997) show that when the correlation between instruments and endogenous variables is weak, IV regression coefficients may be biased. They suggest that the \textit{F}-statistic of the hypothesis that the instruments do not enter the first-stage regression should be sufficiently large to avoid the weak-instrument bias. In our univariate regressions of Table 4 these statics range from 15 to 26, although they are smaller in multi-variate tests.
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 that are 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. Shumway (2001) shows that discrete-time hazard regressions are equivalent to logit regressions that include all firm-quarter observations for each firm, defaulting and non-defaulting. Thus, we estimate a set of logit regressions of default for the different prediction horizons using our panel of quarterly observations for the full sample of 2,247 firms. For the horizon of \( m \) years, the dependent variable is equal to one if the firm defaults in the \( m^{th} \) year from the observation date (but not before). Under this regression design, prediction horizons for different firm-quarters overlap, which may bias conventional test statistics. Thus, we use bootstrap, estimating each regression for 1,000 panels re-sampled from firm-level clusters.\(^{29}\)

The results are presented in Table 6. Panel A uses the variables that enter Altman’s (1968) z-score model, including \( WC/TA \), the ratio of working capital to total assets, as a proxy for liquidity. Panel B employs the specification suggested by Zmijewski (1984), which includes the current ratio to control for liquid assets. Panel C uses a different proxy for liquidity, the quick ratio (Davydenko (2010)), and controls for other credit risk factors by including the Expected Default Frequency (EDF) from MKMV, variations of which have been frequently used in recent empirical studies.

While the effect of most variables are consistent with expectations and prior studies (e.g, Shumway (2001)), the effect of liquidity proxies changes depending on the prediction horizon. The regressions in column (1) are for the one-year probability of default. At this horizon, in all three

\(^{29}\)See Horowitz (2001) for a detailed discussion of bootstrap procedures. We thank Andrew Karolyi (the editor) for alerting us to these issues, and Mitch Petersen and Tyler Shumway for their advice on statistical inference under our empirical test design. [SSS Serg: this any good?]
models liquidity ratios are negatively correlated with the probability of default. Depending on the
model, a one standard deviation increase in the liquidity ratio reduces the probability of default by
between one quarter (in Panels A and B) and one-third (in Panel C).\(^{30}\) These results are consistent
with Davydenko (2010), who finds that, controlling for the level of economic distress, the short-term
probability of default is higher when the firm’s liquid assets fall short of its current liabilities, and
that the importance of illiquidity relative to insolvency in triggering default depends on the level of
financing constraints. [SSS Serg: check last para]

In contrast with the short-term results, columns (2) through (4) show that liquidity is \textit{positively}
related to the probability of default at the two to five year horizons, and the coefficients are strongly
statistically significant. The coefficients are broadly similar in magnitude to those in column (1),
but have the opposite sign. A more detailed illustration of this sign reversal for the Zmijweski model
is provided in Figure 3. It plots the coefficient for the current ratio, \(\frac{CA}{CL}\), in regressions of Panel
B, estimated for quarterly rather than yearly prediction intervals (i.e., predicting default within a
certain quarter in the future, rather than within a certain year). The graph shows that liquidity
is negatively correlated with the probability of default for horizons of up to approximately one
year, but the correlation reverses its sign and becomes highly statistically significant for longer-term
predictions. In our model, equilibrium cash reserves are driven by the precautionary motive for
saving cash, and are larger for riskier firms with a higher probability of default. Thus, the long-term
default probability is positively correlated with liquidity. This contrast with the simple intuition
that traditional default-predicting studies rely on implicitly, which only holds for short horizons.

Consistent with the hypothesized effect of endogeneity, columns (5) through (7) of Table 6 show
that the sign of the liquidity coefficients in long-term regressions becomes negative when we use the
instrumental variables introduced in Section 4. The instrumented liquidity ratios are all negative,
and statistically significant for horizons of three years or more.

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 emphasize once again the importance of recognizing that firms
can choose their cash policy endogenously, depending in particular on the firm’s credit risk.

\(^{30}\) King and Zeng (2001) show that when the event of interest is rare (as is the case in studies of default), standard
quantitative predictions in logit regressions are biased in finite samples. Thus, to compute the marginal effect of cash
on the probability of default, we employ the correction for the bias proposed in their study.
Fig. 3. **Liquid assets and the probability of default at different horizons.** This graph shows the point estimate and the 95% confidence interval for the logit regression coefficient for QA/CL in Zmijewski’s (1984) model, for different prediction horizons. For a horizon of \( m \) quarters, the dependent variable equals one if the firm defaults in the \( m \)th quarter from the observation date, and zero otherwise. The regressions also include \( NI/TA \) and \( TL/TA \) as control variables, and the sample consists of 76,349 firm-quarter observations. The confidence interval is obtained by bootstrapping from firm-level clusters.

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 response of firms’ cash holdings to 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 relationship between cash and spreads; it misses the indirect relationship due to the endogeneity of cash, which, as our evidence suggests, dominates in practice. The important implication is that recognizing that balance sheet liquidity is endogenous is crucial for credit risk studies, which is a key effect largely ignored in existing literature.
Appendix A: Continuous-time model

In this Appendix, we develop a continuous-time model of a firm’s optimal cash policy in the presence of costly default and restricted access to external financing. Its purpose is to confirm and extend the results of the base-case model developed in Section 2 in a dynamic setting. The intuition and most of the assumptions parallel those of base-case model, and their discussion can be found in Section 2. A more detailed description of the model can be found in a Supplement, available online and from the authors upon request.

A.1. Model setup

The model features a single levered firm with assets in place in a continuous-time economy. Let $x_t$ be the firm’s cumulative cash flow generated by these assets. We assume that $x_t$ follows an arithmetic Brownian motion under the risk-neutral measure $Q$:

$$dx_t = \mu dt + \sigma dW^Q_t,$$

(A1)

where $\mu$ is the expected change in the cumulative cash flow, $\sigma$ is the instantaneous volatility of the change, and $W_t$ is a standard Brownian motion defined on a filtered probability space $(\Omega, \mathcal{F}, Q, (\mathcal{F}_t)_{t \geq 0})$. Examples of studies using this modeling framework and its discussion can be found in DeMarzo and Sannikov (2007), Piskorski and Tchistyi (2010), and Gryglewicz (2011).

The firm’s capital structure consists of common equity and infinite-maturity debt with a promised coupon rate of $b$, whose level is assumed to be predetermined (a legacy of the past). As long as the coupon is paid, equityholders have ownership rights to the residual value of the firm. If the coupon is not paid, the firm defaults immediately and equityholders forfeit all cash flow rights. Debt cannot be renegotiated and debtholders do not recover any salvage value in bankruptcy. The risk-free rate of interest, $r$, is constant. Due to market frictions, the firm has no access to external financing. Therefore, cash distributions to creditors and shareholders must be financed with internally generated cash flow. To reduce the probability of an insufficient cash flow resulting in default, the firm maintains a cash reserve, denoted as $C_t$.

Absent default before $t$, the accumulated cash reserve can be written as:

$$C_t = C_0 + x_t - bt - D_t,$$

(A2)

where $C_0$ is the initial cash endowment and $D_t$ is the cumulative value of dividends paid out between time 0 and $t$. The firm defaults when its cash reserve falls to zero, i.e., at time $\tau = \inf\{s > 0 : C_s = 0\}$.

Managers act in the best interest of shareholders, choosing the dividend policy to maximize the present value of dividends:

$$\max E^Q \int_0^\tau e^{-rs} dD_s,$$

(A3)

where max is taken over all policies $D_s$, which are independent of the future increments of $dW_t$, $t > s$. In other words, the optimal policy consists of finding among all feasible dividend paths the path that maximizes the present value of the dividend stream.

A.2. Model solution

The firm faces the following trade-off between retaining cash and paying it out as a dividend: On the one hand, higher dividend payments increase the value of equity conditional on survival. On the other hand, by lowering the dividend the firm increases its cash buffer, and with it, the likelihood of survival.
The state variable in the model is the level of cash reserve, $C_t$. The next lemma gives the general solution to the regulated Brownian motion problem (all proofs for this Appendix are available as part of the online Supplement):

**Lemma 1.** There exist a threshold, $\bar{C}$, such that for all non-negative values of $C$ below $\bar{C}$ the dividends are paid at zero rate, and for all values of $C$ above $\bar{C}$ the dividends are paid at infinite rate.

Figure 4 illustrates the solution. The target cash level $\bar{C}$ summarizes the firm’s optimal cash policy. When the accumulated cash reserve is at this level, all earnings are paid out as dividends and cash holdings remain constant. If cash flows decline, so that the cash reserve falls below $\bar{C}$, the firm stops paying dividends and accumulates retained earnings until cash goes back up to the target level.

For $C \leq \bar{C}$, cash holdings follow the following process:

$$dC_t = dx_t - b dt = (\mu - b) dt + \sigma dW_t^Q, \quad 0 \leq C < \bar{C}. \quad (A4)$$

Let $V(C)$ be shareholders’ value function. From the application of Itô’s lemma, $V(C)$ solves the following differential equation:

$$-rV(C) + (\mu - b)V'(C) + \frac{1}{2}\sigma^2 V''(C) = 0, \quad 0 \leq C < \bar{C}. \quad (A5)$$

The general solution to this equation is given by:

$$V(C) = \begin{cases} 
V_1(C) = L_1 e^{\xi_1 C} + L_2 e^{\xi_2 C}, \quad & \text{for } 0 \leq C < \bar{C}, \\
V_2(C) = L_3 C + L_4, \quad & \text{for } C \geq \bar{C}, 
\end{cases} \quad (A6)$$

where $L_1$, $L_2$, $L_3$, and $L_4$ are unknown constants determined from boundary conditions, and $\xi_1$ and $\xi_2$ are, respectively, the positive and negative solutions of the fundamental quadratic equation (see e.g. Stokey (2007)):

$$\xi_1 = \frac{-(\mu - b) + \sqrt{(\mu - b)^2 + 2r\sigma^2}}{\sigma^2}; \quad (A7)$$

$$\xi_2 = \frac{-(\mu - b) - \sqrt{(\mu - b)^2 + 2r\sigma^2}}{\sigma^2}. \quad (A8)$$
For the problem at hand, the boundary conditions take the form:

\begin{align*}
V(0) &= 0; \quad (A9) \\
V_1(\overline{C}) &= V_2(\overline{C}); \quad (A10) \\
V_1'(\overline{C}) &= V_2'(\overline{C}); \quad (A11) \\
V_1''(\overline{C}) &= V_2''(\overline{C}). \quad (A12)
\end{align*}

These conditions are standard for optimal control problems. Condition (A9) follows from the assumption that equityholders receive no payment in default. Condition (A10) imposes the continuity requirement on the value function. Condition (A11) is the smooth-pasting condition and condition (A12) is the super-contact condition (Dumas (1989)).

The next proposition finds the optimal value of the policy-switching threshold as a function of the primitives of the model, \( \mu, b, \sigma, \) and \( r \):

**Proposition 5.** The optimal trigger \( \overline{C} \) is given by:

\[
\overline{C} = \frac{1}{\xi_1 - \xi_2} \ln \frac{\xi_2^2}{\xi_1^2}. \quad (A13)
\]

Importantly, the optimal cash policy is time-invariant.

**A.3. Debt value**

To determine the value of debt and the corresponding credit spread at the point \( C = \overline{C} \), consider a contingent-claim security that pays $1 if the firm’s cash reserve reaches 0 and nothing otherwise. The value of this security, denoted \( A(C) \), satisfies the familiar differential equation (A5) within the region \( C \in [0, \overline{C}] \), and is constant for values of \( C \) greater than or equal to \( \overline{C} \). The general solution is:

\[
A(C) = \begin{cases} 
A_1(C) = K_1 e^{\xi_1 C} + K_2 e^{\xi_2 C}, & 0 \leq C < \overline{C}, \\
A_2(C) = K_3, & C \geq \overline{C},
\end{cases} \quad (A14)
\]

where \( K_1, K_2, \) and \( K_3 \) are constants determined from boundary conditions. For the default claim, the boundary conditions are:

\begin{align*}
A_1(0) &= 1; \quad (A15) \\
A_1(\overline{C}) &= A_2(\overline{C}); \quad (A16) \\
A_1'(\overline{C}) &= 0. \quad (A17)
\end{align*}

The value of the default claim is 1 at the time of default, as implied by Condition (A15). Condition (A16) imposes the continuity requirement on the value function, and condition (A11) is the smooth-pasting condition.

The next proposition gives the value of this claim:

**Proposition 6.** The value of \( A(C) \) is:

\[
A(C) = -\frac{\xi_2 e^{\xi_2 \overline{C}} e^{\xi_1 C}}{\xi_1 e^{\xi_1 \overline{C}} - \xi_2 e^{\xi_2 \overline{C}}} + \frac{\xi_1 e^{\xi_1 \overline{C}} e^{\xi_2 C}}{\xi_1 e^{\xi_1 \overline{C}} - \xi_2 e^{\xi_2 \overline{C}}}. \quad (A18)
\]

Under the assumption that creditors’ recovery in default is zero, the value of debt, \( B(C) \), is given by:

\[
B(C) = \frac{c}{r} (1 - A(C)), \quad 0 \leq C \leq \overline{C}. \quad (A19)
\]
The credit spread, \( s(C) \), is therefore:

\[
s(C) = \frac{b - r}{B(C)} - r = r \frac{A(C)}{1 - A(C)}, \quad 0 \leq C \leq \bar{C}.
\]  

(A20)

A.4. Cash policy and credit risk

In this subsection, we study the effect that changes in model parameters have on optimal cash holdings, credit spreads, and the term structure of default probabilities. Our focus is on the firm’s behavior in those states in which its optimal discretionary cash policy includes dividend payouts, i.e., when cash is at its threshold level: \( C = \bar{C} \). Thus, we look at the correlation between \( \bar{C} \) and \( s(\bar{C}) \) that arises when model parameters vary.

Consider variations in the expected mean cash flow, \( \mu \), as a source of variation in cash and credit spreads. It is easy to show that the optimal cash level \( \bar{C} \) becomes arbitrarily small as the cash flow growth rate increases: \( \lim_{\mu \to \infty} \bar{C} = 0 \).

A.4.1. Cash holdings and credit spreads

The next proposition builds on this intuitive result and shows how equilibrium cash holdings, \( \bar{C} \), and credit spread, \( s(\bar{C}) \), change as \( \mu \) varies:

**Proposition 7.** Assume that \( \mu \geq b \). Then:

1. There exists \( \bar{\mu} > b \) such for all \( \mu > \bar{\mu} \), the optimal cash reserve \( \bar{C} \) is a decreasing function of \( \mu \);
2. The credit spread \( s(\bar{C}) \) is decreasing in \( \mu \).

![Fig. 5. The effect of variation in cash flow on cash policy.](image)

Figure 5 illustrates a typical dependence of the equilibrium cash reserve on \( \mu \). As Proposition 7 states, when the expected cash flow increases above some critical value \( \bar{\mu} \), equilibrium cash holdings decrease in response.

Figure 5 also shows that the relationship is reversed for very low levels of cash flow growth, when the precautionary motive for saving cash is dominated by the incentive to engage in “asset shifting” by receiving a certain current dividend at the expense of making the firm even riskier. In practice, debt covenants are likely to restrict a firm’s ability to pay dividends to shareholders in financial distress, so that the model may
be inapplicable when $\mu < \bar{\mu}$. Therefore, for our purposes, the relevant case is when $\mu > \bar{\mu}$. In this area, an increase in $\mu$ has two effects on spreads, direct and indirect. The direct effect of a higher cash flow growth is to move the firm further away from default, making debt safer and lowering the credit spread. The indirect effect is through the adjustment in the cash reserve: A higher value of $\mu$ implies a lower $C$, which in turn increases the probability of default and hence the credit spread. The second part of Proposition 7 states that the direct effect dominates.

**A.4.2. Cash holdings and the probability of default**

![Fig. 6. The effect of variation in cash flow on the term structure of default probabilities.](image)

The model also sheds light on the relationship between cash policy and the term structure of default probabilities. Although a closed-form solution for finite horizon default probabilities is not available, quantitative results can be easily obtained by numerical methods or simulation. To explore how the variation in expected cash flow changes the dependence of default propensity over time on optimal cash holdings, we employ the following standard simulation method. We simulate $N = 1,000$ firms, which at date 0 all have their cash reserves at their respective $C_i$, $i = 1, \ldots, N$. At date 0, firms are identical apart from their expected cash flow, which we assume to be uniformly distributed. We first simulate random cash flow paths for $t = 100$ years to make sure the initial conditions are forgotten. If any firm defaults during this initial simulation, we replace it with a date-0 twin. After date $t$, we run the simulation for another five years and for each $t + T$, $T = 0.5, \ldots, 5$ years, run a logistic regression of default until $t + T$ on a constant and cash at date $t$. This is similar to the regressions that we use in our empirical tests, except that in the model we don’t need to control for other factors.

Figure 6 plots the average cash coefficient from these regressions over 1,000 runs, as well as the 95% confidence intervals, for a typical range of parameters, as a function of the prediction horizon, $T$.$^{31}$ It shows

---

$^{31}$For this particular figure, we assumed that $b = 1$, $\sigma = 3$, $r = 0.05$, and $\mu$ is uniformly distributed between 2.5 and 10.
that the correlation between cash and the probability of default increases with $T$. The intuition behind this result is the same as that behind the relationship between cash holdings and credit spreads: as firms become riskier (their expected cash flows fall), their optimal cash policy becomes more conservative ($C$ increases). Nonetheless, they are more likely to default, because the direct effect dominates. The comparison of Figure 6 with the corresponding empirical graph in the paper shows that the predictions of the model are consistent with what we observe empirically.

Appendix B: Proofs of model propositions

**Proof of Proposition 1.** Define function $m(I^*, \pi_1)$, where $I^*$ is the optimal investment level from the first-order condition (6), as:

$$m(I^*, \pi_1) = f'(I^*) - 1 - (f(I^*) + x_2) h(u_B). \quad (A21)$$

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

$$\frac{dc^*}{dx_1} = -\frac{dI^*}{dx_1} = - \left( -\frac{\partial m}{\partial \pi_1} \right). \quad (A22)$$

The second-order condition of optimization implies that $\frac{\partial m}{\partial I^*} \leq 0$, as:

$$\frac{\partial m}{\partial I^*} = f''(I^*) - f'(I^*) h(u_B) - (f(I^*) + x_2) h'(u_B), \quad (A23)$$

which is negative because $f'' < 0$ and $h' \geq 0$. Also:

$$\frac{\partial m}{\partial x_1} = -(f(I^*) + x_2) h'(u_B) \frac{\partial u_B}{\partial x_1} > 0, \quad (A24)$$

because $\frac{\partial u_B}{\partial x_1} = -1$. Therefore, $\frac{dc^*}{dx_1} \leq 0$.

*Part 2.* From definitions of $D$ and $s$ (Equations (8) and (9)), it follows that:

$$\frac{\partial s}{\partial x_1} = -\frac{B}{D^2} \frac{\partial D}{\partial x_1} = -\frac{B}{D^2} G(u_B), \quad (A25)$$

and

$$\frac{\partial s}{\partial c^*} = -\frac{B}{D^2} \frac{\partial D}{\partial c^*} = -\frac{B}{D^2} G(u_B). \quad (A26)$$

Therefore:

$$\frac{ds}{dx_1} = \frac{\partial s}{\partial x_1} + \frac{\partial s}{\partial c^*} \frac{dc^*}{dx_1} = -\frac{B}{D^2} G(u_B) \left( 1 + \frac{dc^*}{dx_1} \right). \quad (A27)$$

Because $\frac{dc^*}{dx_1} \leq 0$, for this quantity to be negative, it is sufficient to establish that $\frac{dc^*}{dx_1} > -1$. From Equation (A47):

$$\frac{dc^*}{dx_1} = \frac{(f(I^*) + x_2) h'(u_B) - f''(I^*) h(u_B)}{f''(I^*) - f'(I^*) h(u_B) - (f(I^*) + x_2) h'(u_B)}. \quad (A28)$$

The right-hand of this equation is greater than $-1$ as:
\[ f''(I^*) - f'(I^*)h(u_B) < 0. \] (A29)

Therefore, \( \frac{ds}{dx_1} < 0. \) \( \Box \)

**Proof of Proposition 2.** Because \( \frac{\partial s}{\partial y} = 0, \) it follows that:

\[
\frac{ds^*}{dy} = \frac{\partial s}{\partial c^*} \frac{\partial c^*}{\partial y}. \] (A30)

In the proof of Proposition 1, we showed that:

\[
\frac{\partial s}{\partial c^*} = -\frac{B}{D^2} \frac{\partial D}{\partial c^*} = -\frac{B}{D^2} G(u_B) < 0. \] (A31)

Therefore, the sign of \( \frac{ds^*}{dy} \) is the opposite of the sign of \( \frac{\partial c^*}{\partial y}. \) \( \Box \)

**Proof of Proposition 3.** As \( q = G(u_B), \) we can write:

\[
\frac{dG(u_B)}{dx_1} = g(u_B) \frac{du_B}{dx_1}. \] (A32)

From (2), we know that \( I^* = u_B + \bar{x} - B + x_0, \) and so we can define function \( n(u_B, \bar{x}), \) such that:

\[
n(u_B, \bar{x}) = m(I^*(u_B), \bar{x}) = f'(u_B + \bar{x} - B + x_0) - 1 - (f(u_B + \bar{x} - B + x_0) + x_2) h(u_B). \] (A33)

It follows that:

\[
\frac{du_B}{dx_1} = -\frac{\partial n}{\partial u_B}, \] (A34)

where:

\[
\frac{\partial n}{\partial x_1} = f''(\cdot) - f'(\cdot)h(u_B) < 0, \] (A35)

and

\[
\frac{\partial n}{\partial u_B} = f''(\cdot) - f'(\cdot)h(u_B) - (f(\cdot) + x_2) h'(\cdot) < 0, \] (A36)

so that \( \frac{du_B}{dx_1} < 0. \) \( \Box \)

**Proof of Proposition 4.** From (12) and (13), the first-order condition can be written as:

\[
f'(I) = \frac{1 + (1 - \tau) (f(I) + x_2) h(\psi_B)}{1 + \tau(1 - \tau) (f(I) + x_2) h(\psi_B)}. \] (A37)

Similar to the proof of Proposition 1, define function \( m(I^*, \bar{x}), \) where \( I^* \) is the optimal investment level from the first-order condition (A37), as:
\[ m(I^*, \tau_1) = f'(I^*) - \frac{1 + (1 - \tau) (f(I^*) + vh_2) h(u_B)}{1 + \tau (1 - \tau) (f(I^*) + x_2) h(u_B)}. \]  

(A38)

**Part 1.** Because \( c^* = c_0 - I^* \),

\[ \frac{dc^*}{dx_1} = -\left( -\frac{\partial m}{\partial \tau} \right). \]  

(A39)

The second-order condition of optimization implies that \( \frac{\partial m}{\partial \tau} \leq 0 \). To see it, re-write it as:

\[ \frac{\partial m}{\partial \tau} = f''(I^*) - \frac{(1 - \tau)^2 (f(I^*) + x_2) h'(u_B) (1 - \tau f'(I^*))}{(1 + \tau (1 - \tau) (f(I^*) + x_2) h(u_B))^2}, \]  

(A40)

which is non-positive because \( f'' < 0 \), \( h' > 0 \), and \( f'(I^*) < \frac{1}{\tau} \) (the latter holds from the first-order condition (A37)). Also:

\[ \frac{\partial m}{\partial x_1} = -\frac{(1 - \tau)^2 (f(I^*) + x_2) h'(u_B) \frac{\partial u_B}{\partial x_1}}{(1 + \tau (1 - \tau) (f(I^*) + x_2) h(u_B))^2} > 0, \]  

(A41)

because \( \frac{\partial u_B}{\partial x_1} = -1 \). Therefore, \( \frac{dc^*}{dx_1} \leq 0 \).

**Part 2.** From definitions of \( D \) and \( s \) (Equations (8) and (9)), it follows that:

\[ \frac{ds}{dx_1} = -\frac{B}{D^2} \frac{\partial D}{\partial x_1} = -\frac{B}{D^2} (G(u_B) + g(u_B)\tau (f(I^*) + x_2)), \]  

(A42)

and

\[ \frac{\partial s}{\partial c^*} = -\frac{B}{D^2} \frac{\partial D}{\partial \tau} = -\frac{B}{D^2} (G(u_B) + g(u_B)\tau (f(I^*) + x_2) - \tau^2 f'(I^*) g(u_B)). \]  

(A43)

Therefore:

\[ \frac{ds}{dx_1} = \frac{ds}{dx_1} + \frac{ds}{dx_1} \frac{\partial c^*}{dx_1} \]  

(A44)

\[ = -\frac{B}{D^2} (G(u_B) + g(u_B)\tau (f(I^*) + x_2)) \left(1 + \frac{\partial c^*}{dx_1} \right) + \frac{B}{D^2} \tau^2 (f(I^*) + x_2) f'(I^*) g(u_B) \frac{\partial c^*}{dx_1}. \]

Because \( \frac{\partial c^*}{dx_1} \leq 0 \), for this quantity to be negative, it is sufficient to establish that \( \frac{\partial c^*}{dx_1} > -1 \). From Equation (A47):

\[ \frac{\partial c^*}{dx_1} = -\frac{\frac{(1 - \tau)^2 (f(I^*) + x_2) h'(u_B) \frac{\partial u_B}{\partial x_1}}{(1 + \tau (1 - \tau) (f(I^*) + x_2) h(u_B))^2}} {f''(I^*) - \frac{(1 - \tau)^2 f'(I^*) h(u_B) + (f(I^*) + x_2) h'(u_B) (1 - \tau f'(I^*))}{(1 + \tau (1 - \tau) (f(I^*) + x_2) h(u_B))^2}}. \]  

(A45)

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

\[ Z(\tau) \equiv f''(I^*) - f'(I^*) (1 - \tau f'(I^*))^2 (h(u_B) - \tau (f(I^*) + x_2) h'(u_B)) < 0. \]  

(A46)

Recall from the proof of Proposition 1 that \( Z(0) = f''(I^*) - f'(I^*) h(u_B) < 0 \). Because \( Z(\tau) \) is continuous in \( \tau \), there exist such \( \tilde{\tau} > 0 \) that for all \( \tau < \tilde{\tau} \), the condition (A46) is satisfied. \( \square \)

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B.5. Growth options and managerial losses

**Proposition B1.** The equilibrium level of cash holdings $c^*$ is positively related to the growth option $x_2$. Credit spread $s$ is negatively related to the growth option $x_2$ only through the change in optimal cash balance.

**Proof of Proposition B1.** Similar to the proof of Proposition 1, we can write that:

$$\frac{dc^*}{dx_2} = -\left( -\frac{\partial m}{\partial x_2} \right),$$

where $m(I^*, x_1)$ is defined in (A38). As we established earlier, $\frac{\partial m}{\partial x^*} < 0$. By taking derivative, $\frac{\partial m}{\partial x_2} = -h(u_B) < 0$, and therefore $\frac{dc^*}{dx_2} > 0$. This establishes the first result in the Proposition.

The result on credit spread follows because $\frac{\partial s}{\partial x_2} = 0$ by assumption, and, as shown earlier, $\frac{\partial s}{\partial c^*} < 0$. □

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

**Proof of Proposition B2.** The first-order condition of the manager’s objective function (10) can be written as:

$$\frac{\partial M}{\partial I} = \theta \int_{u_B}^{\infty} [-1 + f'(I)]g(\psi)d\psi - [-I + (c_0 + x_1 + u_B - B) + f(I)]g(u_B)\frac{\partial u_B}{\partial I} - \gamma g(u_B)\frac{\partial u_B}{\partial I} = 0, \quad (A48)$$

which results in a condition identical to the first-order condition 7, with $x_2$ replaced by $\gamma y$. The result then follows from applying the proof of Proposition 1. □
References


BHARATH, SREEDHAR T., AND TYLER SHUMWAY, 2008, Forecasting default with the Merton Distance to Default model, Review of Financial Studies 21, 1339–1369.


CROSIE, PETER J., AND JEFFREY R. BOHN, 2001, Modeling default risk, KMV LLC.


Table 1
Sample composition by rating

This table shows the number of unique firms and the number of observations for the full sample (columns (1) and (2)), and for the subsample of firms with straight bonds with observed spreads (columns (3) and (4)), by the firm’s senior unsecured rating. The ratings in columns (1) and (3) are as of the first date that the firm appears in the data set, and in columns (2) and (4) as of the observation date.

<table>
<thead>
<tr>
<th></th>
<th>Study of defaults</th>
<th>Study of spreads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Firms</td>
<td>Firm-quarters</td>
</tr>
<tr>
<td>AAA</td>
<td>16</td>
<td>546</td>
</tr>
<tr>
<td>AA</td>
<td>77</td>
<td>2,184</td>
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<td>A</td>
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<td>11,745</td>
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<td>BBB</td>
<td>383</td>
<td>19,099</td>
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<tr>
<td>BB</td>
<td>449</td>
<td>15,136</td>
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<tr>
<td>B</td>
<td>870</td>
<td>24,444</td>
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<tr>
<td>CCC and below</td>
<td>157</td>
<td>6,778</td>
</tr>
<tr>
<td>Total</td>
<td>2,247</td>
<td>79,932</td>
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</table>
Table 2  
Statistics on credit spreads and liquidity ratios

Panel A reports the annualized bond spread, averaged over all outstanding straight bonds for each firm-month, by firm’s senior unsecured rating. The benchmark risk-free yield is the yield on a cash flow-matched portfolio of STRIPS as of the observation date. Panel B reports liquidity ratios for the full sample of firm-quarters. $TA$ 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.

<table>
<thead>
<tr>
<th>Panel A: Credit spreads</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>St. dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>2.24</td>
<td>1.53</td>
<td>0.95</td>
<td>2.60</td>
<td>2.18</td>
<td>35,206</td>
</tr>
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<td>AAA</td>
<td>0.91</td>
<td>0.84</td>
<td>0.62</td>
<td>1.15</td>
<td>0.36</td>
<td>700</td>
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<td>AA</td>
<td>0.87</td>
<td>0.77</td>
<td>0.55</td>
<td>1.05</td>
<td>0.44</td>
<td>2,245</td>
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<td>A</td>
<td>1.25</td>
<td>1.09</td>
<td>0.76</td>
<td>1.55</td>
<td>0.71</td>
<td>10,980</td>
</tr>
<tr>
<td>BBB</td>
<td>1.96</td>
<td>1.62</td>
<td>1.03</td>
<td>2.28</td>
<td>1.44</td>
<td>13,120</td>
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<td>BB</td>
<td>3.61</td>
<td>3.08</td>
<td>2.05</td>
<td>4.46</td>
<td>2.27</td>
<td>5,280</td>
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<tr>
<td>B</td>
<td>5.42</td>
<td>4.41</td>
<td>3.02</td>
<td>7.08</td>
<td>3.18</td>
<td>2,158</td>
</tr>
<tr>
<td>CCC and below</td>
<td>8.33</td>
<td>7.83</td>
<td>5.28</td>
<td>12.24</td>
<td>3.57</td>
<td>723</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Liquid asset reserves</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>St. dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash/Assets</td>
<td>0.071</td>
<td>0.031</td>
<td>0.010</td>
<td>0.088</td>
<td>0.101</td>
<td>79,633</td>
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<tr>
<td>WC/TA</td>
<td>0.115</td>
<td>0.087</td>
<td>0.001</td>
<td>0.212</td>
<td>0.164</td>
<td>76,600</td>
</tr>
<tr>
<td>CA/CL (current ratio)</td>
<td>1.696</td>
<td>1.446</td>
<td>1.004</td>
<td>2.071</td>
<td>1.073</td>
<td>76,599</td>
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<tr>
<td>QA/CL (quick ratio)</td>
<td>1.061</td>
<td>0.836</td>
<td>0.543</td>
<td>1.256</td>
<td>0.905</td>
<td>75,458</td>
</tr>
</tbody>
</table>
This table reports summary statistics on control variables used in regressions of spreads (Panel A) and the probability of default (Panel B). TA is the total book value of assets. Leverage is the book value of total debt divided by the sum of the book value of debt and the market value of equity. Asset volatility is the annualized standard deviation of asset returns, estimated as suggested by Schaefer and Strebulaev (2008). Distance to default is a volatility-adjusted measure of leverage computed using the simplified approach of Bharath and Shumway (2008). Bond maturity is the remaining bond maturity in years on the observation date averaged over all bonds with available spreads. Risk-free rate is the 10-year constant-maturity rate, and slope is the difference between the 10-year and the 2-year Treasury rates. Jump is the option-implied measure of market jumps, constructed as in Collin-Dufresne at al. (2001). RE is retained earnings, ME is the market value of equity, S is sales, NI is net income, TL is the book value of total liabilities, and EDF is the Expected Default Frequency provided by MKMV.

### Panel A: Determinants of credit spreads

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>St. dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA, $Bn</td>
<td>16.94</td>
<td>7.66</td>
<td>3.39</td>
<td>18.98</td>
<td>33.68</td>
<td>35,203</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.324</td>
<td>0.287</td>
<td>0.160</td>
<td>0.456</td>
<td>0.205</td>
<td>31,079</td>
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<tr>
<td>Asset volatility</td>
<td>0.239</td>
<td>0.226</td>
<td>0.179</td>
<td>0.283</td>
<td>0.088</td>
<td>29,762</td>
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<tr>
<td>Distance to default</td>
<td>5.993</td>
<td>5.674</td>
<td>3.375</td>
<td>8.313</td>
<td>4.069</td>
<td>29,757</td>
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<td>Bond maturity, yrs</td>
<td>5.035</td>
<td>3.064</td>
<td>1.621</td>
<td>6.209</td>
<td>5.546</td>
<td>35,206</td>
</tr>
<tr>
<td>Risk-free rate, %</td>
<td>5.048</td>
<td>5.060</td>
<td>4.340</td>
<td>5.800</td>
<td>0.939</td>
<td>35,206</td>
</tr>
<tr>
<td>Slope, %</td>
<td>0.851</td>
<td>0.430</td>
<td>0.100</td>
<td>1.860</td>
<td>0.934</td>
<td>35,206</td>
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<tr>
<td>VIX</td>
<td>0.23</td>
<td>0.23</td>
<td>0.19</td>
<td>0.25</td>
<td>0.067</td>
<td>34,821</td>
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<tr>
<td>S&amp;P return, %</td>
<td>0.66</td>
<td>1.00</td>
<td>-2.15</td>
<td>4.35</td>
<td>4.773</td>
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<tr>
<td>Jump</td>
<td>0.043</td>
<td>0.048</td>
<td>0.029</td>
<td>0.057</td>
<td>0.025</td>
<td>35,206</td>
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</table>

### Panel B: Determinants of the default probability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>St. dev.</th>
<th>N</th>
</tr>
</thead>
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<tr>
<td>RE/TA</td>
<td>0.044</td>
<td>0.108</td>
<td>-0.038</td>
<td>0.265</td>
<td>0.447</td>
<td>75,266</td>
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<tr>
<td>EBIT/TA</td>
<td>0.019</td>
<td>0.021</td>
<td>0.009</td>
<td>0.033</td>
<td>0.032</td>
<td>71,942</td>
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<tr>
<td>ME/TA</td>
<td>1.988</td>
<td>1.153</td>
<td>0.579</td>
<td>2.264</td>
<td>2.635</td>
<td>65,100</td>
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<tr>
<td>S/TA</td>
<td>0.255</td>
<td>0.210</td>
<td>0.119</td>
<td>0.327</td>
<td>0.192</td>
<td>79,746</td>
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<tr>
<td>NI/TA</td>
<td>0.005</td>
<td>0.009</td>
<td>0.000</td>
<td>0.018</td>
<td>0.031</td>
<td>79,758</td>
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<tr>
<td>TL/TA</td>
<td>0.690</td>
<td>0.659</td>
<td>0.542</td>
<td>0.785</td>
<td>0.253</td>
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<tr>
<td>EDF, %</td>
<td>2.221</td>
<td>0.390</td>
<td>0.096</td>
<td>1.603</td>
<td>4.648</td>
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<td>z-score</td>
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<td>1.350</td>
<td>0.713</td>
<td>2.250</td>
<td>1.816</td>
<td>53,575</td>
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</table>
Table 4
OLS regressions of bond spreads

The dependent variable is the annualized yield spread 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 annualized standard deviation of asset returns, estimated as suggested by Schaefer and Strebulaev (2008). $Distance to default$ is a volatility-adjusted measure of leverage computed using the simplified approach of Bharath and Shumway (2008). $Bond maturity$ is the remaining bond maturity in years on the observation date averaged over all bonds with available spreads. $Risk-free rate$ is the 10-year constant-maturity rate, and $slope$ is the difference between the 10-year and the 2-year Treasury rates. $Jump$ is the option-implied measure of market jumps, constructed as in Collin-Dufresne et al. (2001). 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.

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<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
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<td>Cash/TA</td>
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<td>1.21***</td>
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<td>WC/TA</td>
<td></td>
<td></td>
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<td>1.21***</td>
<td>0.75**</td>
<td>0.65***</td>
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<td>CA/CL</td>
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<td>0.30***</td>
<td>0.15**</td>
<td>0.14***</td>
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<td>(3.47)</td>
<td>(2.39)</td>
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<tr>
<td>Leverage</td>
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<td>2.70***</td>
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<td>3.06***</td>
<td>7.06***</td>
<td>3.03***</td>
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<tr>
<td>Asset volatility</td>
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<td>2.56***</td>
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<td>8.08***</td>
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<td>Log(Assets)</td>
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<td>-0.12***</td>
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<td>-0.12***</td>
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<td>(-0.37)</td>
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<td>(-0.26)</td>
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</tr>
<tr>
<td>Distance to default</td>
<td>0.0014</td>
<td>-0.054***</td>
<td>0.023*</td>
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<td>0.023*</td>
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<td>(-4.19)</td>
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<tr>
<td>Maturity</td>
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<td>0.039***</td>
<td>0.037***</td>
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<td>0.038***</td>
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<td>(5.96)</td>
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<td>Risk-free rate</td>
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<td>-0.18***</td>
<td>-0.41***</td>
<td>-0.18***</td>
<td>-0.41***</td>
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<td>TS slope</td>
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<td>0.054*</td>
<td>-0.084***</td>
<td>0.053*</td>
<td>-0.085***</td>
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<td>(1.74)</td>
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<tr>
<td>VIX</td>
<td>2.98***</td>
<td>5.12***</td>
<td>2.98***</td>
<td>5.20***</td>
<td>2.98***</td>
<td>5.21***</td>
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<td></td>
<td>(7.81)</td>
<td>(13.4)</td>
<td>(8.04)</td>
<td>(13.5)</td>
<td>(7.94)</td>
<td>(13.5)</td>
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<tr>
<td>S&amp;P return</td>
<td>-0.020***</td>
<td>-0.011***</td>
<td>-0.020***</td>
<td>-0.011***</td>
<td>-0.020***</td>
<td>-0.011***</td>
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<td></td>
<td>(-9.93)</td>
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<td>(-9.76)</td>
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<td>(-9.55)</td>
<td>(-5.95)</td>
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<tr>
<td>Jump</td>
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<td>5.95***</td>
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In Table 5, instrumental variable regressions of credit spreads are reported. The dependent variable is the annualized yield spread 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 ratio of Intangible to Total Assets of the median firm in the same three-digit SIC industry in each quarter 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 annualized standard deviation of asset returns, estimated as suggested by Schaefer and Strebulaev (2008). Distance to default is a volatility-adjusted measure of leverage computed using the simplified approach of Bharath and Shumway (2008). Bond maturity is the remaining bond maturity in years on the observation date averaged over all bonds with available spreads. Risk-free rate is the 10-year constant-maturity rate, and slope is the difference between the 10-year and the 2-year Treasury rates. Jump is the option-implied measure of market jumps, constructed as in Collin-Dufresne et al. (2001). 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. The last row reports the p-value of the F-test of the hypothesis that the instruments do not enter the first-stage regression.

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This table reports logit regressions (columns (1)–(4)) and instrumental-variable logit regressions (columns (5)–(7)) of bond defaults at different prediction horizons. In regression (1), the dependent variable equals 1 if the firm defaults within the following year, and 0 otherwise. In regressions (2) through (7), the dependent variable equals 1 if the firm defaults within a given year from the observation date, but not before. 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 MKMV. Each regression was estimated using 1,000 bootstrapped samples from firm-level clusters; the resulting z-statistics are reported in parentheses. Coefficients marked ***, **, and * are significant at the 1%, 5%, and 10% significance levels, respectively.

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