

CASH HOLDINGS AND CREDIT RISK*

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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. This puzzling finding can be explained by the precautionary motive for saving cash, which in our model causes riskier firms to accumulate higher cash reserves. In contrast, spreads are negatively related to the part of cash holdings that is not determined by credit risk factors. Similarly, although firms with higher cash reserves are less likely to default in the short term, 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

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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 a 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 the 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 close to distress. As a result, larger cash holdings are empirically associated with higher, not lower, levels of credit risk.

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 the firm’s liability structure, and in particular, to the implied credit risk. Hence, a higher level of cash reflects other changes across the firm’s assets and liabilities, and does not necessarily imply a safer firm overall.

We take predictions from this simple theoretical argument to the data to explore complex interactions between cash policy and credit risk. Two of our empirical results are particularly striking and counter-intuitive. First, when we replicate the reduced-form approach commonly used in empirical studies of credit spreads, 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. Thus, it may appear that higher cash holdings increase credit spreads. The effect is robust and persistent.

Second, we explore the role of liquid assets in empirical default-predicting models, such as Altman’s (1968) z -score.¹ 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.² When we re-estimate such models, we find that the correlation of liquidity with default depends crucially on the time 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 over one year, the correlation between cash and default reverses

¹Other prominent studies include Ohlson (1980), Zmijewski (1984), Shumway (2001), and Chava and Jarrow (2004)

²For example, the correlation of the probability of default with the current ratio is positive in Zmijewski (1984) and negative in Shumway (2001), whereas that with the ratio of working capital to total assets is negative in Ohlson (1980) and positive in Hillegeist *et al.* (2004).

sign and becomes positive and strongly statistically significant. It would appear that higher cash holdings increase the long-term probability of default.

What can explain these puzzling empirical findings? We propose a theory based on the endogeneity of a levered firm's cash policy. In the presence of financing constraints, riskier firms (for example, those with lower expected cash flows) optimally choose to maintain higher cash reserves as a buffer against the possible cash flow shortfall in the future. In the model, the firm can either invest its cash long term, or retain it as a cash buffer until the firm's debt comes due.³ Market frictions restrict the firm's access to external capital, and default is costly. The firm faces a trade-off between investing more (and getting higher cash flows in the future, conditional on not defaulting) and keeping more cash in a reserve (implying a lower probability of a cash shortage and thus a higher chance of survival).

In this model, a change in factors that affect the firm's credit risk influences spreads and default probabilities through two channels: directly (the 'direct' channel), and through the adjustment in the level of cash holdings (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. As a result, riskier firms have both higher optimal cash reserves *and* higher credit spreads and long-term default probability.

Conversely, the model implies that variations in cash holdings that are unrelated to credit risk factors (so that there is no direct effect on spreads) should be negatively related to 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 (2011)), but may increase it over a longer period, reconciling the seemingly conflicting evidence of the effect of cash holdings in default-

³We also develop a continuous-time model with fixed investment but endogenous dividends, which delivers similar basic predictions.

predicting studies.

Our findings highlight the importance of adopting the corporate finance prospective in asset pricing studies. For instance, extant credit risk models typically assume that should the firm find itself in a temporary cash shortage, it avoids default by costlessly selling new equity, as long as the share price remains positive, rendering cash policy irrelevant.⁴ This approach is mirrored in empirical credit risk studies, which also do not consider the role of cash holdings.⁵ 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.⁶ Otherwise, employing the most common balance-sheet ‘control’ variables (such as proxies for corporate liquidity) in standard tests (such as predictive regressions of default) may yield economically misleading conclusions.

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)).⁷ However, extant studies do not explicitly link cash holdings to credit risk or credit spreads, as we do. Moreover, we show that precautionary motives for saving cash are of first-order importance even for rated public bond issuers, suggesting that these firms exhibit behavior qualitatively similar to that of more financially constrained firms.

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

⁴This assumption is made 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.

⁵E.g., Collin-Dufresne, Goldstein, and Martin (2001), Duffee (1998), and Schaefer and Strebulaev (2008).

⁶Although the endogeneity of firm characteristics is recognized as a major issue in empirical corporate finance and many other areas of economic research (Roberts and Whited (2012)), it appears to have attracted less attention in asset pricing studies.

⁷Studies of corporate cash holdings include, among others, Kim, Mauer, and Sherman (1998), Opler, Pinkowitz, Stulz, and Williamson (1999), Almeida, Campello, and Weisbach (2004), and Bates, Kahle, and Stulz (2009).

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. Appendix A outlines a continuous-time model of endogenous cash policy, which, while very different, delivers the same main results.

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 $[\underline{u}, \infty)$,⁸ and with the associated cumulative distribution function $G(u)$ and the hazard rate $h(u)$, defined as:

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

We assume the hazard rate $h(u)$ to be weakly monotonically increasing.⁹ For our purposes, it is sufficient that the cash-flow shock u is the only source of randomness in the model, and hence 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.

At date $t = 0$, the assets in place generate a positive cash flow $x_0 > 0$. 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.

⁸Although the firm’s cash flow can be negative, it is 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.

⁹This assumption is unrestrictive and often appears in economic applications, such as game theory and auctions (e.g., Fudenberg and Tirole (1991, p.267)). Bagnoli and Bergstrom (2005) show that the hazard rate is weakly monotonic if the function $(1 - G(u))$ is log-concave, which holds for uniform, normal, logistic, exponential, and many other probability distributions.

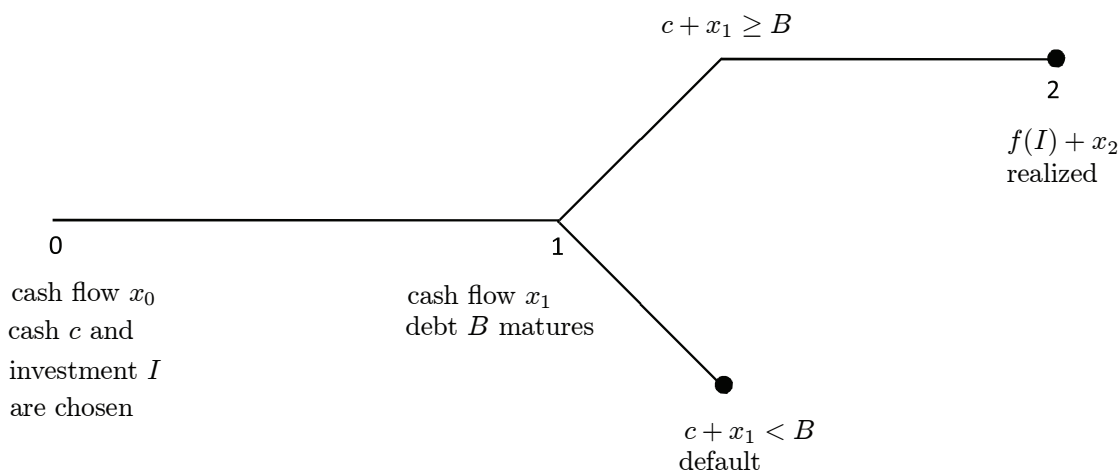


Fig. 1. The timeline of the model.

We denote the cash reserve as c , so that $c = x_0 - I$.

At date $t = 1$, the firm must make a debt payment of B , which is assumed to be predetermined (a legacy of the past).¹⁰ 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 the 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 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 interests of shareholders. Figure 1 illustrates the model's timeline.

¹⁰Although 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 (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 holdings are likely to be more easily adjusted than debt levels. Therefore, in our analysis of the optimal cash policy we treat debt as exogenous.

2.2. Discussion

Before proceeding further, we want to stress that the exact specification of the model can vary widely 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 are 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 is likely to be universally met. While the base-case model assumes that external financing is prohibited altogether, Subsection 2.6 extends the model by allowing the firm to borrow up to a certain fraction of its future cash flows at $t = 1$, and shows that our main results 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. 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, in addition to saving and investing, firms can also 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 in the model 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. In our base-case model, we assume that in order to prevent such behavior, discretionary dividends are prohibited by covenants. In Appendix A, we relax this assumption, and develop a continuous-time model with optimal dividend and cash retention policies.

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. Selling equity 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 cash is exactly offset by the increase in the required debt repayment (i.e., cash is negative debt in our model). In our base-case model, we assume that financing constraints at $t = 0$ preclude the firm from accessing any additional financing. Allowing for optimally chosen financing ex ante could be an interesting extension of our model.

Returning 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 cost of cash holdings is convenient, but by no means unique. 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. In our model, forgone investment should be understood more broadly as the opportunity cost of cash. For example, in Appendix A, we present a continuous-time model in which investment is fixed but the dividend policy is optimally determined. In that model, the opportunity cost of retaining cash is represented by the value of unpaid dividends.

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 the 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.¹¹

The amount of cash available for debt service at date 1 is $c + x_1$, where $c = x_0 - I$ is the cash reserve and $x_1 = \bar{x}_1 + u$ 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:¹²

$$u_B = B - x_0 + I - \bar{x}_1. \quad (2)$$

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 \underline{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:

$$E = \int_{u_B}^{\infty} [x_0 - I + \bar{x}_1 + u - B + f(I) + x_2]g(u) du, \quad (3)$$

which can also be rewritten intuitively as:

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

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

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:¹³

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

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

¹¹Covenant 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.

¹²Without loss of generality, we assume that $u_B \geq \underline{u}$.

¹³It 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.

condition as:

$$f'(I) = 1 + (f(I) + x_2) h(u_B). \quad (6)$$

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:

$$(f'(I) - 1) \times (1 - G(u_B)) dI = (f(I) + x_2) \times g(u_B) du_B. \quad (7)$$

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:

$$D = B - \int_{\underline{u}}^{u_B} [B - (c + \bar{x}_1 + u)] g(u) du, \quad (8)$$

which equals the face value of debt B adjusted for the loss that creditors expect to incur in default states $[\underline{u}, u_B]$. (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:

$$s = \frac{B}{D} - 1. \quad (9)$$

2.4. Cash holdings and credit spreads

In this subsection, we study the correlation between credit spreads and cash reserves, which arises 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 Appendix B 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 holdings, 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.¹⁴

As noted above, similar effects can arise due to variations in firm characteristics other than the cash flow, if they affect both spreads and optimal cash holdings. For example, suppose that the firm's debt level increases. The direct effect of this increase is to raise spreads. However, optimal

¹⁴This discussion underscores 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 pledgeability in Subsection 2.6.

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.

PROPOSITION 2. *If $\frac{\partial s}{\partial y} = 0$, then $\text{sign}\left(\frac{ds^*}{dy}\right) = -\text{sign}\left(\frac{\partial c}{\partial y}\right)$.*

This Proposition states that when a 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’ (to credit risk) changes in cash.

In our empirical analysis, we refer to factors y that induce an exogenous variation in cash as *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 the parameters of the production function, $f(\cdot)$, satisfy these requirements. Variations in cash induced by changes in these variables would be negatively correlated with 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.¹⁵ One example of an instrument would be any unanticipated shock to the firm's cash that occurs between $t = 0$ and debt maturity.¹⁶ As discussed above, non-collateralizable long-term growth options also induce exogenous variations in cash. Other non-collateralizable assets, such as human capital, can play the same role.¹⁷

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 (2007), and Ozelge and Saunders (2008) 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

¹⁵We would like to thank the referee for pointing out this property of instruments.

¹⁶For 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.

¹⁷It is worth emphasizing that in 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 outstanding bonds 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 the 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 affects the value of the long-term debt directly (by increasing the amount of cash available at T_2), and hence cannot be used as a long-term instrument.

structure of their compensation contracts.¹⁸ 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 compensation can induce an exogenous variation in cash holdings.

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 θ , the manager's incentives to retain cash increase with the private cost of distress γ . Conversely, given γ , they decline with her ownership of the firm θ . The overall effect on the manager's chosen cash policy depends on the ratio of managerial cost to equity stake, $\frac{\gamma}{\theta}$, which can be interpreted as a measure of agency problems between the manager and equityholders. The higher the manager's private cost of default and the lower her equity stake, the more conservative the firm's cash policy (relative to one that maximizes the overall value of equity), resulting in lower credit spreads for the same underlying level of credit risk. Formally, the manager's objective is to choose investment I to maximize:

$$M = \theta \times E - \gamma G(u_B). \tag{10}$$

As Appendix B shows, this case is technically very similar to that of the variation in x_2 , and the cross-sectional correlation between cash holdings and spreads induced by variations in the agency factor $\frac{\gamma}{\theta}$ 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 on a short notice. Therefore, the relationship between cash and default in the short term should be studied *conditional* on past cash and investment choices.

¹⁸Managerial incentives have also been shown to be important in studies of capital structure (Carlson and Lazrak (2010)) and corporate takeovers (Pinkowitz, Sturgess, and Williamson (2011)).

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 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:

$$q = \int_{\underline{u}}^{u_B} g(u) du = G(u_B). \quad (11)$$

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, \bar{x}_1 . According to Proposition 1, as \bar{x}_1 increases, shareholders optimally decrease the cash reserve c^* at $t = 0$. 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 \bar{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 pledgeability

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 pledgeability of future cash flows. Suppose that at $t = 1$ the firm can use a fraction τ 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 flow, whereas $\tau = 1$ implies frictionless access to external capital.¹⁹

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 $x_1 = \bar{x}_1 + u$, 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:

$$u_B = B - c_0 - \bar{x}_1 + I - \tau(f(I) + x_2). \quad (12)$$

The value of equity can be written as:

$$E = \int_{u_B}^{\infty} [(u - u_B) + (1 - \tau)(f(I) + x_2)]g(u) du, \quad (13)$$

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 the period-2 cash flow, conditional on the firm not defaulting in the interim.

As previously, changes in model parameters can 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 constraints are sufficiently binding:

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

¹⁹One economic interpretation of τ is that it represents the extent to which future cash flows are verifiable at date 1. Low values of τ correspond to unverifiable cash flows that are difficult to pledge as collateral to providers of outside finance.

1. The equilibrium cash reserve c^* is a non-increasing function of \bar{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 \bar{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 \bar{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 restrictive enough.

It is worth noting that when asset pledgeability τ 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 substitution’ 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 investments have no value in default. Thus, under such scenarios the overall effect of the increase in the expected interim cash flow may be to increase spreads.²⁰

3. Data description

This section describes our data and discusses the variables that we use in the empirical tests.

3.1. Data sources and sample composition

Our empirical analysis focuses on credit spreads and the probability of default. We restrict our attention to firms that issue public bonds, because private-debt defaults and credit spreads are

²⁰Note that incentives to engage in asset substitution disappear in the absence of financing frictions. 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.

difficult to observe. 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. The pricing data consists of monthly bid quotes from Merrill Lynch's bond trading desks, and is only available for a subset of bond issuers.²¹ Our sample extends from December 1996 (the month when the indices were created) to September 2010.

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 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. Overall, the sample consists of 79,932 firm-quarter observations for 2,247 bond issuers at risk of default.

Bond pricing information is available from the Merrill Lynch indices for 1,595 of our firms. 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 less than one year or more than thirty years, because risk-free yields 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 that we use to estimate bond spreads.

Table 1 shows the composition of our sample, as well as that of the subsample for which spreads are available.²² As can be seen from column (1), B-rated firms are the most common in the firm-

²¹The 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.

²²The number of firms in each rating class does not stay constant throughout the sample period, because ratings change over time. Statistics reported in columns (1) and (3) of Table 1 show ratings for each firm as of the date when

quarter 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 underrepresented in the subsample of spreads is that 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 of spreads 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)).

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.²³ 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 spread 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

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-quarters and firm-months in the sample is higher than the proportion of firms.

²³In 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 spreads instead of bond spreads.

regression residuals at the firm level (see Petersen (2009)).

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.²⁴

Panel B summarizes various measures of balance sheet liquidity. To measure liquid asset reserves, we use the Cash/Assets ratio popular in empirical corporate finance studies, as well as liquidity ratios employed in empirical default-predicting models. Among the best known models, Altman's (1968) z -score includes WC/TA , the ratio of working capital (the difference between current assets and current liabilities) to total assets; Zmijewski's (1984) model and the ZETA-score model of Altman, Haldeman, and Narayanan (1977) use the current ratio CA/CL (current assets over current liabilities); and Ohlson (1980) and Chava and Roberts (2004) use both WC/TA and CL/CA to proxy for liquidity. Davydenko (2011) 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 the discussion of Fig. 2b below) confirm that our main results are likely to be even stronger for them, as they are more financially constrained and

²⁴Potentially, 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.

thus more concerned about internal cash reserves.

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-years 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, from the 10th (safest) to the 1st (riskiest), separately for firms with total assets above and below the median in the year of observation.

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 are substantially higher than those for our 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 relatively unconstrained (e.g.,

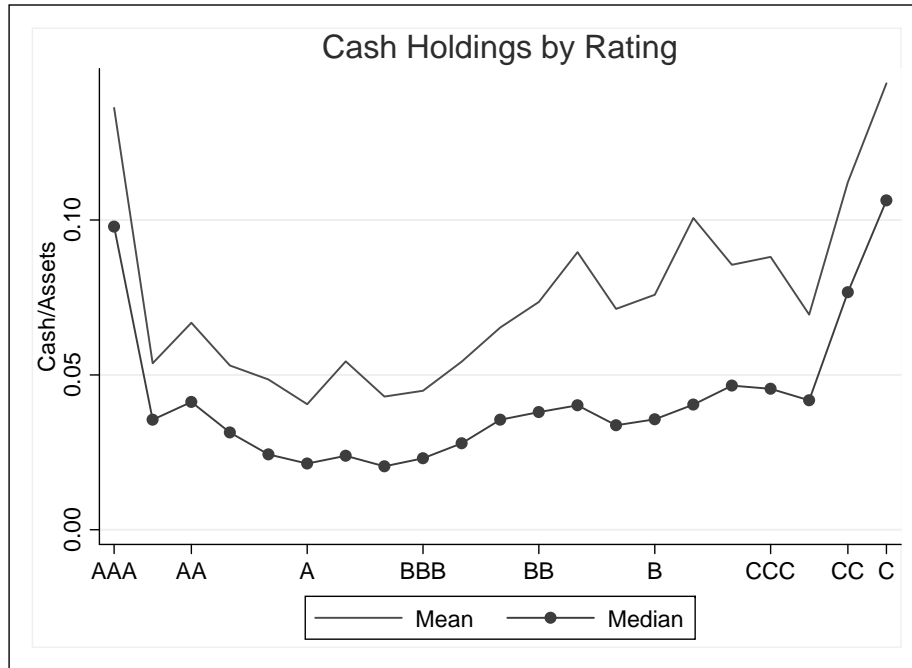


Fig. 2a. Cash holdings by rating: Bond issuers. This graph shows means and medians of the ratio of cash to total assets by the firm’s senior unsecured rating. The sample consists of all firm-quarters for non-financial U.S. firms that had bonds outstanding between December 1996 and September 2010.

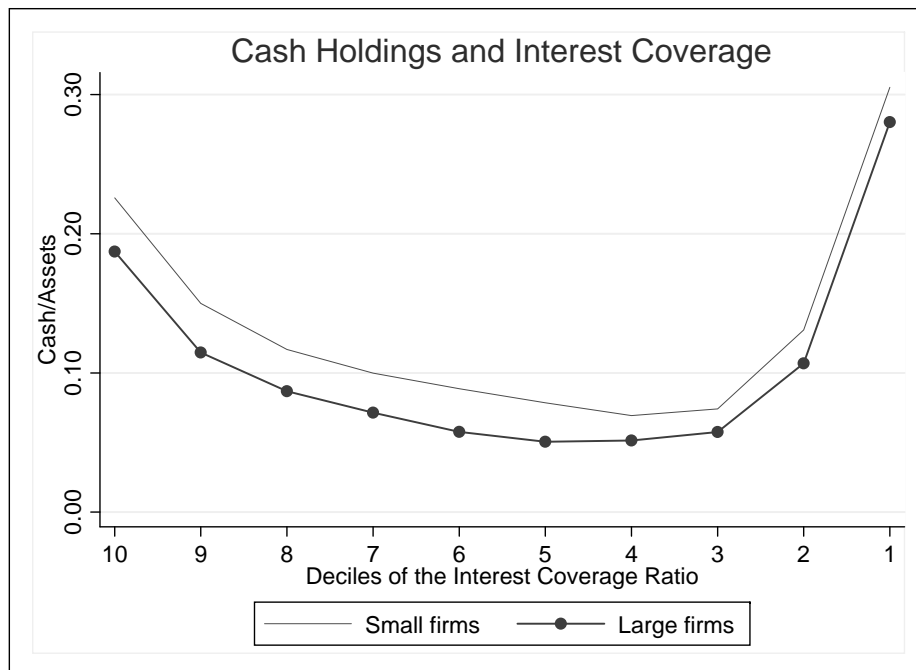


Fig. 2b. Cash holdings by interest coverage: All Compustat firms. For each decile of the interest coverage ratio, this graph plots the mean of the cash-to-asset ratio among small and large firms. The sample consists of all firm-years for non-financial U.S. firms in annual Compustat between 1950 and 2011. 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.

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 rated bond issuers the precautionary motive for saving cash is a first-order determinant of the relationship between liquid assets and credit risk.

3.3. Control variables

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

Based on insights from structural models of credit risk, empirical studies of spreads control for leverage, volatility, debt maturity, and various macroeconomic factors, in particularly those related to the term structure of 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. 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 further 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 Merton's (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 dummies for the firm's senior unsecured credit rating (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 their study 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 value.²⁵

Empirical default-predicting models identify 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 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 studies of spreads (e.g., Schaefer and Strebulaev (2008)). 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.

²⁵Following 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 $\sigma(K) = a + bK + cK^2$, 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.

4. Cash holdings and credit spreads

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

In these tests, the dependent variable is the bond spread relative to a cash flow-matched portfolio of Treasuries, averaged across all of the firm’s outstanding bonds for each date. To proxy for balance sheet liquidity, we use the ratio of cash to total assets, as well as working capital over total assets (as in Altman’s (1968) z -score), and the current ratio, equal to current assets over current liabilities (as in Zmijewski (1984)), although many other proxies yield similar results.

The regression 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 after controlling for firm-specific credit risk using leverage and volatility proxies (from 53%–55% to 63%–65%). Thus, though ratings provide an admittedly crude summary of credit risk (as evidenced by the strong significance of leverage and volatility in columns (4), (6), and (9)), 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.²⁶

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 spreads. 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 appear 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

²⁶See Murfin (2012) for a recent study of the determinants of bank loan covenants.

the median ratio of intangible to total assets in the firm's three-digit SIC industry in each calendar year.²⁷

Second, the model suggests the ratio of managerial private costs of financial distress to the fraction of the firm's equity that the manager owns as another instrument. The higher this fraction, the higher is the manager's 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 CEO's salary, bonus, and other monetary compensation, to the market value of her shares and options, estimated using the ExecuComp database.²⁸

We employ these two instruments in 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 p -value of the F -test of the instruments' relevance. It shows that our two instruments are jointly strongly significant determinants of the liquidity ratios.²⁹ 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 full-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 the endogeneity of cash, which strongly dominates in standard OLS regressions 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

²⁷We 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 correlated with the market leverage ratio, which renders it unsuitable as a potential instrument. We use an industry-based measure of intangibles to avoid endogeneity concerns.

²⁸Specifically, the *agency term* is defined as (salary + bonus + other annual compensation + long-term incentive plan + all other compensation)/(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.

²⁹Staiger 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 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 5 these statistics range from 15 to 26, although they are smaller in multi-variate tests.

for understanding the role of liquid assets in credit risk.

5. Balance sheet liquidity and the probability of default

Most empirical default-predicting models include some proxies for balance sheet liquidity, treating them as independent variables expected to reduce the probability of default. However, despite the intuitive appeal and the widespread use of liquidity ratios in this context, Begley, Ming, and Watts (1996), Shumway (2001), and Hillegeist *et al.* (2004), as well as Ohlson (1980) and Zmijewski (1984) in their original work, find them unrelated to 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 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, to compute the standard errors in these tests, we use bootstrap, estimating each regression for 1,000 panels re-sampled from firm-level clusters.³⁰

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 (2011)), 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

³⁰See 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.

regressions in column (1) are for the one-year probability of default. At this horizon, in all three 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).³¹ These results are consistent with Davydenko (2011), 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.

In contrast with the short-term results, columns (2) through (4) show that liquidity is *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 – implying similar economic significance, but in the wrong direction. A more detailed illustration of this sign reversal for the Zmijewski model is provided in Figure 3. It plots the coefficient for the current ratio, 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.

The continuous-time model that we develop in Appendix A, in which the firm makes debt coupon payments continuously, allows us to study the term structure of default probabilities theoretically in more detail. Fig. A3 on p.36 shows that the model predicts that a long-term default probability is positively correlated with cash. These results are qualitatively similar to our empirical findings in Fig. 3.

Consistent with the hypothesized effect of endogeneity, columns (5) through (7) of Table 6 show

³¹King 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.

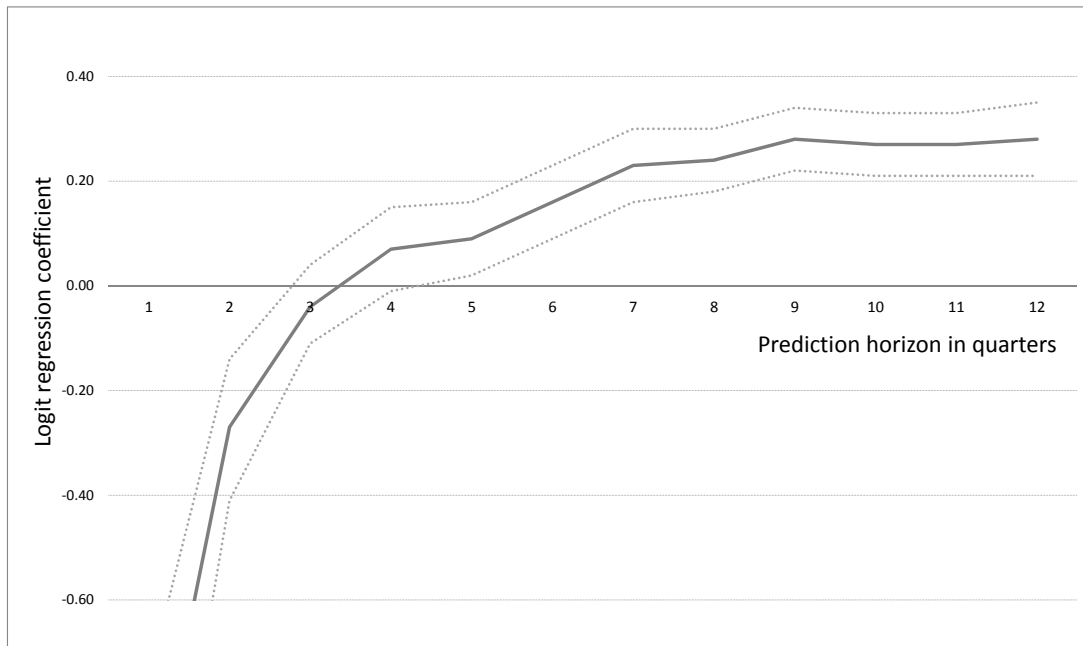


Fig. 3. Liquid assets and the probability of default at different horizons. This graph shows the point estimate and the 95% confidence interval for the logit regression coefficient for QA/CL in Zmijewski's (1984) model, for different prediction horizons. For a horizon of m quarters, the dependent variable 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. The sample consists of 76,349 firm-quarter observations. The confidence interval is obtained by bootstrapping from firm-level clusters.

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 credit risk.

6. Concluding remarks

In this paper, we document a robust positive correlation of corporate cash holdings with credit spreads and with the long-term probability of default. These findings run contrary to the simple intuition that higher cash reserves make corporate debt 'safer.' We argue that they arise because of endogenous response of firms' cash holdings to the possibility of a liquidity shortage, which in the presence of restrictions on external financing can trigger costly default. 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. An 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. More generally, our findings highlight the importance of adopting the corporate finance perspective in asset-pricing studies of the firm. 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.

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 the base-case model, and their discussion can be found in Section 2. A full description of the model, as well as proofs of the results, can be found in the Online Supplement, also available 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 \mathbb{Q} :

$$dx_t = \mu dt + \sigma dW_t^{\mathbb{Q}}, \quad (\text{A1})$$

where μ is the expected change in the cumulative cash flow, σ is the instantaneous volatility of the change, and W_t is a standard Brownian motion defined on a filtered probability space $(\Omega, \mathcal{F}, \mathbb{Q}, (\mathcal{F}_t)_{t \geq 0})$. Examples of studies using this modeling framework and its discussion can be found in DeMarzo and Sannikov (2006), Piskorski and Tchisty (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:

$$C_t = C_0 + x_t - bt - D_t, \quad (\text{A2})$$

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:

$$\max \mathbb{E}^{\mathbb{Q}} \int_0^{\tau} e^{-rs} dD_s, \quad (\text{A3})$$

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):

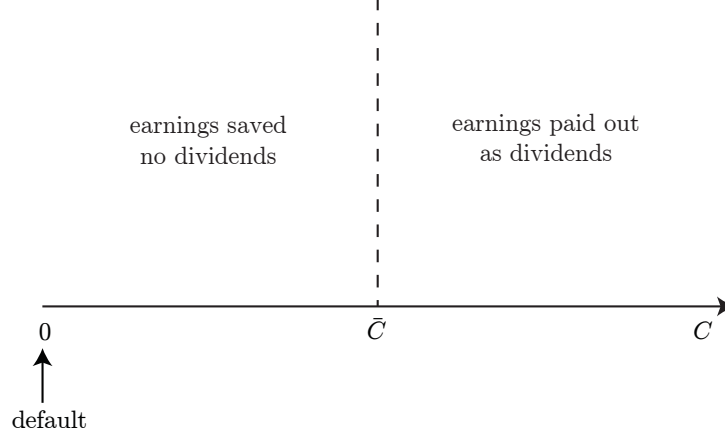


Fig. A1. Optimal dividend policy.

LEMMA A1. *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 A1 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:

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

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

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

The general solution to this equation is given by:

$$V(C) = \begin{cases} V_1(C) = L_1e^{\xi_1 C} + L_2e^{\xi_2 C}, & \text{for } 0 \leq C < \bar{C}, \\ V_2(C) = L_3C + L_4, & C \geq \bar{C}, \end{cases} \quad (\text{A6})$$

where L_1 , L_2 , L_3 , and L_4 are unknown constants determined from boundary conditions, and ξ_1 and ξ_2 are, respectively, the positive and negative solutions of the fundamental quadratic equation (see e.g. Stokey (2007)):

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

$$\xi_2 = \frac{-(\mu - b) - \sqrt{(\mu - b)^2 + 2r\sigma^2}}{\sigma^2}. \quad (\text{A8})$$

For the problem at hand, the boundary conditions take the form:

$$V(0) = 0; \tag{A9}$$

$$V_1(\bar{C}) = V_2(\bar{C}); \tag{A10}$$

$$V_1'(\bar{C}) = V_2'(\bar{C}); \tag{A11}$$

$$V_1''(\bar{C}) = V_2''(\bar{C}). \tag{A12}$$

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, μ , b , σ , and r :

PROPOSITION A1. *The optimal trigger \bar{C} is given by:*

$$\bar{C} = \frac{1}{\xi_1 - \xi_2} \ln \frac{\xi_2^2}{\xi_1^2}. \tag{A13}$$

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 $C = \bar{C}$, 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 $C \in [0, \bar{C})$, and is constant for values of C greater than or equal to \bar{C} . The general solution is:

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

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

$$A_1(0) = 1; \tag{A15}$$

$$A_1(\bar{C}) = A_2(\bar{C}); \tag{A16}$$

$$A_1'(\bar{C}) = 0. \tag{A17}$$

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 A2. *The value of $A(C)$ is:*

$$A(C) = -\frac{\xi_2 e^{\xi_2 \bar{C}} e^{\xi_1 C}}{\xi_1 e^{\xi_1 \bar{C}} - \xi_2 e^{\xi_2 \bar{C}}} + \frac{\xi_1 e^{\xi_1 \bar{C}} e^{\xi_2 C}}{\xi_1 e^{\xi_1 \bar{C}} - \xi_2 e^{\xi_2 \bar{C}}}. \tag{A18}$$

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

$$B(C) = \frac{c}{r}(1 - A(C)), \quad 0 \leq C \leq \bar{C}. \tag{A19}$$

The credit spread, $s(C)$, is therefore:

$$s(C) = \frac{b}{B(C)} - r = r \frac{A(C)}{1 - A(C)}, \quad 0 \leq C \leq \bar{C}. \quad (\text{A20})$$

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, μ , 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: $\lim_{\mu \rightarrow \infty} \bar{C} = 0$.

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 μ varies:

PROPOSITION A3. *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 μ ;*
2. *The credit spread $s(\bar{C})$ is decreasing in μ .*

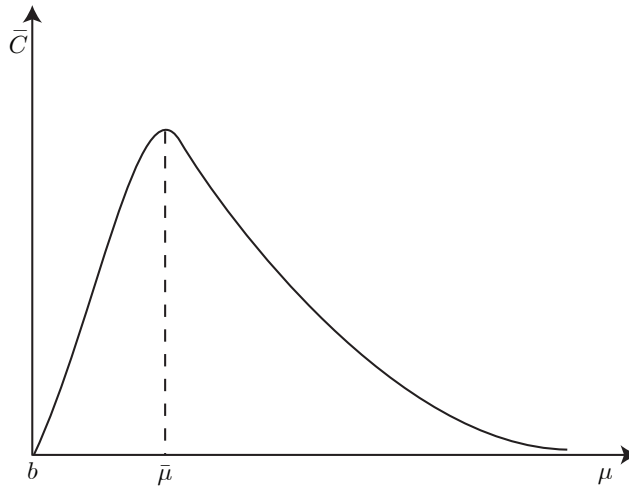


Fig. A2. The effect of variation in cash flow on cash policy.

Figure A2 illustrates a typical dependence of the equilibrium cash reserve on μ . As Proposition A3 states, when the expected cash flow increases above some critical value $\bar{\mu}$, equilibrium cash holdings decrease in response. Figure A2 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 substitution’ 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 μ 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 μ implies a lower \bar{C} , which in turn increases the probability of default and hence the credit spread. The second part of Proposition A3 states that the direct effect dominates.

A.4.2. Cash holdings and the probability of default

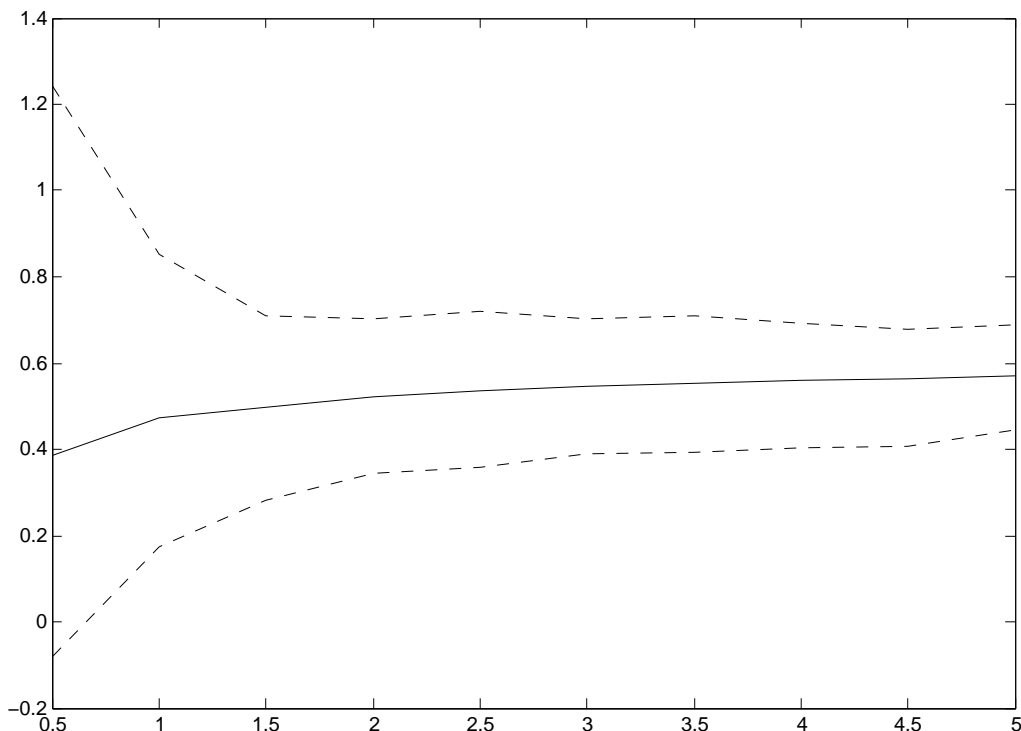


Fig. A3. The effect of variation in cash flow on the term structure of default probabilities.

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 \bar{C}_i , $i = 1, \dots, N$. 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 $t + T$, $T = 0.5, \dots, 5$ 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 A3 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 .³² It shows 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

³²Here, we assume that $b = 1$, $\sigma = 3$, $r = 0.05$, and μ is uniformly distributed between 2.5 and 10.

riskier (their expected cash flows fall), their optimal cash policy becomes more conservative (\bar{C} increases). Nonetheless, they are more likely to default, because the direct effect dominates. The comparison of Figure A3 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 $m(I^*, \bar{x}_1)$, where I^* is the optimal investment level from the first-order condition (6), as:

$$m(I^*, \bar{x}_1) = f'(I^*) - 1 - (f(I^*) + x_2)h(u_B). \quad (\text{A21})$$

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

$$\frac{dc^*}{d\bar{x}_1} = -\frac{dI^*}{d\bar{x}_1} = -\left(-\frac{\frac{\partial m}{\partial \bar{x}_1}}{\frac{\partial m}{\partial I^*}}\right). \quad (\text{A22})$$

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

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

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

$$\frac{\partial m}{\partial \bar{x}_1} = -(f(I^*) + x_2)h'(u_B)\frac{\partial u_B}{\partial \bar{x}_1} > 0, \quad (\text{A24})$$

because $\frac{\partial u_B}{\partial \bar{x}_1} = -1$. Therefore, $\frac{\partial c^*}{\partial \bar{x}_1} \leq 0$.

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

$$\frac{\partial s}{\partial \bar{x}_1} = -\frac{B}{D^2} \frac{\partial D}{\partial \bar{x}_1} = -\frac{B}{D^2} G(u_B), \quad (\text{A25})$$

and

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

Therefore:

$$\frac{ds}{d\bar{x}_1} = \frac{\partial s}{\partial \bar{x}_1} + \frac{\partial s}{\partial c^*} \frac{\partial c^*}{\partial \bar{x}_1} = -\frac{B}{D^2} G(u_B) \left(1 + \frac{\partial c^*}{\partial \bar{x}_1}\right). \quad (\text{A27})$$

Because $\frac{\partial c^*}{\partial \bar{x}_1} \leq 0$, for this quantity to be negative, it is sufficient to establish that $\frac{\partial c^*}{\partial \bar{x}_1} > -1$. From Equation (A47):

$$\frac{dc^*}{d\bar{x}_1} = \frac{(f(I^*) + x_2)h'(u_B)}{f''(I^*) - f'(I^*)h(u_B) - (f(I^*) + x_2)h'(u_B)}. \quad (\text{A28})$$

The right-hand of this equation is greater than -1 as:

$$f''(I^*) - f'(I^*)h(u_B) < 0. \quad (\text{A29})$$

Therefore, $\frac{ds}{d\bar{x}_1} < 0$. \square

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

$$\frac{ds^*}{dy} = \frac{\partial s}{\partial c^*} \frac{\partial c^*}{\partial y}. \quad (\text{A30})$$

In the proof of Proposition 1, we showed that:

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

Therefore, the sign of $\frac{ds^*}{dy}$ is the opposite of the sign of $\frac{\partial c^*}{\partial y}$. \square

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

$$\frac{dG(u_B)}{d\bar{x}_1} = g(u_B) \frac{du_B}{d\bar{x}_1}. \quad (\text{A32})$$

From (2), we know that $I^* = u_B + \bar{x}_1 - B + x_0$, and so we can define function $n(u_B, \bar{x}_1)$, such that:

$$n(u_B, \bar{x}_1) = m(I^*(u_B), \bar{x}_1) = f'(u_B + \bar{x}_1 - B + x_0) - 1 - (f(u_B + \bar{x}_1 - B + x_0) + x_2) h(u_B). \quad (\text{A33})$$

It follows that:

$$\frac{du_B}{d\bar{x}_1} = -\frac{\frac{\partial n}{\partial \bar{x}_1}}{\frac{\partial n}{\partial u_B}}, \quad (\text{A34})$$

where:

$$\frac{\partial n}{\partial \bar{x}_1} = f''(\cdot) - f'(\cdot) h(u_B) < 0, \quad (\text{A35})$$

and

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

so that $\frac{du_B}{d\bar{x}_1} < 0$. \square

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

$$f'(I) = \frac{1 + (1 - \tau)(f(I) + x_2) h(\psi_B)}{1 + \tau(1 - \tau)(f(I) + x_2) h(\psi_B)}. \quad (\text{A37})$$

Similar to the proof of Proposition 1, define function $m(I^*, \bar{x}_1)$, where I^* is the optimal investment level from the first-order condition (A37), as:

$$m(I^*, \bar{x}_1) = f'(I^*) - \frac{1 + (1 - \tau)(f(I^*) + hx_2) h(u_B)}{1 + \tau(1 - \tau)(f(I^*) + x_2) h(u_B)}. \quad (\text{A38})$$

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

$$\frac{dc^*}{d\bar{x}_1} = - \left(- \frac{\frac{\partial m}{\partial \bar{x}_1}}{\frac{\partial m}{\partial I^*}} \right). \quad (\text{A39})$$

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

$$\frac{\partial m}{\partial I^*} = f''(I^*) - \frac{(1-\tau)^2(f'(I^*)h(u_B) + (f(I^*) + x_2)h'(u_B)(1-\tau f'(I^*)))}{(1+\tau(1-\tau)(f(I^*) + x_2)h(u_B))^2}, \quad (\text{A40})$$

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:

$$\frac{\partial m}{\partial \bar{x}_1} = - \frac{(1-\tau)^2(f(I^*) + x_2)h'(u_B)\frac{\partial u_B}{\partial \bar{x}_1}}{(1+\tau(1-\tau)(f(I^*) + x_2)h(u_B))^2} > 0, \quad (\text{A41})$$

because $\frac{\partial u_B}{\partial \bar{x}_1} = -1$. Therefore, $\frac{\partial c^*}{\partial \bar{x}_1} \leq 0$.

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

$$\frac{ds}{d\bar{x}_1} = - \frac{B}{D^2} \frac{\partial D}{\partial \bar{x}_1} = - \frac{B}{D^2} (G(u_B) + g(u_B)\tau(f(I^*) + x_2)), \quad (\text{A42})$$

and

$$\frac{\partial s}{\partial c^*} = - \frac{B}{D^2} \frac{\partial D}{\partial c^*} = - \frac{B}{D^2} (G(u_B) + g(u_B)\tau(f(I^*) + x_2) - \tau^2(f(I^*) + x_2)f'(I^*)g(u_B)). \quad (\text{A43})$$

Therefore:

$$\begin{aligned} \frac{ds}{d\bar{x}_1} &= \frac{\partial s}{\partial \bar{x}_1} + \frac{\partial s}{\partial c^*} \frac{\partial c^*}{\partial \bar{x}_1} \\ &= - \frac{B}{D^2} \left(G(u_B) + g(u_B)\tau(f(I^*) + x_2) \right) \left(1 + \frac{\partial c^*}{\partial \bar{x}_1} \right) + \frac{B}{D^2} \tau^2 (f(I^*) + x_2) f'(I^*) g(u_B) \frac{\partial c^*}{\partial \bar{x}_1}. \end{aligned} \quad (\text{A44})$$

Because $\frac{\partial c^*}{\partial \bar{x}_1} \leq 0$, for this quantity to be negative, it is sufficient to establish that $\frac{\partial c^*}{\partial \bar{x}_1} > -1$. From Equation (A47):

$$\frac{\partial c^*}{\partial \bar{x}_1} = - \frac{- \frac{(1-\tau)^2(f(I^*)+x_2)h'(u_B)\frac{\partial u_B}{\partial \bar{x}_1}}{(1+\tau(1-\tau)(f(I^*)+x_2)h(u_B))^2}}{f''(I^*) - \frac{(1-\tau)^2(f'(I^*)h(u_B)+(f(I^*)+x_2)h'(u_B)(1-\tau f'(I^*)))}{(1+\tau(1-\tau)(f(I^*)+x_2)h(u_B))^2}}. \quad (\text{A45})$$

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

$$Z(\tau) \equiv f''(I^*) - f'(I^*) (1 - \tau f'(I^*))^2 (h(u_B) - \tau (f(I^*) + x_2) h'(u_B)) < 0. \quad (\text{A46})$$

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

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:

$$\frac{dc^*}{dx_2} = - \left(- \frac{\frac{\partial m}{\partial x_2}}{\frac{\partial m}{\partial I^*}} \right), \quad (\text{A47})$$

where $m(I^*, \bar{x}_1)$ is defined in (A38). As we established earlier, $\frac{\partial m}{\partial I^*} < 0$. 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, $\frac{\partial s}{\partial c} < 0$. \square

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

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

$$\frac{\partial M}{\partial I} = \theta \int_{u_B}^{\infty} [-1 + f'(I)]g(\psi)d\bar{x}_1 - [-I + (c_0 + \bar{x}_1 + u_B - B) + f(I)]g(u_B)\frac{\partial u_B}{\partial I} - \gamma g(u_B)\frac{\partial u_B}{\partial I} = 0, \quad (\text{A48})$$

which results in a condition identical to the first-order condition 7, with x_2 replaced by $\frac{\gamma}{\theta}$. The result then follows from applying the proof of Proposition 1. \square

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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.

	Study of defaults		Study of spreads	
	Firms (1)	Firm-quarters (2)	Firms (3)	Firm-months (4)
AAA	16	546	9	700
AA	77	2,184	38	2,245
A	295	11,745	163	10,980
BBB	383	19,099	205	13,120
BB	449	15,136	75	5,280
B	870	24,444	38	2,158
CCC and below	157	6,778	2	723
Total	2,247	79,932	530	35,206

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.

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

Panel B: Liquid asset reserves						
	Mean	Median	25%	75%	St. dev.	N
Cash/Assets	0.071	0.031	0.010	0.088	0.101	79,633
WC/TA	0.115	0.087	0.001	0.212	0.164	76,600
CA/CL (current ratio)	1.696	1.446	1.004	2.071	1.073	76,599
QA/CL (quick ratio)	1.061	0.836	0.543	1.256	0.905	75,458

Table 3
Statistics on control variables

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

Panel B: Determinants of the default probability						
	Mean	Median	25%	75%	St. dev.	N
RE/TA	0.044	0.108	-0.038	0.265	0.447	75,266
EBIT/TA	0.019	0.021	0.009	0.033	0.032	71,942
ME/TA	1.988	1.153	0.579	2.264	2.635	65,100
S/TA	0.255	0.210	0.119	0.327	0.192	79,746
NI/TA	0.005	0.009	0.000	0.018	0.031	79,758
TL/TA	0.690	0.659	0.542	0.785	0.253	79,897
EDF, %	2.221	0.390	0.096	1.603	4.648	55,825
z-score	1.688	1.350	0.713	2.250	1.816	53,575

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.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<i>Cash/TA</i>	3.28*** (3.14)	2.52*** (4.31)	1.21*** (2.68)						
<i>WC/TA</i>				1.21*** (2.67)	0.75** (2.39)	0.65*** (3.17)			
<i>CA/CL</i>							0.30*** (3.47)	0.15** (2.39)	0.14*** (3.58)
<i>Leverage</i>		6.51*** (15.1)	2.70*** (8.51)		7.09*** (15.5)	3.06*** (8.64)		7.06*** (15.3)	3.03*** (8.61)
<i>Asset volatility</i>		7.47*** (11.3)	2.56*** (5.84)		8.04*** (12.7)	2.87*** (6.73)		8.08*** (12.6)	2.87*** (6.66)
<i>Log(Assets)</i>		-0.18*** (-5.73)	-0.036 (-1.38)		-0.12*** (-3.60)	-0.010 (-0.37)		-0.12*** (-3.56)	-0.0075 (-0.26)
<i>Distance to default</i>		0.0014 (0.10)	-0.054*** (-5.29)		0.023* (1.76)	-0.040*** (-4.16)		0.023* (1.70)	-0.041*** (-4.19)
<i>Maturity</i>		0.036*** (5.96)	0.039*** (8.97)		0.037*** (5.98)	0.039*** (8.86)		0.036*** (5.98)	0.038*** (8.82)
<i>Risk-free rate</i>		-0.40*** (-11.7)	-0.18*** (-6.89)		-0.41*** (-12.4)	-0.18*** (-6.86)		-0.41*** (-12.5)	-0.18*** (-6.83)
<i>TS slope</i>		-0.083** (-2.48)	0.054* (1.80)		-0.084** (-2.50)	0.053* (1.76)		-0.085** (-2.51)	0.053* (1.74)
<i>VIX</i>		2.98*** (7.81)	5.12*** (13.4)		2.98*** (8.04)	5.20*** (13.5)		2.98*** (7.94)	5.21*** (13.5)
<i>S&P return</i>		-0.020*** (-9.93)	-0.011*** (-6.29)		-0.020*** (-9.76)	-0.011*** (-6.07)		-0.020*** (-9.55)	-0.011*** (-5.95)
<i>Jump</i>		4.10*** (8.25)	5.95*** (14.0)		4.16*** (8.28)	6.15*** (14.3)		4.11*** (8.21)	6.12*** (14.2)
<i>Rating dummies</i>			Yes			Yes			Yes
<i>Const.</i>	1.97*** (28.8)	0.75 (1.49)	0.039 (0.088)	2.02*** (28.4)	-0.031 (-0.056)	-0.44 (-0.95)	1.69*** (12.7)	-0.19 (-0.33)	-0.60 (-1.26)
<i>N</i>	34,837	29,146	29,146	32,899	27,541	27,541	32,899	27,541	27,541
<i>Adj. R²</i>	1.0%	53.5%	63.8%	0.6%	54.2%	64.1%	1.0%	54.2%	64.2%

Table 5
Instrumental-variable regressions of credit 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. 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.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<i>Cash/TA</i>	-14.9** (-2.15)	-29.7** (-2.01)	-17.0* (-1.79)						
<i>WC/TA</i>				-7.08** (-2.05)	-13.3** (-2.32)	-5.88* (-1.85)			
<i>CA/CL</i>							-1.62** (-1.97)	-2.83** (-2.35)	-1.33* (-1.80)
<i>Leverage</i>		8.10*** (9.39)	2.73*** (4.97)		6.23*** (7.64)	2.07*** (3.63)		6.41*** (7.85)	2.17*** (3.63)
<i>Asset volatility</i>		17.3*** (3.92)	6.54*** (2.72)		14.3*** (5.20)	4.87*** (3.39)		13.8*** (5.42)	4.82*** (3.15)
<i>Log(Assets)</i>		0.018 (0.14)	0.069 (0.85)		-0.57*** (-3.23)	-0.23** (-2.13)		-0.66*** (-3.23)	-0.27** (-2.09)
<i>Distance to default</i>		0.12** (2.01)	-0.022 (-0.86)		0.044 (1.24)	-0.050*** (-2.99)		0.041 (1.18)	-0.049*** (-2.67)
<i>Maturity</i>		0.074*** (3.76)	0.060*** (4.99)		0.066*** (3.53)	0.053*** (5.46)		0.078*** (3.53)	0.060*** (4.91)
<i>Risk-free rate</i>		-1.11*** (-4.15)	-0.51*** (-3.26)		-1.01*** (-5.26)	-0.42*** (-3.91)		-1.06*** (-5.21)	-0.45*** (-3.60)
<i>TS slope</i>		-0.36*** (-3.77)	-0.089 (-1.60)		-0.29*** (-4.44)	-0.050 (-1.22)		-0.30*** (-4.26)	-0.054 (-1.23)
<i>VIX</i>		1.36 (0.93)	5.13*** (5.44)		1.32 (0.96)	5.45*** (6.36)		1.22 (0.87)	5.37*** (5.70)
<i>S&P return</i>		-0.028*** (-5.27)	-0.012*** (-3.28)		-0.029*** (-5.49)	-0.011*** (-3.07)		-0.030*** (-5.28)	-0.012*** (-2.86)
<i>Jump</i>		4.24*** (4.01)	4.91*** (6.86)		4.75*** (5.33)	5.35*** (9.24)		5.02*** (5.00)	5.48*** (8.58)
<i>Rating dummies</i>			Yes			Yes			Yes
<i>Const.</i>	3.10*** (8.30)	0.96 (0.80)	1.66 (1.47)	2.78*** (10.9)	6.95*** (2.63)	3.63* (1.92)	4.47*** (4.05)	11.0*** (2.65)	5.51* (1.90)
<i>N</i>	24,743	20,261	20,261	23,431	19,123	19,123	23,431	19,123	19,123
<i>Adj. R²</i>	0.8%	54.7%	65.3%	1.0%	54.7%	65.2%	1.0%	54.7%	65.2%
<i>Instr. P-value</i>	0.000	0.050	0.045	0.000	0.008	0.005	0.000	0.013	0.010

Table 6
Liquid assets and the probability of default at different horizons

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.

	Logit				IV GLS		
	1 year (1)	2 years (2)	3 years (3)	5 years (4)	2 years (5)	3 years (6)	5 years (7)
	Altman's (1968) <i>z</i> -score						
<i>WC/TA</i>	-1.40*** (-3.73)	1.01*** (3.34)	1.52*** (4.69)	1.66*** (4.27)	-13.56 (-0.95)	-24.38** (-2.04)	-21.42* (-1.78)
<i>RE/TA</i>	-0.30** (-2.55)	-0.37*** (-4.24)	-0.52*** (-5.90)	-0.31*** (-3.40)	-0.95*** (-3.11)	-1.08*** (-2.86)	-0.64* (-1.67)
<i>EBIT/TA</i>	-13.49*** (-14.48)	-7.71*** (-8.35)	-5.38*** (-5.37)	-5.27*** (-4.13)	-18.20** (-2.00)	-22.39*** (-2.94)	-17.74** (-2.03)
<i>ME/TL</i>	-4.47*** (-10.70)	-1.21*** (-8.00)	-0.31*** (-3.72)	-0.14** (-2.52)	-0.43 (-0.90)	0.27 (0.83)	0.25 (0.74)
<i>S/TA</i>	0.26 (0.84)	-0.33 (-1.17)	-0.34 (-1.03)	0.20 (0.62)	3.24 (1.06)	5.66** (2.21)	4.94* (1.69)
<i>const.</i>	-1.49*** (-9.37)	-2.65*** (-22.05)	-3.51*** (-27.06)	-4.20*** (-31.21)	-2.90*** (-5.14)	-3.08*** (-5.97)	-3.49*** (-6.02)
<i>N</i>	53,575	53,575	53,575	53,575	33,185	33,196	33,196
	Zmijewski's (1984) model						
<i>CA/CL</i>	-0.22*** (-3.86)	0.20*** (6.38)	0.31*** (9.34)	0.25*** (6.44)	-0.36 (-0.42)	-2.26** (-2.09)	-3.08** (-2.20)
<i>NI/TA</i>	-17.33*** (-28.74)	-9.14*** (-15.19)	-5.71*** (-8.36)	-5.29*** (-5.00)	-12.93*** (-4.90)	-15.21*** (-4.47)	-15.51*** (-3.55)
<i>TL/TA</i>	2.31*** (17.16)	1.86*** (15.74)	1.67*** (12.91)	1.06*** (6.06)	1.69 (0.91)	-2.89 (-1.20)	-5.56* (-1.80)
<i>const.</i>	-5.50*** (-35.96)	-5.53*** (-41.80)	-5.62*** (-38.92)	-5.43*** (-29.64)	-4.96* (-1.87)	1.23 (0.37)	4.15 (0.96)
<i>N</i>	76,439	76,439	76,439	76,439	38,085	38,085	38,085
	EDF-based model						
<i>QA/CL</i>	-0.36*** (-3.01)	0.15*** (2.68)	0.21*** (4.14)	0.14** (2.50)	-2.88** (-2.03)	-3.13** (-2.36)	-2.62** (-2.22)
<i>EDF</i>	0.19*** (29.27)	0.11*** (22.22)	0.07*** (13.21)	0.03*** (3.38)	0.13*** (7.50)	0.08*** (5.02)	0.03 (1.30)
<i>const.</i>	-4.75*** (-36.02)	-4.36*** (-46.90)	-4.30*** (-44.47)	-4.39*** (-44.38)	-1.80 (-1.26)	-1.45 (-1.09)	-2.03* (-1.70)
<i>N</i>	52,939	52,939	52,939	52,939	34,730	34,730	34,730