Real Asset Liquidity, Cash Holdings, and the Cost of Corporate Debt*

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Abstract

We show analytically that there exists a nonlinear (U-shaped) relationship between credit spreads and the liquidity of the market for a firm’s real assets. We empirically verify that indeed there is an interior optimum level of market liquidity at which credit spreads are at their lowest. Our results are particularly pronounced for highly leveraged firms and firms with large growth options. We further find that cash holdings affect the influence of real asset liquidity on credit spreads. However, this interaction between cash holdings and real asset liquidity is only significant in circumstances in which real asset liquidity is high.

JEL Classification: G12, G13, G32

Key Words: Asset Sales, Cash Holdings, Credit Spreads, Corporate Bonds

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1 Introduction

Corporate bonds are claims against the firm’s assets which are composed of both cash holdings and productive real assets. This total asset composition along with the very nature of productive real asset (i.e., the cash flow generation power and the commensurate risk) underpins stalwart risks in corporate bond pricing: default risk (the likelihood of borrower reneging on his debt service obligations) and recovery rate (the dollar amount received upon firm liquidation per dollar lent out). Prudential risk management necessitates that bondholders demand that the firm leave the original asset composition intact. Yet, from the firm’s perspective, threats of competition and technological obsolescence can require asset restructuring which includes the sale of old assets and changing cash holdings. Such restructuring – often viewed by bondholders as the mortal sin of asset stripping – can thus be a necessary prerequisite to the redeployment of assets to more productive avenues. Clearly a firm would avert committing the asset stripping sin if the firm can effectively utilize available resources (e.g. internal cash holdings as well as external capital markets) to restructure assets. Moreover, even if the firm finds asset sales as the only viable option, any such asset restructuring is limited by the liquidity of the firm’s real assets (i.e., the ease with which real assets can be sold without a significant loss in value). Undoubtedly, bondholders *ex ante* ought to consider how the aforementioned decisions about asset sales and cash holdings affect the pricing of their claims.

Conventional wisdom holds that greater real asset liquidity can increase firm value in liquidation (Shleifer and Vishny, 1992). From the perspective of structural models of corporate liabilities (e.g. Merton, 1974; Leland, 1994; Leland and Toft, 1996, among others), greater real asset liquidity improves the creditor’s expected recovery rate in the event of default, hence, *ex ante* decreasing the borrower’s credit spread. However, liquid real assets also give managers the flexibility to use asset sales to transform the asset composition of the firm after debt has been issued, effectively making the existing debt more risky. Weiss and Wruck (1998) argue that “...unless a credible promise can be made not to engage in asset stripping, [...] asset liquidity [could] reduce, not increase, a firm’s ability to issue debt securities”. The illiquid assets within the firm can help to provide such a credible promise and serve as protection from value destructing wealth transfers from bondholders to equityholders. Along these lines, Morellec (2001) shows that when debt is secured by the firm’s assets, increased asset liquidity leads to a narrowing of credit spreads. When debt is unsecured, however, asset liquidity widens yield spreads. Similarly, Myers and Rajan (1998) demonstrate that because greater asset liquidity reduces the firm’s ability to commit to a specific course of action, high asset liquidity (among firms with unsecured debt) may inhibit the their capacity to raise external finance through an increased cost of debt.

The seemingly contractually binding and managerially disciplining feature of illiquid real assets, however,
can limit the firm’s ability to deploy assets optimally. As Morellec (2001) notes, when acting in the best interest of shareholders, managers may find asset liquidation as an optimal exit strategy to reduce idle capacity when economic conditions worsen. Yet, asset liquidation need not to exclusively represent an exit strategy. Managers may find that asset liquidation is a necessary step to divest unproductive business lines in order to redeploy resources into more productive endeavors (Maksimovic and Phillips, 2001). Asset sales are also a pertinent source of financing along side debt and equity issuances (Edmans and Mann, 2017; Arnold et al., 2017). In the absence of financial frictions, firms can access external capital markets instantly at no cost to service any current liquidity needs. Capital market imperfections, however, impose a significant cost on external financing. If access to external finance is costly or unavailable, cash reserves provide a buffer against negative cash flow shocks and allows firms to continue to invest in negative cash flow states without the assistance of the capital markets. In other words, cash holdings provide firms with financial flexibility. Indeed, Usman (2017) finds a negative relationship exists between the liquidity of a firm’s real assets and its cash holdings, suggesting that firms do utilize asset sales rather than cash reserves to cover liquidity needs.

Given the complex and often interactive impacts that asset sales, cash holdings, and external capital markets exert on investment/restructuring decisions, it is of no surprise to see a recent rising interest in incorporating the aforementioned firm characteristics into corporate bond pricing literature. Most notably, Acharya et al. (2012) consider the impact of cash holding on corporate bond pricing. In so doing, they debunk the long-held intuition that “. . . [firms with] 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.” They argue that other things are not equal in that the common intuition about cash holding and firm safety suffers from confluences of endogeneity: firms closer to distress follow conservative cash policies thus indicating an possible adverse impact from cash holding onto credit risk. Here, we extend their framework to examine how real asset liquidity additionally affects credit risk. In essence, we argue that even when a near-distress firm lacks large cash reserves, the ease of liquidating real assets can provide respite from debt burden. In the other extreme, we also argue that real asset liquidity can afford a healthy firm the means to take advantage of profitable opportunities when cash holdings are low.

As such, in the spirit Acharya et al. (2012), we first build a model of debt financing with endogenous cash holding and asset sales policies. Specifically, we develop a simple model in which a firm can liquidate a portion of its productive assets in order to service debt or finance investment opportunities. Selling assets is costly in that the firm incurs a discount when selling price of the asset. Moreover, the sales of assets can also lead to a loss of future cash flows (that would have otherwise been generated from those asset). In order to avoid these costs, the firm may choose to hold precautionary cash reserves. The question then becomes should the firm hold precautionary cash balances or utilize options to voluntarily sell real (productive) assets
when necessary to invest in projects or service debt. In our simple, two period model, we solve for the
optimal level of asset sales and determine the impact of the fire-sale discount on the level of cash holdings.
We then examine the comparative statics to glean insights about the expected relationship between asset
liquidity and cash holdings on the cost of corporate debt.

Our main analytical finding is that the credit spreads (at optimal cash holding) are convex function of
real asset liquidity: up to a point, as the market for firm’s real asset becomes illiquid, credit spread actually
decline. However, beyond this point (roughly at about 30% of theoretical range of absolute liquidity and
illiquidity), credit spread rise sharply as real asset liquidity declines. Our empirical analyses for most part
confirm these analytical findings. We find indeed observed credit spreads are convexly related to the real
asset liquidity and this convexity is exacerbated across the domains of leverage and firm profitability.

2 Related Literature

2.1 Motives for Asset Sales

The sale of a firm’s assets has been commonly posed in the literature as a method to resolve financial distress
(Shleifer and Vishny, 1992; Asquith et al., 1994). Asset sales, however, need not only occur for reasons of
financial distress. Voluntary asset sales are also used frequently for the purposes of corporate restructuring
and improving operating efficiency by allocating inefficiently used resources to more productive firms (see

Moreover, asset sales can be used as a method to obtain financing for new investment. While much of
the literature studies a firm’s choice between using debt and equity financing, obtaining financing through
the sale of productive assets is another possible alternative. Edmans and Mann (2017) and Arnold et al.
(2017) present models in which firms sell assets in order to finance investments. Adding on to the pecking
order theory of Myers and Majluf (1984), Edmans and Mann (2017) argue that because the value of new
equity issuances and existing equity are perfectly correlated, selling equity diminishes the market’s valuation
of the entire firm. Partial asset sales, however, are not a reflection of the quality of the firm as a whole and
thus will not diminish the value of the firm to the same degree as equity issuances.

Arnold et al. (2017) show that financing with asset sales may be optimal under certain conditions since
asset sales help to mitigate the debt overhang problem of Myers (1977). For a highly levered firm, much of
the benefits of equity financed investment will be diverted to bondholders. Asset sales, however, naturally
increase leverage making existing debt riskier (and less valuable). This reduction in the wealth transfer
from equity to debtholders gives rise to a preference for financing with asset sales. Since the wealth transfer
problem is more prominent among highly levered firms, they demonstrate that more levered firms have a stronger incentive to finance through asset sales rather than equity issues.

There is ample evidence in the empirical literature to support the use of asset sales to finance investment. Bates (2005) finds that firms that retain the proceeds from asset sales (as opposed to payouts to bond or equity holders) tend to use those proceeds to over-invest relative to industry benchmarks. Similarly, Hovakimian and Titman (2006) and Borisova and Brown (2013) show that firms invest more when they generate cash from asset sales.

2.2 The Impact of Asset Liquidity on Debt Policy

The ability to sell assets for financing purposes naturally has implications for the claimholders of the firm, debtholders in particular. Indeed, the agency cost of debt arises due to the managers’ incentives to increase the value of equity by transferring wealth from bondholders (Jensen and Meckling, 1976). One way that managers can reallocate wealth from debt to equity is by transforming the asset composition of the firm into a riskier structure, the so called asset substitution problem. Because equity can be viewed as a long position in a call option on the firm’s assets and debt a short position in a put option, an increase in asset risk through asset sales will increase (decrease) the value of the firm’s equity (debt) (Black and Scholes, 1973; Merton, 1974). Thus an increased ability to sell assets increases the amount of asset substitution risk the firm’s debtholders face. Myers and Rajan (1998) argue that because an increased ability to sell assets reduces the firm’s commitment to a particular course of action, debt capacity is diminished.

Extant research has shown that the liquidation value of the firm’s assets should be a crucial determinant of a firm’s optimal debt policy (Harris and Raviv, 1990; Aghion and Bolton, 1992). An asset’s liquidation value is of great importance to creditors since it represents the value they can expect to recover if they must seize assets from management and sell them on the open market in order to resolve their outstanding debt claims. The liquidation value of an asset is largely dependent on the asset’s liquidity. As described by Williamson (1988) and Shleifer and Vishny (1992), the degree to which assets are redeployable to alternative uses is a main determinant of an asset’s liquidity (measured as the difference between the intrinsic value of the asset and the selling price).

Hart and Moore (1994) argue that in the presence of incomplete contracting, firms with more liquid real assets are desirable in the eyes of creditors because they attract higher liquidation values in the event of default. They state that “...general, nonspecific assets are good for debt and specific or intangible assets are good for equity financing”. As such, firms with assets which are more easily redeployed will possess larger debt capacities and longer debt maturities, and real assets will facilitate borrowing only to the extent that
they are sellable.

2.3 Asset Liquidity and Credit Risk

Asset liquidity should play a key role in structural models of corporate debt. The credit risk of a firm can typically be decomposed into two components: the probability of default and the recovery rate. Together, these two items give a measure of creditor’s expected loss given default. The recovery rate represents the percentage of promised principal and interest payments the creditor will receive in the event of a default on the firm’s debt. Often times, an assumption is made that the recovery rate is exogenous, constant and known with certainty in order to facilitate an analysis of the probability of default.\footnote{For instance, Giesecke et al. (2011) study corporate bond default rates over a 150 year period and assume a constant recovery rate of 50%, equal to the long-run historical average recovery rate.} However, this assumption may not be appropriate. In the structural credit risk models of Merton (1974) and Black and Cox (1976) among others, the recovery rate is a function of the asset value of the firm at default. If asset liquidity is heterogeneous on an industry level as suggested by Shleifer and Vishny (1992), then recovery rates will differ among firms. Morellec (2001) improves upon these earlier models by endogenizing asset liquidity into the structural framework not only in regards to liquidation values in default, but also as a key strategic variable that affects the firm’s operating policy.

Empirical work linking asset liquidity to the cost of debt has been limited since it is difficult to measure the market value of a firm’s assets prior to realizing the selling price. Thus the existing empirical literature tends to utilize small samples focused on a particular industry or a specific type of asset in which the true value of the asset can be either directly observed or easily inferred (for example, Pulvino (1998) and Gavazza (2010) examine the airline industry, Ramey and Shapiro (2001) examine the aerospace industry, Kim (1998) looks at the oil drilling industry, and Benmelech et al. (2005) focus on the commercial real estate industry). In regards to the effects of asset liquidity on the pricing of corporate debt, Benmelech and Bergman (2009) examine just secured debt among U.S. airlines. They find that debt that is secured by collateral that is more easily transferred to other firms has lower credit spreads. This is due to the right creditors have to seize and liquidate these secured assets should the firm fail to service its debt properly. The more sellable the collateral, the smaller the creditor’s expected losses in default.

2.4 The Relationship Between Cash Holdings and Asset Liquidity

Bolton et al. (2011) relate the cash holdings decision to the asset sale decision by considering the idea that the firm may want to engage in asset sales in order to replenish its stock of cash and avoid liquidity defaults. In their model, asset sales are costly both because of underinvestment and physical adjustment
costs. Nevertheless, the model shows that when the firm’s cash reserves are low, the firm will engage in asset sales to raise cash and move away from the liquidity default boundary. Even when costly equity issuances are possible, they show that asset sales are still feasible when cash balances become depleted.

Warusawitharana (2008) shows that the level of liquid assets on a firm’s balance strongly impacts the choice of a firm to sell assets. He finds that a one standard deviation increase in cash holdings decreases the probability that the firm will sell assets by 32%. Additionally, the quantity of assets sold depends on the marginal value of capital inside the firm (marginal Q). That is to say less profitable firms with fewer growth opportunities tend to sell a larger quantity of assets. Similarly, Usman (2017) finds that, among financially constrained firms, there exists a negative relationship between the level of cash holdings and real asset liquidity. These findings coincide with the financing hypothesis of asset sales put forth by Lang et al. (1995) which argues that firms sell assets to generate funds to pursue its objectives when other sources of funding are either unavailable or too expensive. They find that firms close to financial distress tend sell assets to generate the necessary cash, which provides evidence for this financing hypothesis.

2.5 The Role of Cash in Credit Risk Models

The ability to costlessly sell equity eliminates the role of precautionary cash holdings in determining financial policy and the value of corporate securities. In the structural credit risk models with endogenous default such as those developed by Black and Cox (1976), Geske (1979), Leland (1994), Leland and Toft (1996), He and Xiong (2012), among others, the default boundary arises as an optimal decision made by the shareholders. For example, in Leland (1994) and Leland and Toft (1996), shareholders optimally choose a default boundary which maximizes the value of equity. If debt obligations can not be covered by internal cash flows, equity holders will contribute the necessary funds to fill the shortfall as long as the marginal value of equity is positive. In each of these models, since capital markets are frictionless and there are no costs to issuing equity, there is no need for a firm to hold cash reserves for hedging purposes.

Acharya et al. (2012) develop a model in which they restrict access to external financing and thus introduce a role for cash holdings in the context of credit risk. Because default is costly, firms hold precautionary cash balances in order to hedge cash flow risk and avoid default. In their two period model, the firm makes a choice between investing in cash and investing in a long-term project. Increasing investment in the project results in higher payoffs conditional on not defaulting. Retaining cash reduces the payoff from the long-term project but increases the likelihood of survival. The optimal level of cash holdings is found by choosing the level of investment the maximizes the value of equity.
2.6 Contribution

In this paper, we develop a model that is similar in spirit and set up to Acharya et al. (2012). However, we introduce a few key distinctions to evaluate the role of asset sales on the relationship between cash holdings and credit risk. First while Acharya et al. (2012) consider only a single investment opportunity, we introduce a second investment opportunity to generate a second motive for holding cash in addition to simply avoiding default. By holding large cash balances today the firm is increasing their likelihood of survival (i.e. by making the necessary debt payments). But at the same time, they are reducing their outlays in both current and future investment. Second, while we assume that the firm does not have access to debt or equity markets, they do have the ability to liquidate their assets in place (at a cost that is a function of the asset’s liquidity) to generate funds for debt service and investment. Also, contrary to the literature on the pricing of risky debt in which the level of assets sales is exogenous (i.e. Leland, 1994), our model assumes that the quantity of assets sold is determined endogenously.

Empirically, our work is related to recent work exploring the role of real asset liquidity on firm characteristics (e.g. Pulvino, 1998; Ramey and Shapiro, 2001; Benmelech and Bergman, 2009). These studies, however, are limited in the ability to make broad conclusions as they focus their attention on a small number of firms in very specific industries. There are two key exceptions to these small sample studies. Sibilitkov (2009) and Ortiz-Molina and Phillips (2014) both use measures of asset liquidity similar to the one we propose here which allow them to investigate the role of real asset liquidity over a broad cross-section of firms. However, while Ortiz-Molina and Phillips (2014) investigate the role of asset liquidity on the cost of equity capital, we examine its role on the pricing of corporate debt.

3 Basic Model

Our theoretical argument can be summarized as follows. Cash holdings are a zero NPV investment. Therefore it would benefit the firm to direct funds away from cash reserves and into more productive investments. The existence of debt service requirements, future investment opportunities, and restricted access to capital markets gives rise to a precautionary motive for cash holdings. If asset sales are permitted, however, the firm has the option to liquidate its real assets in order to meet its liquidity needs. Therefore, asset sales and cash holdings are substitutes. That is, with permissible asset sales firms will hold smaller cash balances. This follows directly from asset sales acting as a means of reducing financing constraints. The degree to which asset sales reduce financial constraints and subsequently reduce the size of cash balances will depend on the liquidation cost of the firm’s assets. When sold at a fire sale price, the disparity between the selling price
and intrinsic value of the asset represents a substantial cost to accessing the asset sale market. Therefore asset sales will be decreasing and cash holdings increasing with the cost of liquidation.

The implications of the expected liquidation cost on the asset sale / cash holdings relationship will play a key role in the pricing of the firm’s bonds. As cash balances provide debt holders with additional assurances that the claims will be repaid, asset sales will reduce the potential recovery value for creditors in the event of default. The selling price of the firm’s assets will be a determining factor in the level of cash the firm will choose to hold and simultaneously affect the level of asset sales the firm will choose to engage in. Both of these actions will have an impact on the expected payoff to creditors and thus impact the cost of corporate debt. With the proposed model we will detail these relationships and derive testable empirical implications.

3.1 Assumptions

We consider a two period model of firm’s investment and financing decisions when asset sales are permissible. The firm $i$ has real assets in place which can be liquidated in a timely fashion at any time $t$ for a price of $A_t$. However, an asset sale will result in a discounted selling price from the intrinsic value of the asset. We assume that the selling price of the asset, $A_t(\eta)$, is a direct function of percentage of the firm’s assets that are liquidated, $\eta$. Additionally, while the liquidation value of the assets is decreasing function of liquidation percentage, that is, $\frac{\partial A_t(\eta)}{\partial \eta} < 0$, the decrease decelerates as the percentage liquidated increases, or, $\frac{\partial^2 A_t(\eta)}{\partial \eta^2} \geq 0$. We assume that the selling price is a linear function of percentage assets liquidated and liquidity of the asset market, whereby $A_t(\eta, \alpha) = A_t - (1 - \alpha)A_t\eta = A_t(1 - (1 - \alpha)\eta)$. $\alpha \in [0, 1]$ can be viewed as the liquidity of the asset market in that $\alpha = 1$ denotes an infinitely liquid market in which the percentage of liquidation has no bearing on the selling price of the asset. $\alpha = 0$ denotes an illiquid market in which full liquidation leads to a selling price of zero. With any other value of $\alpha$, at full liquidation, the liquidation price is $\alpha A_t$.

Figure 1 provides a simple illustration of this linear pricing function. In this example, the true value of the asset is $100 per unit. When $\alpha = 1$, that is when market for the firm’s assets are very liquid, the selling price will equal the true value no matter the quantity sold. If $\alpha = 0.6$, the assets will yield a price of $60$ per unit in full liquidation and $80$ per unit if the firm sells 50% of its assets. In the extreme case where $\alpha = 0$ which represents a very illiquid market for the firm’s assets, full liquidation leads to a selling price of $0$ per unit and selling 50% of its assets yields a selling price of $50$ per unit.

[Figure 1 about here.]

The firm’s real assets generate a sequence of cash flows of $x_0, \tilde{x}_1, x_2$ at times $t = \{0, 1, 2\}$. From this sequence, only $\tilde{x}_1$ is random. We assume that $\tilde{x}_1$ is distributed uniformly, $\tilde{x}_1 \sim U[\underline{x}, \bar{x}]$. We assume that a
firm undertakes an investment project at \( t = 0 \) by outlaying \( I_0 \) in return for receiving a sure payoff of \( f(I_0) \) at time \( t_2 \). At time \( t = 0 \), the firm issues bonds with face value \( B \) which is due at time \( t = 1 \). At time \( t = 0 \), the firm and bondholders agree on permissible level of asset sales. Thus at \( t = 0 \), the firm must decide how much cash, \( c \), to hold. At time \( t = 1 \), the firm has the opportunity to expand by investing \( I_1 \) amount in a project which yields \( g(I_1) \) at time \( t = 2 \). For simplicity, as in Acharya et al. (2012), we also assume that the risk-free interest rate is zero and investors are risk-neutral.

### 3.2 The Model

Consider the case of an expansion project in which after repaying debt, residual resources (cash holdings and incoming cash flows) plus full liquidation asset value are not large enough to afford the initial outlay of the project. In an intuitive sense, in the presence of such an expansion project, asset sales are not large enough to simply bifurcate states of nature over a set where investment is paid with asset sales and another set where asset sales prevents default. With expansion, there exists a set of states of nature that despite not defaulting, the firm cannot undertake the investment. To elucidate this situation, we now explore such a case in which there are five possible states of nature the firm can face at \( t = 2 \). Here we present each state and the payoff outcomes for both equity holders and bond holders.

**State 1** \( c + \tilde{x}_1 \geq B \) and \( c + \tilde{x}_1 - B \geq I_1 \)

The cash flow received at \( t = 1 \) in addition to cash holdings is sufficient to to repay debt, as well as undertake the expansion project without asset sales. At \( t = 1 \), equityholders (i.e., the firm) will fully repay the bondholders and invest \( I_1 \) to expand. Bondholders will receive the full par value of their claim, \( B \). At \( t = 2 \), equityholders will receive total cash flows of \( f(I_0) + x_2 + A_2 + g(I_1) + c + \tilde{x}_1 - B - I_1 \).

**State 2** \( c + \tilde{x}_1 \geq B \) and \( c + \tilde{x}_1 - B < I_1 \) but \( c + \tilde{x}_1 - B + A(\eta^*) = I_1 \)

The cash flow received at \( t = 1 \) in addition to cash holdings is sufficient to to repay debt, but not sufficient enough to undertake the expansion project. However, there exists a unique percentage of assets liquidated, \( \eta^* \), at which the proceeds from a liquidation, \( A(\eta^*) \), is equal to the investment shortfall, \( I_1 - (c + \tilde{x}_1 - B) \).

At \( t = 1 \), the firm will fully repay bondholders. But the firms sells \( \eta^* \) percentage of assets to invest \( I_1 \) for expansion. Bondholders receive the full par value of their claim, \( B \). At \( t = 2 \), equityholders receive total cash flows of \( (1 - \eta^*) [f(I_0) + x_2 + A_2] + g(I_2) \).\(^2\)

**State 3** \( c + \tilde{x}_1 \geq B \) and \( c + \tilde{x}_1 - B < I_1 \) but \( c + \tilde{x}_1 - B + A(\eta = 1) < I_1 \)

Cash flows received at \( t = 1 \) in addition to cash holdings are sufficient to repay debt. However, there

\(^2\)It is noteworthy that \( \eta^* \) is a function of \( \tilde{x}_1 \) and can be solved for via \( A(\eta^*) = A_1 (1 - (1 - \eta^*) = I_1 - (c + \tilde{x}_1 - B) \).
does not exist any percentage of assets liquidated, $\eta^*$, at which the proceeds from asset sales, $A(\eta^*)$, is equal to the shortage needed to invest and expand, $I_1 - (c + \tilde{x}_1 - B)$.

At $t = 1$, the firm fully repays bondholders and forgoes the expansion project. Bondholders will receive the full par value, $B$. At $t = 2$, equityholders will receive total cash flows of $f(I_0) + x_2 + A_2$.

**State 4** $c + \tilde{x}_1 < B$ but $c + \tilde{x}_1 + A(\eta^\dagger) = B$

Cash flows received at $t = 1$ in addition to cash holdings are insufficient to fully repay bondholders. Additionally, there does not exist any percentage assets liquidated, $\eta^*$, at which the proceeds from liquidation, $A(\eta^*)$, is enough to undertake the expansion. Even at full liquidation, asset sale proceeds are less than what is necessary to invest and expand: $A(\eta^* = 1) < I_1 - (c + \tilde{x}_1 - B)$. However, there does exist a unique percentage assets liquidated, $\eta^\dagger$, at which the proceeds from a liquidation, $A(\eta^\dagger)$, is equal to what is needed to fully pay the bondholders, $B - c - \tilde{x}_1$.

At $t = 1$, the firm sells $\eta^\dagger$ percentage of assets in order to fully repay bondholders. Bondholders receive the full par value, $B$ and at $t = 2$, equityholders receive total cash flows of $(1 - \eta^\dagger) [f(I_0) + x_2 + A_2]$.

**State 5** $c + \tilde{x}_1 < B$ but $c + \tilde{x}_1 + A(\eta = 1) < B$

Cash flows received at $t = 1$ in addition to cash holdings are insufficient to repay creditors. Moreover, there does not exist any percentage assets liquidated, $\eta^\dagger$, at which the proceeds from asset sales, $A(\eta^\dagger)$, is equal to what is needed to fully repay the bondholders, $B - c - \tilde{x}_1$.

At $t = 1$, the firm defaults and bondholders take over the firm. Bondholders force full liquidation and receive $c + \tilde{x}_1 + A(\eta = 1)$. Equity holders receive a payoff of zero.

Figure 2 summarizes the aforementioned states.

[Figure 2 about here.]

### 3.2.1 Pricing of Debt and Equity Claims

To price equity and debt claims, we need to find the risk-neutral expected payoff of each claim. We first derive the debt claim value since given the above states, only under state (5) do bondholders receive anything.

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3It is noteworthy that $\eta^\dagger$ is a function of $\tilde{x}_1$ and can be solved for via $A(\eta^\dagger) \equiv A_1(1 - (1 - \alpha)\eta^\dagger) = B - c - \tilde{x}_1$. 
less than the face value, $B$. The value of debt, $D$, is given by:

$$D = \int_{\frac{\bar{x}}{\bar{x} - x}}^{\frac{\bar{x}}{\bar{x} - x}} B \Pr[\tilde{x}_1|\tilde{x}_1 \geq B - c - A(\eta = 1)] \, d\tilde{x}_1$$

$$+ \int_{\frac{\bar{x}_1}{\bar{x}_1 - x}}^{\frac{\bar{x}_1}{\bar{x}_1 - x}} [c + \tilde{x}_1 + A(\eta = 1)] \Pr[\tilde{x}_1|\tilde{x}_1 < B - c - A(\eta = 1)] \, d\tilde{x}_1. \quad (1)$$

Equation 1 has two parts: 1) the repayment of the face value conditioned on using both cash holdings and liquidating assets, and 2) receiving cash holdings, the cash flow at $t = 1$, and the asset value at full liquidation upon default. With the assumption that cash flows (or alternatively, cash flow shocks) are uniformly distributed, $\tilde{x}_1 \sim U[\bar{x}, \underline{x}]$, we can rewrite equation 1 as

$$D = \frac{\bar{x} + c + A(\eta = 1) - B}{\underline{x} - \bar{x}} B + \frac{B - c - A(\eta = 1) - \underline{x}}{\underline{x} - \bar{x}} (c + A(\eta = 1)) + \frac{1}{2} \left[\left(\frac{B - c - A(\eta = 1)}{\underline{x} - \bar{x}}\right)^2 - \underline{x}^2\right] \quad (2)$$

Since with $\eta$ fractional asset liquidation, the asset value at liquidation is given by $A(\eta)_1 = (1 - (1 - \alpha)\eta)A_1$ where $\alpha$ is the discount per dollar liquidated, we know that $A(\eta = 1) \equiv \alpha A_1$, and thus we can find the value of debt as

$$D = \frac{\bar{x} + c + \alpha A_1 - B}{\underline{x} - \bar{x}} B + \frac{B - c - \alpha A_1 - \underline{x}}{\underline{x} - \bar{x}} (c + \alpha A_1) + \frac{1}{2} \left[\left(\frac{B - c - \alpha A_1}{\underline{x} - \bar{x}}\right)^2 - \underline{x}^2\right] \quad (3)$$

or,

$$D = \frac{1}{\underline{x} - \bar{x}} \left[ B\underline{x} - (c + \alpha A_1)\bar{x} - \frac{1}{2} \left(\underline{x}^2 + (B - c - \alpha A_1)^2\right) \right] \quad (4)$$

Because the debt is a discount bond and investors are risk neutral, the corporate yield spread is given by $s = \frac{B}{D} - 1$.

Aggregating the cash flows over each of the five possible states of nature, the value of equity is given by

$$E = \int_{\frac{\bar{x}}{\bar{x} - x}}^{\frac{\bar{x}}{\bar{x} - x}} \left[ f(I_0) + x_2 + A_2 + g(I_1) + c + \tilde{x}_1 - B - I_1 \right] \Pr[\tilde{x}_1|\tilde{x}_1 \geq B + I_1 - c] \, d\tilde{x}_1$$

$$+ \int_{\frac{\bar{x}_1}{\bar{x}_1 - x}}^{\frac{\bar{x}_1}{\bar{x}_1 - x}} \left[ (1 - \eta^*) \left[ f(I_0) + x_2 + A_2 + g(I_2) \right] \Pr[\tilde{x}_1|B + I_1 - c - A(\eta = 1) \leq \tilde{x}_1 < B + I_1 - c] \, d\tilde{x}_1\right.$$
As noted, in state 2, the firm liquidates $\eta^*$ fraction of assets so as to raise enough funds to undertake the expansion project. This necessitates that $A(\eta^*) = I_1 - (c + \hat{x}_1 - B)$. Replacing $A(\eta^*)$ with its corresponding functional value, we can show that

$$\eta^* = \frac{1}{1 - \alpha} \left[ 1 - \frac{I_1 + B - c - \hat{x}_1}{A_1} \right]$$

Similarly, in state 4, the firm liquidates $\eta^\dagger$ fraction of assets so as to raise enough funds to undertake the expansion project. This necessitates that $A(\eta^\dagger) = B - c - \hat{x}_1$. Replacing $A(\eta^\dagger)$ with its corresponding functional value, we can show that

$$\eta^\dagger = \frac{1}{1 - \alpha} \left[ 1 - \frac{B - c - \hat{x}_1}{A_1} \right]$$

Substituting the above values of $\eta^*$ and $\eta^\dagger$ as well as the identity $A(\eta = 1) = \alpha A_1$ into equation 5, we then have

$$E = \int_{B + I_1 - c}^{\hat{x}} \left[ f(I_0) + x_2 + A_2 + g(I_1) + c + \hat{x}_1 - B - I_1 \right] \Pr[\hat{x}_1|\hat{x}_1 \geq B + I_1 - c] \, d\hat{x}_1$$

$$+ \int_{B + I_1 - c}^{B + I_1 - \alpha A_1} \left[ \left( \frac{I_1 + B - c - \hat{x}_1 - \alpha A_1}{(1 - \alpha)A_1} \right) (f(I_0) + x_2 + A_2) + g(I_1) \right] \times \Pr[\hat{x}_1|B + I_1 - c - \alpha A_1 \leq \hat{x}_1 < B + I_1 - c] \, d\hat{x}_1$$

$$+ \int_{B - c}^{B - c - \alpha A_1} \left[ (B - c - \hat{x}_1 - \alpha A_1) \frac{(f(I_0) + x_2 + A_2)}{(1 - \alpha)A_1} \right] \times \Pr[\hat{x}_1|B - c - \alpha A_1 \leq \hat{x}_1 < B - c] \, d\hat{x}_1. \quad (6)$$
Evaluating the integrals, we then have
\[
E = \frac{1}{\bar{x} - x} \times \left\{ \bar{x} - B - I_1 + c \right\} \left[ f(I_0) + x_2 + A_2 + g(I_1) + c - B - I_1 \right]
+ \frac{1}{2} \left[ \bar{x}^2 - (B + I_1 - c)^2 \right]
+ \left[ \left( \frac{I_1 + B - c - \alpha A_1}{(1 - \alpha)A_1} \right) \left( f(I_0) + x_2 + A_2 \right) \right] + \alpha A_1 g(I_1)
- \left( \frac{f(I_0) + x_2 + A_2}{2(1 - \alpha)A_1} \right) \left[ (B + I_1 - c)^2 - (B + I_1 - c - \alpha A_1)^2 \right]
+ (I_1 - \alpha A_1) \left( f(I_0) + x_2 + A_2 \right)
+ \left( \frac{B - c - \alpha A_1}{(1 - \alpha)A_1} \right) \left( f(I_0) + x_2 + A_2 \right)
- \left( \frac{f(I_0) + x_2 + A_2}{2(1 - \alpha)A_1} \right) \left[ (B - c)^2 - (B - c - \alpha A_1)^2 \right] \right\}. \tag{7}
\]

After some algebra, we can show that
\[
E = \frac{1}{\bar{x} - x} \times \left\{ \frac{1}{2} \bar{x} \left[ \bar{x} - B - I_1 + c \right] + g(I_1) \left( \bar{x} - B - I_1 + c + \alpha A_1 \right) \right\}
+ \left[ f(I_0) + x_2 + A_2 \right] \left( \bar{x} - B + c - \frac{\alpha}{1 - \alpha} A_1 \right) \right\}. \tag{8}
\]

Equation 8 represents three components. First, the expectation of receiving \(f(I_0)\) proceeds from investing \(I_0\), the terminal asset value \(A_2\), and the terminal cash flow, \(x_2\), conditional on the probability that firm does not default. To avoid default, the firm utilizes cash flows, cash holdings, and even partial asset sales. Second, the expectation of receiving \(g(I_1)\) proceeds from investing \(I_1\) conditional on the probability that firm does not default and is able to undertake the investment at \(t = 1\). And third, the conditional volatility of cash flows in excess of debt repayment and investment outlay in presence of cash holdings.

### 3.3 Asset Liquidity and Optimal Cash Holdings

From equation 4, we can show that
\[
\frac{\partial D}{\partial c} = \frac{1}{\bar{x} - x} \left[ - \bar{x} + B - c - \alpha A_1 \right] \tag{9}
\]

This implies that from the bondholder’s perspective, the optimal cash holding, \(c^* = B - \alpha A_1 - \bar{x}\), is equal to the par value minus the combined full liquidation asset value and the minimum cash flow. This reflects a desire to fully hedge the business risk that the bondholders are exposed to using the firm’s cash holdings.
Obviously from equityholders point of view this can be much too excessive since it forces the firm to set aside resources that could otherwise be deployed towards profitable investment projects. Assuming that managers maximize shareholder value, the firm will choose the level of cash holdings that maximizes the value of equity given in equation 8. However, in our setting, the problem is an two-period investment problem. This simply then means that the managers ought to choose optimal level of investment at time $t=0$ and $t=1$. The objective function then is to maximize equity value with respect to $I_0$ and $I_1$. To do so, we start by utilizing the fact that $c = x_0 - I_0$, $f(I_0) = \beta_0 I_0$, and $g(I_1) = \beta_1 I_1$. Replacing these in 8, our objective function then becomes $\max_{I_0, I_1} E$, where:

$$E = \frac{1}{\bar{x} - x} \times \left\{ \frac{1}{2} \bar{x} \left( \bar{x} - B - I_1 + x_0 - I_0 \right) + \beta_1 I_1 \left( \bar{x} - B - I_1 + x_0 - I_0 - \frac{\alpha}{1-\alpha} A_1 \right) \right\}. \quad (10)$$

Having solved for the first order conditions, $\partial E/\partial I_0 = 0$ and $\partial E/\partial I_1 = 0$, we then can derived the optimal levels of investment at time $t=0$ and $t=1$.

**Proposition 1.** Consider the case of a firm with an initial investment opportunity and a future an expansion project. The firm can initially raise debt to fund the investment opportunity. The firm must repay debt prior to undertaking the expansion project. Debt repayment may be funded through partial sales of assets-in-place. Providing that firm can repay debt and avoid default, the firm may undertake the expansion project using internal cash resources and/or partial sales of assets-in-place. Note that even if all resources on hand (both cash and asset sales) are utilized, there would be states of nature in which the firm would be forced to forgo expansion. Assuming that profit functions initial investment project, $f$, and, the expansion project, $g$, are linear functions of the investments, that is, $f(I_0) = \beta_0 I_0$ and $g(I_1) = \beta_1 I_1$, the optimal levels of investments at time $t=0$ and $t=1$ are given by:

$$I_0^* = \left[ 4\beta_0 - \beta_1 \right]^{-1} \times \left\{ (2\beta_0 - \beta_1)(\bar{x} - B + x_0) - \left( \frac{2\beta_0}{1-\alpha} + \beta_1 \right) \alpha A_1 - 2(x_2 + A_2) - \frac{1}{2} \bar{x} \right\}, \quad (11)$$

and,

$$I_1^* = \left[ 4\beta_0 - \beta_1 \right]^{-1} \times \left\{ x_2 + A_2 + \beta_0 x_0 - \beta_0 B + \frac{\beta_0}{\beta_1} (\beta_1 - 1) \bar{x} + \beta_0 \alpha \left( \frac{1}{1-\alpha} + 2 \right) A_1 \right\}. \quad (12)$$

**Proof.** See Appendix. □

**Proposition 2.** Consider the case of a firm with an initial investment opportunity and a future an expansion
The firm can initially raise debt to fund the investment opportunity. The firm must repay debt prior to undertaking the expansion project. Debt repayment may be funded through partial sales of assets-in-place. Providing that firm can repay debt and avoid default, the firm may undertake the expansion project using internal cash resources and/or partial sales of assets-in-place. Note that even if all resources on hand (both cash and asset sales) are utilized, there would be states of nature in which the firm would be forced to forgo expansion. Assuming that profit functions initial investment project, $f$, and, the expansion project, $g$, are linear functions of the investments, that is, $f(I_0) = \beta_0 I_0$ and $g(I_1) = \beta_1 I_1$, the optimal cash holding, $c^* = x_0 - I_0^*$, is given by:

$$c^*_0 = \left[4\beta_0 - \beta_1\right]^{-1} \times \left\{2(x_2 + A_2) + \left(\frac{2\beta_0}{1-\alpha} + \beta_1\right)\alpha A_1 + (2\beta_0 - \beta_1)B\right. \right.
+ \left. -2\beta_0 + \beta_1 + \frac{1}{2}\right\}x_0$$

Assuming that $\beta_0 > \frac{1}{4}\beta_1$, this optimal cash holding, $c^*$, is:

- an increasing function of the asset market liquidity, $\alpha$; the assets-in-place values at $t = 1$ and $t = 2$, (i.e., $A_1$, $A_2$); the cash flow at $t = 2$, $x_2$; and, the debt face value, $B$.
- an increasing (decreasing) function of upper limit of cash flows at $t = 1$, $\bar{x}$; if $-2\beta_0 + \beta_1 + \frac{1}{2} > 0(<0)$.
- an increasing (decreasing) function of the cash flow at $t = 0$, $x_0$; if $-2\beta_0 + \beta_1 + 1 > 0(<0)$.
- an decreasing (increasing) function of the initial project’s profitability, $\beta_0$; if $(\alpha(2 + \frac{1}{1-\alpha})A_1 + \bar{x} + x_0 - B)\beta_0 + \bar{x} + 2x_0 + 4(x_2 + A_2) > 0(<0)$.
- an increasing (decreasing) function of the expansion project’s profitability, $\beta_1$; if $(\alpha(2 + \frac{1}{1-\alpha})A_1 + \bar{x} + x_0 - B)\beta_0 + \frac{1}{2}\bar{x} + x_0 + 2(x_2 + A_2) > 0(<0)$.

Proof. See Appendix

3.4 Asset Liquidity and Credit Spreads at Optimal Cash Holding

By substituting the optimal level of cash holdings from equation 13 into equation 4, we can arrive at a closed-form expression for the bond’s value. We first compute the optimal level of cash holdings (i.e. the level which maximizes the value of equity) and then determine the credit spread at this optimized level of cash holdings. The closed form expression is rather unwieldy and complex. Therefore, to facilitate the intuition we illustrate the comparative statics of the credit spread, $s = \frac{B}{D} - 1$, with respect to firm and asset sale market conditions graphically. We consider a baseline case where $x_0 = 10, x_1 \sim U[20,10]$, and,
Additionally, $B = 150$, $I_0 = 100$, and, $I_1 = 120$. Moreover, $f(I_0) = \beta_0 I_0$, where, $\beta_0 = 1.3$ and $g(I_1) = \beta_1 I_1$, where, $\beta_1 = 1.5$. Figures 3 to 6 illustrate some of the comparative statics of the model. In each, we examine the relationship between asset liquidity and credit spreads for while varying different parameters of the model. In particular we vary the degree of initial leverage ($B$), the profitability of the project ($\beta_0$).

A consistent feature in each figure is a convex relationship between the liquidity of the firm’s assets and credit spreads. For low levels of liquidity, an increase in asset liquidity, $\alpha$, is associated with a lowering of credit spreads. But for higher levels of asset liquidity, the relationship reverses. At high levels of asset liquidity, increasing $\alpha$ results in a widening of credit spreads. This finding is consistent with the argument put forth by Myers and Rajan (1998) in which managers will not sell assets to expropriate wealth from bondholders if they gain little compared to the benefits the gaining from operating the assets. If the costs of transferring wealth from bondholders by way of asset sales is too high (as measured by $\alpha$), then managers will chose not to do so. Therefore the creditor’s claims to the assets are protected from expropriation even when the debt is unsecured. When the cost of asset sales is low (i.e. $\alpha$ is large), selling assets to expropriate wealth from bondholders becomes more attractive. Thus creditors compensate for this possibility ex-ante by increasing the cost of debt and widening credit spreads.

In figure 3 we vary the face value of debt, $B$, to show the effects of leverage on the asset liquidity-credit spread relationship. Because the size of the expansion project is constant, varying the face value of debt is analogous to varying the firm’s leverage ratio. Figure 3 shows that while this convex relationship exists across a wide range of leverage ratios, it is most apparent among high leverage firms. And it is among these high leverage firms in which the threat and degree of wealth expropriation from bond holders is the highest (Maxwell and Rao, 2003; Maxwell and Stephens, 2003).

Figure 4 illustrates the asset liquidity-credit spread relationship while varying the profitability of the initial investment opportunity, $\beta_0$. In general, credit spreads are increasing with the project’s profitability. When the profitability of the firm’s investment opportunity is high the firm has an incentive to investment more funds into the project and hold less cash, this leaving less protection for the bondholders. We can see that at lower levels of profitability, the relationship between asset liquidity and credit spreads becomes flatter. This is precisely because these firms with less profitable investments will hold more cash and thus the likelihood and intensity of asset sales will be less. As such, the cost of assets sales will have minimal impact on the bondholder’s claims. Conversely for firms with more profitable initial investment opportunities, funds will be diverted away from cash and into the project and as a result the intensity and likelihood of asset sales are larger.
sales will be greater. Therefore the firm’s creditors must consider the impact the asset sales on their claims and increase the price of debt ex-ante. This results in a large disparity in the credit spreads between low and high profitability firms in the high liquidity regions where wealth expropriating asset sales are likely to take place.

Intuitively if the expected cash flows to the firm are higher, the firm will be less likely to default. Therefore credit spreads will be decreasing with the size of expected cash flows. Figure 5 illustrates this simple and intuitive relationship by varying the expected size of the uncertain cash flow at time 1, \( E[x_1] \). We can see that at all levels of asset liquidity, credit spreads a lower for firms with higher expected cash flow size. But similar to figure 4, the disparity in credit spreads between low and high average cash flow firms widens substantially in the high asset liquidity regions. This occurs because firms with low cash flows and high asset liquidity are more likely to undertake asset sales in order to fund future investment opportunities, to the detriment of the bond holders. Additionally, the scale of these asset sales will be larger among the firms with lower expected cash flows since there would be a larger financing gap. Because the likelihood and degree of asset sales will be greater for firms with low expected cash flows, the bond holders will require greater compensation to offset the probable wealth transfers.

Figure 6 varies the range of the uncertain cash flow at time 1 (i.e. \( x - \bar{x} \)) to demonstrate the impact of cash flow volatility on the asset liquidity-credit spread relationship. When cash flows are more volatile, it is more likely to have a cash shortfall leading to financial distress or default. Consistent with this logic, Minton and Schrand (1999), Molina (2005), and Tang and Yan (2010) each find that credit spreads are generally increasing with the volatility of the firm’s cash flows. In our model, however, this relationship only holds partially. In the lower liquidity regions, we do indeed see that firms with more cash flow volatility have higher credit spreads. This pattern flips in the high asset liquidity regions, with firms with more cash flow volatility having smaller credit spreads.

3.5 Credit Spreads and Asset Liquidity at Given Level of Cash Holdings

Clearly at a point in time, a firm may not necessary be holding optimal cash holding. We thus examine how credit spreads change vis-à-vis real asset liquidity at various given cash holdings. Since there is no guarantee
that, given parametric values, cash holdings are optimal, we can simply derive debt values from 4. In which
case, credit spreads are defined as \( s = \frac{B}{D} - 1 \). As is demonstrated clearly in 7, the relationship between
credit spreads and cash holdings is convex even when cash holdings are not at optimal levels. As asset
liquidity decreases, so do credit spreads rapidly. However, this is only true up to a point after which credit
spreads gradually rise as asset liquidity drops. As noted in 7, this optimum point varies but saddles \( \alpha = 0.30 \).
Moreover, for reasonable parametric values, when cash holdings are not excessively low, it is possible for
credit spreads to become zero. This is because bondholders may find some level of asset liquidation which can
make the bond payment safe when the market for real assets is fairly liquid. Not surprisingly, this optimum
can occur at even low asset liquidity when cash holdings are high. With low cash holdings, a high asset
liquidity level is required to safeguard debt. While not shown for brevity, given reasonable parametric values,
we also find comparative statics with respect to cash flow characteristics, leverage, and project profitability
are qualitatively similar.

[Figure 7 about here.]

3.6 Hypotheses

Motivated by the comparative statics results illustrated in the previous section as well as results developed
in the extant literature, we now develop a set of testable hypotheses. From the perspective of structural
credit risk models (e.g. Merton, 1974; Black and Cox, 1976), the value of assets only serves to determine
the probability of default as well as the recovery value given default. When firms may choose to voluntarily
sell assets, however, the selling price potentially has an impact on optimal firm behavior. However, as noted
previously, Myers and Rajan (1998) suggest that when debt is unsecured, greater asset liquidity makes it
less costly for managers to sell the firm’s assets, change the risk of the firm, and expropriate value from
creditors. Although managers have the ability to sell assets at any level of liquidity, they will choose not to
do so when liquidity is low. If the transaction cost incurred while selling the illiquid asset is greater than
the benefits the equityholders would receive by simply operating the assets, managers would prefer to forgo
asset sales. Therefore, unsecured debt of firms with low asset liquidity will behave similarly to secured debt
in the sense that managers are constrained in the ability to expropriate wealth through asset sales. When
asset liquidity is high, transaction costs associated with selling assets are reduced, giving managers a greater
incentive to transform the firm’s asset composition and expropriate wealth from bondholders.

The general convex shape of figures 3 to 7 demonstrates this idea clearly. Up to about an optimal level
of asset liquidity, \( \alpha^* \), roughly equal to 0.30, as asset liquidity decreases, so do credit spreads but rapidly.
Beyond this point, as asset liquidity decrease, credit spreads increase, albeit ever so gradually. Again, this
is not surprising in that in our setting

**Hypothesis 1.** *There will exist a non-linear relationship between asset liquidity and credit spreads such that for low levels of asset liquidity credit spreads are decreasing with liquidity, and for higher level of liquidity credit spreads are increasing with asset liquidity.*

Figure 3 suggests that while the relationship between asset liquidity and credit spreads is somewhat flat at lower levels of leverage, at high leverage a convex relationship becomes apparent. This effect arises because the threat and degree of wealth expropriation is higher among firms with high leverage. Consistent with this idea, Maxwell and Rao (2003) find that following a spin-off announcement bondholders suffer significant losses partially through the loss of coinsurance. If the cash flows generated from a firm’s assets are not perfectly correlated, then a sale of assets increases the bondholder’s risk and make his claims less valuable. The authors find evidence that the magnitude of these bondholder losses is amplified as the firms become more highly levered and these losses are transferred to equityholders. Thus as assets become more easily sold, bondholders of high leverage firms will be more exposed to potential losses and thus required additional compensation for this risk.

**Hypothesis 2.** *The relationship between asset liquidity and credit spreads will be stronger among high leverage firms*

The literature has shown that firms do resort to asset sales to fund investments (e.g. Bates, 2005; Borisova and Brown, 2013). Firms with better growth opportunities will be more likely to sell off their assets to fund investments. If the proceeds generated from selling existing assets are used to fund more risky investment opportunities, then there will be a transfer of wealth from debtholders to equityholders. Therefore as better asset liquidity increases the feasibility of using asset sales to finance investment, bondholders exposure to risk may increase.

**Hypothesis 3.** *The relationship between asset liquidity and credit spreads with be stronger among firms with larger growth opportunities.*

Acharya et al. (2012) demonstrate that there is a negative relationship between cash holdings and credit spreads.\(^4\) This arises due to the certainty effect of cash. With more cash on the balance sheet, the firm becomes more able to service its debt and as a result the probability of default as well as credit spreads decrease.

\(^4\)Using basic OLS regressions they actually find a positive relationship, but after addressing the endogenous relation between credit risk and the choice of cash holdings with instrumental variables and identifying the effect ‘pure’ cash holdings on credit spreads, they observe a negative relationship.
Lastly, Acharya et al. (2012) documents a negative empirical relationship between cash holdings and asset liquidity. These three facts suggest that an endogenous relationship exists between these three items: cash, asset liquidity, and credit spreads. The main issue is summarized graphically in figure 8.

[Figure 8 about here.]

All else equal, a firm with a high degree of liquid real assets will have larger credit spreads. However, it is not the case that all else is equal. Firms with liquid real assets tend to hold less cash and the impact of lower cash holdings is an increase in credit spreads. If highly liquid assets are accompanied by large cash balances, the credit spread increasing impact of asset liquidity will be diminished.

**Hypothesis 4.** *The positive relationship between asset liquidity and credit spreads is reduced with higher cash holdings.*

### 4 Empirical Analysis

#### 4.1 Data

In this section, we briefly describe the data sources and variable construction. Bond data comes from multiple sources, as decreed in the following section. Firm-level accounting and stock price information are gathered from COMPUSTAT and CRSP. All accounting data from COMPUSTAT is winsorized at the 1% and 99% level to control for potential outliers and reporting errors. Data regarding asset sale transactions is obtained from Thompson-Reuters SDC Platinum. We exclude financial firms (SIC codes 6000 - 6999).

**4.1.1 Bond Data**

Daily corporate bond yields for the period of 1994 to 2005 are obtained from transaction prices reported in the Mergent Fixed Income Securities Database (FISD). FISD reports transaction data from the National Association of Insurance Commissioners (NAIC), and therefore only trades conducted by insurance companies are included. While insurance companies are the most prominent investors in corporate bonds (Campbell and Taksler, 2003), we supplement the FISD data with transactions reported to the Trade Reporting and Compliance Engine (TRACE) provided by FINRA.\(^5\) Introduced in 2002, TRACE reports tick-by-tick transaction data for all US corporate bonds and as of 2005 approximately 99% of all public bond transactions are reported.

\(^5\)Insurance companies hold about 25% of corporate bonds in the US market from 2004 to 2012. See: [http://www.naic.org/capital_markets_archive/140307.htm](http://www.naic.org/capital_markets_archive/140307.htm)
We delete erroneous bond prices by removing transactions conducted at prices greater than $220 (per $100 par) and less than $25 (per $100 par). Additionally, we implement the algorithm of Dick-Nielsen (2009) to filter reporting errors (i.e. canceled trades, corrections, reversals, etc.). Additionally, we remove bonds with less than one year and greater than 30 years until maturity. Finally, following the methodology of Bessembinder et al. (2009), we eliminate trades of less than $100,000 and convert intra-day yields into daily yields using a trade-size weighted average. The resulting combination of FISD and TRACE transactions results in a total of 3,397,682 daily transactions. We take the average of the daily yields within the month to obtain monthly bond yields. To ensure homogeneity among the bonds in the sample we exclude all bonds with option-like features (convertibles, putable, callable, and floating rate bonds), non US firms, and bonds denominated in foreign currencies. After merging with COMPUSTAT and FISD bond characteristic data, we are left with 34,041 firm-month bond yields.

We compute the credit spread, \( \text{CSPRD}_{i,t} \), of the firm \( i \) at time \( t \) as the difference between the corporate bond yield-to-maturity, \( \text{Yield}_{i,t} \), and its maturity-matched Treasury bond yield, \( \text{TYield}_{i,t} \).

\[
\text{CSPRD}_{i,t} = \text{Yield}_{i,t} - \text{TYield}_{i,t} \tag{14}
\]

Following Collin-Dufresne et al. (2001), we use Treasury Constant Maturity rates from the St. Louis Federal Reserve Bank’s Federal Reserve Economic Data (FRED) for maturities of 1, 2, 3, 5, 7, 10, 20, and 30 years to estimate a simple interpolated Treasury yield curve everyday. For every bond in our sample, we then define its maturity-matched Treasury yield to be the linearly interpolated yield from above scheme at the corresponding maturity. The credit spread for the bond is simply the difference between yield-to-maturity and this maturity-matched Treasury yield.

4.1.2 Asset Liquidity

As a measure of real asset liquidity, we use an industry based index of asset turnover (Schlingemann et al., 2002; Sibilkov, 2009; Ortiz-Molina and Phillips, 2014). The index is motivated by the notion that firm assets tend to be industry specific as shown in both the theoretical and empirical literature (Shleifer and Vishny, 1992; Ramey and Shapiro, 2001; Benmelech and Bergman, 2009). The index is constructed as follows. From Thomson-Reuters SDC Platinum, we identify 20,362 corporate transactions completed between 1982 and 2013 in which the form of the deal is classified as either an acquisition of assets or an acquisition of certain assets. We require that the value of the deal is disclosed and that the target is either a publicly traded firm

\footnote{Asquith et al. (2013) considers $220 the maximum price for a risk-free bond and thus prices greater must be errors in reporting. Similarly, Edelington et al. (2012) consider prices of less than $25 to either be errors or defaulted bonds.}

\footnote{Firm-month observations with an S&P credit rating of D or with a credit spread greater than 40% are also deleted. This filter removes 215 observations (158 removed due to credit rating, 57 removed due to credit spread).}
or a subsidiary. Each transaction is assigned to the target firm’s industry as defined by its 2 digit SIC code. The manufacturing sector makes up a large portion of the asset sales. Over the sample period of 1982-2013 there were a total of 8,749 asset sale transactions in the manufacturing sector with a cumulative value of over $1.4 trillion. Panel B presents a finer industry classification (two-digit SIC code) for a limited group of industries of significance. The telecommunications industry is a relatively active asset sale industry with 2,027 total transactions over the period totaling over $403 billion.

The asset liquidity index is then computed as the ratio of the sum of industry transactions within the year to the total industry book value of assets (each converted to 1984 dollars). Industries which had no corporate transactions within a year receive an index value of 0 for that year. Because the liquidity of the industry should not solely depend on the number of transactions in the one single period, we use a five-year moving average of the index as the proxy for industry-wide asset liquidity. This procedure results in 1,663 industry-year values for the index. All firms within the same industry will each have identical values for the liquidity index each year. The asset liquidity index has an average value of 0.009 over the sample period. This means that on average, each industry in the economy (as defined by two digit SIC code) sells off about 0.90% of its assets each year. The value for the index ranging from 0% to 21.3% indicating that there may be substantial heterogeneity in the index across both industry and time.

4.1.3 Control Variables

Structural models of corporate debt (Merton (1974), Black and Cox (1976), among others) show that yield spreads should reflect the bondholder’s expected loss given default. That is, credit spreads should be function of the probability of default and the expected recovery rate. While many papers in the literature use structural estimation to generate quantitative estimates from these models, others (e.g Collin-Dufresne et al., 2001; Chen et al., 2007; Güntay and Hack Barth, 2010; Acharya et al., 2012; Nejadmalayeri et al., 2013b,a) translate the theoretical determinants of credit spreads into their empirical counterparts and estimate reduced-form linear regression models. Following this literature, we use a set of variables to control for a number of firm specific characteristics, macroeconomic conditions, and bond level features which have been shown to be related to credit risk.

At the firm level and bond level, we include controls for:

**Size:** Defined as the natural log of the book value of total assets

**Leverage:** Defined as the ratio of the book value debt to the sum of the book value of debt plus the market value of equity (i.e., the number of shares outstanding times price per share)
**Asset Volatility:** Computed using the iterated process of Bharath and Shumway (2008) who use the Merton (1974) model to infer the market value of assets each day. Asset volatility is then the standard deviation of implied daily asset returns over each year.

**Distance to Default:** Computed as \( d_2 \) in the Merton (1974) option pricing model using the iterative procedure of Bharath and Shumway (2008).

**Credit Rating:** As in Collin-Dufresne et al. (2001), we use COMPUSTAT numerically translated version of the S&P letter ratings. This numeric rating takes values from 1-23 such that AAA=1, AA+=2, ..., CCC+=17, ..., C=20.

**Time to Maturity:** The natural log of years to maturity for the firm’s bonds. If a firm has more than one debt issue outstanding, time to maturity equals the average time to maturity of all outstanding bonds.

To control for macroeconomic conditions, following as in Collin-Dufresne et al. (2001), we include:

**Risk-free interest rate:** Defined as the 10-year constant-maturity Treasury yield obtained for the Federal Reserve Bank of St. Louis (FRED).

**Slope of Term Structure:** Defined as the difference between the 10- and 2-year constant maturity Treasury yields.

**Market Volatility:** Defined as the monthly level of the implied market level volatility obtained from the Chicago Board Options Exchange (CBOE).

**Business climate** Defined as the S&P 500 index monthly return as reported by CRSP.

### 4.1.4 Summary Statistics

Table 1 provides summary statistics for the main variables of interest as well as the control variables. These values are consistent with credit spreads observed in other studies (e.g. Güntay and Hackbarth, 2010; Acharya et al., 2012; Nejadmalayeri et al., 2013b,a). A majority of the bonds in the sample have a credit rating of either A (A+, A, or A-) or BBB (BBB+, BBB, BBB-). 33% and 39% of the bonds have either an A rating or BBB rating, respectively. Very few bonds (2%) have a rating in the AAA range. Consistent with intuition, as credit ratings decline the credit spread increases. The average time to maturity for the bonds in the sample is 8.25 years. The mean credit spread over the sample period is 2.32% and a median of 1.34%. While not reported for brevity, our correlations analysis of the main variables of interest and the control variables yields well documented patterns. Exception is asset liquidity which displays very little unconditional correlation.
with credit spreads at 1% (or any of the control variables). Given our analytical findings which hints to a nonlinear relationship between asset liquidity and credit spreads, this findings is not surprising.

[Table 1 about here.]

4.1.5 Univariate Analysis

To gain insight into the relationship between real asset liquidity and credit spreads, we sort firms each year into quartiles based on their asset liquidity index value. Firms with low asset liquidity are placed into group 1 and firms with high asset liquidity are placed into group 4. Table 2 presents the credit spread statistics for each of these liquidity groups. Panel A considers bonds over the entire sample period (1996 - 2013). We can see that firms in the low liquidity group on average have smaller credit spreads than firms with high liquidity. For the full sample the difference in means between the high and low liquidity groups is a relatively small 7 basis points. However, the difference is statistically significant at the 10% level. Additionally, consistent with the theoretical predictions, a non-linear relationship between credit spreads and asset liquidity is apparent. This non-linear relationship is especially apparent in the time period prior to the Financial Crisis. While mean credit spreads are high for low liquidity firms, they decrease in the middle range of asset liquidity, finally rising again in the upper quartile. As expected, credit spreads are substantially higher in the post-crisis period. The patterns observed in the full sample as well as the pre-crisis period break down in the post-crisis period. After 2008, we see that credit spreads for low liquidity firms are higher than for high liquidity firms (3.34% versus 3.12%). Yet, the non-linearity of credit spreads across liquidity groups continues to persist.

[Table 2 about here.]

4.2 Results

Following recent literature, we estimate a reduced-form model of credit spreads taking into account the firm and macroeconomic characteristics which have been shown to be the main determinants of credit risk (e.g. Collin-Dufresne et al., 2001; Acharya et al., 2012, among others).

\[
CSPRD_{i,t} = \alpha + \beta_1 AssetLiq_{i,t} + \beta_2 AssetLiq_{i,t}^2 + \Phi X_{i,t} + \varepsilon_{i,t}\tag{15}
\]

where, \(CSPRD_{i,t}\) is the credit spread on a bond issue of firm \(i\) at month \(t\) and \(AssetLiq_{i,t}\) is the Industry Asset Liquidity Index as described previously. \(X_{i,t}\) is a vector of control variables motivated by structural

\(^8\)Observations prior to 2008 are designated as pre-crisis. Observations from 2008 - 2013 are designated as post-crisis.
credit risk models. Specifically, $X_{i,t}$ contains monthly observations of size ($SIZE_{i,t}$), leverage($LEV_{i,t}$), asset volatility ($VOL_{i,t}$), distance to default ($DD_{i,t}$), credit rating ($CRD_{i,t}$), the risk free rate ($RF_{i,t}$), the slope of the term structure ($TS_{i,t}$), the level of the VIX ($VIX_{i,t}$), and the S&P 500 return ($SP_{i,t}$). The quadratic term, $AssetLiq^2_{i,t}$ is included to capture the non-linearity demonstrated by the theoretical model. Each model in the baseline specification is estimated using pooled OLS regressions with firm-level fixed effects. The panel regressions employ heteroskedasticity, autocorrelation robust standard errors corrected for correlation across multiple observations of a given firm (i.e., firm-level clustering).

Similar to interest coverage in Blume et al. (1998), asset liquidity in our case is a highly skewed variable, as evident from Table 1. Moreover, unlike our theoretical case, this empirical proxy of asset liquidity at worse is 21.3% making testing for the nonlinearity observed in the data challenging. To remedy these problems, we follow Blume et al. (1998) in including a piecewise linear transformation of asset liquidity instead of the quadratic specification. To be precise, we compute 15th, 50th, and 85th percentile breakpoints—denoted by $P_{15}$, $P_{50}$, $P_{85}$, respectively—for the asset liquidity index each year and assign firms to their corresponding liquidity group. This transformation leads to four variables, $AL_{1,i,t}$, $AL_{2,i,t}$, $AL_{3,i,t}$, and $AL_{4,i,t}$ for every $i$ firm at time $t$ which capture the non-linearity in the credit spread-asset liquidity relationship. These variables are defined as:

<table>
<thead>
<tr>
<th>$AssetLiq_{i,t} \in [0, P_{15})$</th>
<th>$AssetLiq_{i,t}$</th>
<th>$AL_{1,i,t}$</th>
<th>$A_{2,i,t}$</th>
<th>$AL_{3,i,t}$</th>
<th>$AL_{4,i,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{15}$</td>
<td>$AssetLiq_{i,t} - P_{15}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$P_{50}$</td>
<td>$P_{50} - P_{15}$</td>
<td>$AssetLiq_{i,t} - P_{50}$</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$P_{85}$</td>
<td>$P_{85} - P_{50}$</td>
<td>$P_{85} - P_{50}$</td>
<td>$AssetLiq_{i,t} - P_{85}$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$P_{100}$</td>
<td>$P_{100}$</td>
<td>$P_{100}$</td>
<td>$P_{100}$</td>
<td>$P_{100}$</td>
<td></td>
</tr>
</tbody>
</table>

We then modify our baseline regression model 15 to include these terms instead of $AssetLiq_{i,t}$ and $AssetLiq^2_{i,t}$ as the following:

$$CSPRD_{i,t} = \alpha + \sum_{j=4}^{4} \eta_j AL_{j,i,t} + \Phi X_{i,t} + \varsigma_{i,t}$$ (16)

### 4.2.1 Asset Liquidity and Credit Spreads

Table 3 presents estimates of the baseline regression models and illustrates the overall relationship between real asset liquidity and credit spreads.

[Table 3 about here.]

Models (1) - (3) present estimates of the model shown in equation 15. Over the full sample period, as
well as the pre-financial crisis period (pre-2008), there is a negative relationship between the liquidity of a firm’s real assets and its credit spread. The positive coefficient on $\text{AssetLiq}_{i,t}$ indicates that as the firm’s assets get more liquid, investors demand greater yields on their bonds.

Models (4) - (6) estimates the model using the piecewise linear function of asset liquidity in equation 16. In the pre-crisis period the coefficient on $AL_1$ is negative and statistically significant. This finding suggests that firms with low asset liquidity (in the range of 0 to the 15th percentile) will experience decreasing credit spreads as asset liquidity increases. This is consistent with the convex relationships between credit spreads and liquidity depicted in figures 3 to 6. This result holds in the pre-Financial Crisis period, but the relationship reverses post-2007. The coefficient on $AL_1$ becomes positive, suggesting a concave relationship between spreads and liquidity among low liquidity firms. That is as liquidity increases within this range, credit spreads increase as well. This finding could a result of increased asset sales that were undertaken by firms in distress during the financial crisis period. Firms which possess assets with low liquidity will usually choose not to use asset sales during normal times as they fetch prices lower than their true values. However during the financial crisis period all firms increased their level of assets sales (Campello et al., 2010). If these asset sales conducted by low asset liquidity firms during the crisis were conducted for reasons of distress, we would observe this concave relationship.

4.2.2 The Effects of Leverage and Credit Rating

Bondholders of high leverage firms are more exposed to agency problems than creditors of less levered firms. The potential for asset sales magnifies this agency problem as it becomes more feasible for managers to engage in asset substitution and expropriate wealth from bondholders. To test this hypothesis, we segment the firms into three categories based on leverage tertiles (i.e., low, mid and top 33%iles). We then re-estimate our benchmark regressions for each of these sub-samples.

Consistent with hypothesis 2, panel A of table 4 shows that asset liquidity is positively related to credit spreads only among firms with high leverage. In models (1) and (2) we see that for lower leverage firms, asset liquidity has no significant association with credit spreads. As the the bondholders of these firms are not as exposed to the risks of wealth transfers due to asset sales, creditors will not demand as much of a premium for their investment. Conversely, among high leverage firms, the positive relationship between real asset liquidity and credit risk continues to persist.

Panel B of table 4 illustrates interesting results consistent with agency problems of leverage. Among low leverage firms there is a concave relationship between asset liquidity and credit spreads. Low liquidity
(\(AL_1\)) is related to increasing credit spreads while high liquidity (\(AL_4\)) is related to decreasing credit spreads. When we shift our focus to high leverage firms, however, the relationship between asset liquidity and credit spreads flips and becomes convex. Low liquidity (\(AL_1\)) is related to decreasing credit spreads while high liquidity (\(AL_4\)) is related to increasing credit spreads. This is likely a result of the increased possibility of wealth expropriation among highly levered firms. For firms with low leverage, high asset liquidity could be viewed as a positive characteristic due to the increased liquidation value in the event of default. Thus these firms will have lower credit spreads. For high leverage firms, high asset liquidity may pose a more credit threat of asset substitution within the firm. Therefore creditors of these firms will demand higher premiums for their investments in these bonds.

4.2.3 The Effects of Growth Opportunities

Hypothesis 3 suggests that the impact of asset liquidity on credit spreads should be stronger among firms with larger growth opportunities. The rationale is that selling assets to finance investment may not be worthwhile when the gains to investment are minimal. Especially for firms with low levels of asset liquidity, the costs associated with asset sales outweigh the benefits from investment. When profitable growth opportunities are prevalent, asset sales become more feasible particularly for those firms that can liquidate assets are relatively low costs. The increased possibility of asset sales increases the risk of bondholder payoffs and, as a result, the value of debt will fall (credit spreads will rise).

To test this hypothesis, we subset the sample according to the size of each firm’s growth opportunities. I measure a firm’s growth opportunities with an industry level proxy. Specifically, a firm’s growth options is defined as the firm’s forward 8 quarter moving average EBITDA. Each year, firms are ranked on this measure of growth opportunities and placed into three groups. The highest 33% of firms are classified as having high growth opportunities and the lowest 33% are classified as having low growth opportunities.

Table 5 presents regression results on this segmented sample. Model (1) shows that for firms with low growth opportunities there is a negative relationship between asset liquidity in credit spreads. This is consistent with the notion that firms with low growth opportunities will choose not to sell assets in order to finance investment. In this case, the assets within the firm will remain in place and thus increased liquidity increases the recovery value to bondholders rather than increase the probability of wealth transfers due to asset sales. Consistent with hypothesis 3, model (3) indicates that for firms with high growth opportunities, increased asset liquidity results in higher credit spreads.

[Table 5 about here.]

The curvilinear relationship displayed previously exhibits puzzling properties when focusing on growth
options. While there exists a U-shaped pattern in the credit spread-asset liquidity relationship over the full sample, the negative coefficient on the quadratic terms in models (2) and (4) suggests that an inverted U-shape exists when the sample is segmented by growth options.

4.2.4 The Intermediating Effects of Cash

Hypothesis 4 suggests that cash holdings play an intermediating role in the connection between corporate credit spreads and real asset liquidity. To examine this effect we introduce an interaction term, $AssetLiq_{i,t} \times Cash_{i,t}$, into the model, where $Cash$ is the ratio of cash and short-term investments to total assets. Specifically, we estimate equation 17.

$$CSPRD_{i,t} = \alpha + \beta_1 AssetLiq_{i,t} + \beta_2 Cash_{i,t} + \beta_3 AssetLiq_{i,t} \times Cash_{i,t} + \Phi X_{i,t} + \epsilon_{i,t} \quad (17)$$

Coefficient estimates from equation 17 are presented in table 6. Models (1) and (2) are estimated using OLS. In both models indicate that after introducing the effects of cash, a positive relationship remains between asset liquidity and credit spreads. The positive coefficient on the interaction term $AssetLiq_{i,t} \times Cash_{i,t}$ suggests that higher cash balances amplify the credit risk effects of asset liquidity. That is at higher levels of cash holdings, the positive effects of asset liquidity on credit spreads become stronger. This result is at odds with intuition.

Additionally, the positive coefficient on cash found in models (1) and (2) is counterintuitive. Common economic intuition suggests that larger cash reserves should make a firm’s corporate debt safer and decrease its probability of default and thus lower its spreads. As shown in equation 9, the optimal level of cash from the bondholder’s perspective reflects the desire to completely hedge the firm’s business risk. A positive relationship between cash and credit spreads suggests, however, that holding more cash increases the risks that bondholders are exposed to. Acharya et al. (2012) argue that the an endogenous connection cash holdings to credit spreads drives the puzzling positive correlation observed in OLS regressions. Riskier firms naturally hold larger cash balances simply because they are exposed to more risks.

The authors utilize an instrumental variables approach to remove the confounding effects of endogeneity in the relationship between cash and credit spreads isolate the effects of cash which are unrelated to credit. The instruments are selected so as to affect the level of cash holdings, and at the same time have no impact on payoffs to debtholders. To ensure that we examine the ‘pure’ effect of cash holdings on the asset liquidity-credit spreads relationship in our analysis, we employ the instrumental variables approach of Acharya et al. (2012).

Acharya et al. (2012) determine that a firm’s growth options and managerial agency costs are appropriate
instruments for cash. We proxy for growth options using the median ratio of intangible assets to total assets in the firm’s industry each year (\(GrowthOps_{i,t}\)). Managerial agency is measured as the ratio of the CEO’s cash compensation to the market value of his shares and options (\(Agency_{i,t}\)).

Models (3) - (5) of table 6 are estimated using this instrumental variable regression approach. Model (5) includes the interaction term \(AssetLiq_{i,t} \times Cash_{i,t}\), which itself is an endogenous variable. Balli and Srensen (2013) show that in the case where a variable, \(X_2\) is endogenous, \(X_1\) is exogenous, and \(Z\) is a valid instrument for the endogenous variable \(X_2\), then the interaction \(X_1Z\) will be a valid instrument for the interaction \(X_1X_2\). Therefore, we include interactions with the instruments (\(AssetLiq_{i,t} \times GrowthOps_{i,t}\) and \(AssetLiq_{i,t} \times Agency_{i,t}\)) to serve as an instruments for \(AssetLiq_{i,t} \times Cash_{i,t}\).

Model (3) confirms the result of Acharya et al. (2012). After controlling for the endogenous nature of cash and credit risk, credit spreads are decreasing with cash. Including asset liquidity into model (4) we see that the positive cash and credit spreads remain positively related. Model (5) introduces the interaction variable \(AssetLiq_{i,t} \times Cash_{i,t}\). While the sign on the interaction coefficient is negative, it lacks any meaningful statistical significance. This may be, however due to the non-linearity in the relationship between bond spreads and asset liquidity. As illustrated previously, the relationship between credit spreads and asset liquidity is convex. That is, spreads are decreasing with asset liquidity in the low liquidity ranges and increasing in high liquidity ranges. Therefore, we would not to see any ameliorating effects of cash holdings on the relationship among firms with low asset liquidity. It is the firms with high asset liquidity which pose the greatest threat to the claims of bondholders. High cash balances will work to partially alleviate this threat. To test if there are differential impacts at the two extreme ends of the asset liquidity index, we classify firms as high and low liquidity according to the non-linear regression scheme in table 4.2. Specifically, define High Asset Liquidity as an indicator variable that takes on a value of 1 if the firm is ranked in the top 15th percentile and 0 otherwise. Similarly, we define Low Asset Liquidity as an indicator variable that takes on a value of 1 if the firm is ranked in the bottom 15th percentile and 0 otherwise.

Indeed as shown in table 7, the intermediating effect of cash holdings for high asset liquidity firms is quite apparent. Model (1) shows that while firms with high asset liquidity tend to have larger credit spreads, increasing cash balances works to diminish the magnitude of the impact. Conversely for firms with low real asset liquidity, the interaction term in Model (2) is statistically insignificant. This consistent with the

---

9Managerial agency is computed using ExecuComp and is defined as (salary + bonus + other annual compensation + long-term incentive plan + all other compensation) / (value of the CEO’s equity stake + value of all unexercised options owned.)
notion that the likelihood that the firm with low liquidity would choose to sell its assets. Firms with low asset liquidity would receive low prices in asset sales and thus they are unlikely to exhibit such behavior. Therefore, the mitigating impact of cash holdings on firms with low real asset liquidity is negligible.

5 Conclusion

Motivated by recent ideas that asset sales can indeed as means for raising capital, we extend Acharya et al. (2012) model and show that market liquidity for real assets affects credit spreads nonlinearly in a U-shaped manner. The intuition is simple: a firm will partially liquidate assets so long as the liquidation can prevent default and safeguard future lucrative payoffs. Such a firm essentially may trade-off having larger cash holdings upfront in favor of asset liquidation when market liquidity for assets is high enough. However, as market liquidity dismisses, so does the cost of making such a trade-off. The firm would at some point find it more beneficial to hold large cash at hand and consider asset liquidation a forgone conclusion. Our analytical comparative statics demonstrate that as the firm’s leverage and growth options increase, so does the aforementioned nonlinearity of the link between real asset liquidity and credit spreads. We empirically test our predication and find that indeed the link between credit spreads and real asset liquidity is U-shaped. Moreover, highly levered firms and firms with growth option face much more pronounced nonlinearity. Our empirical analyses also shows that that the trade-off between cash holding and market liquidity is only significantly present when liquidity is high.
References


A Proof of Proposition 1

Proof. Having taken partial derivative of 10 with respect to $I_0$, we have:

$$\frac{\partial E}{\partial I_0} = \frac{1}{x-\bar{x}} \times \left\{ -\frac{1}{2} \bar{x} - \beta_1 I_1 + \beta_0 (\bar{x} - B - I_1 + x_0 - I_0 - \frac{\alpha}{1-\alpha} A_1) - (\beta_0 I_0 + x_2 + A_2) \right\}. $$

This implies that for $\frac{\partial E}{\partial I_0} = 0$, the following expression must be equal to zero as well:

$$-\frac{1}{2} \bar{x} - \beta_1 I_1 + \beta_0 (\bar{x} - B - I_1 + x_0 - I_0 - \frac{\alpha}{1-\alpha} A_1) - (\beta_0 I_0 + x_2 + A_2) = 0. $$

After some algebra, we then have:

$$2\beta_0 I_0 + \beta_1 I_1 = \beta_0 \left( \bar{x} - B + x_0 - \frac{\alpha}{1-\alpha} A_1 \right) - x_2 - A_2 - \frac{1}{2} \bar{x}. \quad (18)$$

Similarly, after taking partial derivative of 10 with respect to $I_1$, we have:

$$\frac{\partial E}{\partial I_1} = \frac{1}{x-\bar{x}} \times \left\{ -\frac{1}{2} \bar{x} + \beta_1 (\bar{x} - B - I_1 + x_0 - I_0 - \alpha A_1) - \beta_1 I_1 \right\}. $$

This implies that for $\frac{\partial E}{\partial I_1} = 0$, the following expression must be equal to zero as well:

$$-\frac{1}{2} \bar{x} + \beta_1 (\bar{x} - B - I_1 + x_0 - I_0 - \alpha A_1) - \beta_1 I_1 = 0. $$

After some algebra, we then have:

$$\beta_1 I_0 + 2\beta_1 I_1 = \beta_1 \left( \bar{x} - B + x_0 + \alpha A_1 \right) - \frac{1}{2} \bar{x}. \quad (19)$$

By combining the above partial derivatives, $\frac{\partial E}{\partial I_0}$ and $\frac{\partial E}{\partial I_1}$, we arrive at a system of equation as following:

$$2\beta_0 I_0 + \beta_1 I_1 = \beta_0 \left( \bar{x} - B + x_0 - \frac{\alpha}{1-\alpha} A_1 \right) - x_2 - A_2 - \frac{1}{2} \bar{x}$$

$$\beta_1 I_0 + 2\beta_1 I_1 = \beta_1 \left( \bar{x} - B + x_0 + \alpha A_1 \right) - \frac{1}{2} \bar{x}. $$

To solve for $I_0^*$, we multiply the first equation by $(1 - 2\beta_1)$ and the second equation by $(\beta_1 - 1)$. After summing up the resulting equations and collecting term, we have:

$$[(1 - 2\beta_0)(1 - 2\beta_1) - (\beta_1 - 1)^2] I_0 = (1 - 2\beta_1) \left[ x_2 + A_2 + \frac{\alpha(1 - 2\alpha)\beta_0}{1-\alpha} A_1 - (\beta_0 - 1)(x_0 + \bar{x} - B) \right] + (\beta_1 - 1) \left[ \alpha \beta_1 A_1 - (\beta_1 - 1)(x_0 + \bar{x} - B) \right].$$

Dividing both side by $[(1 - 2\beta_0)(1 - 2\beta_1) - (\beta_1 - 1)^2]$, then we have:

$$I_0^* = \left[(2\beta_0 - 1)(2\beta_1 - 1) - (\beta_1 - 1)^2\right]^{-1} \times \left\{ (1 - 2\beta_1)(x_2 + A_2) + \left[ (\beta_0 - 1)(2\beta_1 - 1) - (\beta_1 - 1)^2 \right](x_0 + \bar{x} - B) + \frac{\alpha}{1 - \alpha} (1 - 2\alpha)\beta_0 (1 - 2\beta_1) + (1 - \alpha)\beta_1 (1 - \beta_1) \right\} A_1,$$
To solve for $I^*_1$, we multiply the first equation by $(1 - 2\beta_0)$ and the second equation by $(\beta_1 - 1)$. After summing up the resulting equations and collecting term, we have:

$$
[(1 - 2\beta_0)(1 - 2\beta_1) - (\beta_1 - 1)^2] I_1 = (\beta_1 - 1) \left[ x_2 + A_2 + \frac{\alpha(1 - 2\alpha)\beta_0}{1 - \alpha} A_1 - (\beta_0 - 1)(x_0 + \bar{x} - B) \right] + (1 - 2\beta_0) \left[ \alpha \beta_1 A_1 - (\beta_1 - 1)(x_0 + \bar{x} - B) \right].
$$

Dividing both side by $[(1 - 2\beta_0)(1 - 2\beta_1) - (\beta_1 - 1)^2]$, then we have:

$$
I^*_1 = \left[ (2\beta_0 - 1)(2\beta_1 - 1) - (\beta_1 - 1)^2 \right]^{-1} \times \left\{ (\beta_1 - 1)(x_2 + A_2) + \beta_0(\beta_1 - 1)(x_0 + \bar{x} - B) + \frac{\alpha}{1 - \alpha} [ (1 - 2\alpha)\beta_0(\beta_1 - 1) + (1 - \alpha)(1 - 2\beta_0)\beta_1 ] A_1 \right\}.
$$

B Proof of Proposition 2

Proof. It is trivial to show that by substituting $I^*_0$ from 11 in $c^*_0 \equiv x_0 - I^*_0$, we can arrive at the comparative statics, we take partial derivative of above equation with respect to the appropriate variable. First, $\partial c^*_0/\partial x_2 = \partial c^*_0/\partial A_2 = 2 \times [4\beta_0 - \beta_1]^{-1} > 0$. Second, $\partial c^*_0/\partial B = [2\beta_0 - \beta_1] \times [4\beta_0 - \beta_1]^{-1} > 0$. Third, $\partial c^*_0/\partial A_1 = [2\beta_0 - \beta_1] \times [4\beta_0 - \beta_1]^{-1} > 0$.

We then have:

$$
\frac{\partial c}{\partial A_1} = \frac{\beta_0}{2\beta_0 - 1} \cdot \frac{\alpha(1 - 2\alpha)}{1 - \alpha},
$$

The first term is always positive since $\beta_0 \geq 1$. In the second term, the denominator is always positive for $0 \leq \alpha \leq 1$. Since the roots of the numerator in the second term are zero and $\frac{1}{2}$, then we can show that for $0 \leq \alpha < \frac{1}{2}$, the numerator is positive making $\partial c/\partial A_1$ positive. For $\frac{1}{2} \leq \alpha < 1$, $\partial c/\partial A_1$ is then negative.

Having taken the partial derivative of equation 9 with respect to $\alpha$, we have:

$$
\frac{\partial c}{\partial \alpha} = \frac{\beta_0}{2\beta_0 - 1} \left[ 2 - \frac{1}{(1 - \alpha)^2} \right].
$$

As before, the first term is always positive since $\beta_0 \geq 1$. The second term’s roots are $1 \pm \frac{1}{\sqrt{2}}$. Since $0 \leq \alpha < 1$, only $\alpha = 1 - \frac{1}{\sqrt{2}}$ is relevant which then implies that when $0 \leq \alpha < 1 - \frac{1}{\sqrt{2}}$, $\partial c/\partial \alpha$ is positive and negative otherwise.

Taking the partial derivative with respect to $\beta_0$, we have that:

$$
\frac{\partial c}{\partial \beta_0} = \frac{-1}{(2\beta_0 - 1)^2} \left[ x_0 + \bar{x} + 2(x_2 + A_2 + (\beta_1 - 1)I_1) - B + \frac{\alpha(1 - 2\alpha)}{1 - \alpha} A_1 \right]
$$

As long as the second term is positive, $\frac{\partial c}{\partial \beta_0} > 0$. \hfill \Box
This figure shows the relationship between dollar value of assets sold, $A_t(\eta, \alpha)$, versus the percentage of assets sold, $\eta$, across various asset market liquidity, $\alpha \in [0,1]$. Note that we assume that $A_t(\eta, \alpha) = A_t - (1 - \alpha)A_t\eta = A_t(1 - (1 - \alpha)\eta)$. As such, a $\alpha = 0$ denotes a perfectly liquid market for real assets whereas $\alpha = 1$ denotes a perfectly illiquid market.
Figure 2: Possible States of Nature and Stockholder’s Payoff

1. \( c + \bar{x}_1 - B \geq I_1 \)

Invest \( I_1 \) at \( t = 1 \), at \( t = 2 \) receive:
\[ f(I_0) + x_2 + A_2 + g(I_1) + c + \bar{x}_1 - B - I_1 \]

2. \( c + \bar{x}_1 - B < I_1 \) but \( c + \bar{x}_1 - B + A_1(\eta^*) = I_1 \)

Sell of \( \eta^* \) fraction of assets for:
\[ A_1(\eta^*) = I_1 - (c + \bar{x}_1 - B) \]
Invest \( I_1 \) at \( t = 1 \), at \( t = 2 \) receive:
\[ (1 - \eta^*)[f(I_0) + x_2 + A_2] + g(I_1) \]

3. \( c + \bar{x}_1 - B < I_1 \) but \( c + \bar{x}_1 - B + A_1(\eta = 1) < I_1 \)

Do not sell any assets. Do not invest \( I_1 \) at \( t = 1 \), at \( t = 2 \) receive:
\[ f(I_0) + x_2 + A_2 \]

4. \( c + \bar{x}_1 + A_1(\eta^+) = B \)

Sell of \( \eta^+ \) fraction of assets for:
\[ A_1(\eta^+) = B - (c + \bar{x}_1) \]
Payback debt fully, at \( t = 1 \), at \( t = 2 \) receive:
\[ (1 - \eta^+)[f(I_0) + x_2 + A_2] \]

5. \( c + \bar{x}_1 + A_1(\eta = 1) < B \)

Default at \( t = 1 \)
Figure 3: Credit Spread vs. Asset Market Liquidity: Leverage

This figure illustrates how credit spreads change with asset market liquidity $\alpha$ for various leverage ratios. The face value of debt, $B$, denotes the leverage ratio since the expansion project size is kept constant. The parameter settings are as follows: initial cash flow, $x_0 = 10$; first year-end cash flow (which is random and uniformly distributed), $x_1 \sim U[10, 20]$; and, second year-end cash flow, $x_2 = 20$. Additionally, initial project’s outlay, $I_0 = 100$; and, second project’s outlay, $I_1 = 150$. Moreover, initial project’s total dollar returns, $f(I_0) = \beta_0 I_0$, where, $\beta_0 = 1.3$. The second project’s total dollar returns, $g(I_1) = \beta_1 I_1$, where, $\beta_1 = 1.4$. 

\[ \text{Credit Spread} \]
Figure 4: Credit Spread vs. Asset Market Liquidity: Project Profitability

This figure illustrates how credit spreads changes with asset market liquidity $\alpha$ for various levels of initial project’s profitability, $\beta_0$. The initial project’s total dollar returns, $f(I_0) = \beta_0 I_0$; whereas $I_0 = 100$. The parameter settings are as follows: initial cash flow, $x_0 = 10$; first year-end cash flow (which is random and uniformly distributed), $x_1 \sim U[10, 20]$; and, second year-end cash flow, $x_2 = 20$. Additionally, initial leverage, $B = 140$. Moreover, the second project’s outlay, $I_1 = 150$. The second project’s total dollar returns, $g(I_1) = \beta_1 I_1$, where, $\beta_1 = 1.4$. 
Figure 5: Credit Spread vs. Asset Market Liquidity: Average First Year-End Cash Flow

This figure shows how credit spreads change with asset market liquidity, \( \alpha \), for various levels of first year-end expected cash flows, \( x_1 \). The first year-end cash flow is random and uniformly distributed, \( x_1 \sim U[\underline{x}, \bar{x}] \). To generate the comparative statics, the range, \( \bar{x} - \underline{x} \) is fixed to be 10 but \( \bar{x} \) and \( \underline{x} \) change. The expected first year-end cash flow then is: \( E[x] = 0.5(\bar{x} + \underline{x}) \). The parameter settings are as follows: the face value of debt, \( B = 150 \); initial cash flow \( x_0 = 10 \); and the second year-end cash flow, \( x_2 = 20 \). Additionally, initial project’s outlay, \( I_0 = 100 \); and, second project’s outlay, \( I_1 = 150 \). Moreover, initial project’s total dollar returns, \( f(I_0) = \beta_0 I_0 \), where, \( \beta_0 = 1.3 \). The second project’s total dollar returns, \( g(I_1) = \beta_1 I_1 \), where, \( \beta_1 = 1.4 \).
Figure 6: Credit Spread vs. Asset Market Liquidity: First Year-End Cash Flow Range

This figure shows how credit spreads change with asset market liquidity $\alpha$ for various ranges of first year-end cash flows, $\bar{x} - x$. The first year-end cash flow is random and uniformly distributed, $x_1 \sim U[\bar{x}, \bar{x}]$. To generate the comparative statics, the expected first year-end cash flow, $E[x] = 0.5(\bar{x} + \bar{x})$ is fixed at 10. The range, $\bar{x} - \bar{x}$ is then changes as $\bar{x}$ and $\bar{x}$ change. The parameter settings are as follows: the face value of debt, $B = 150$; initial cash flow $x_0 = 10$; and the second year-end cash flow, $x_2 = 20$. Additionally, initial project’s outlay, $I_0 = 100$; and, second project’s outlay, $I_1 = 150$. Moreover, initial project’s total dollar returns, $f(I_0) = \beta_0 I_0$, where, $\beta_0 = 1.3$. The second project’s total dollar returns, $g(I_1) = \beta_1 I_1$, where, $\beta_1 = 1.4$. 
This figure illustrates how credit spreads change with asset market liquidity $\alpha$ for various given levels of cash holding. The parameter settings are as follows: initial cash flow, $x_0 = 10$; first year-end cash flow (which is random and uniformly distributed), $x_1 \sim U[10, 20]$; and, second year-end cash flow, $x_2 = 20$. Additionally, initial project’s outlay, $I_0 = 100$; and, second project’s outlay, $I_1 = 150$. Moreover, initial project’s total dollar returns, $f(I_0) = \beta_0 I_0$, where, $\beta_0 = 1.3$. The second project’s total dollar returns, $g(I_1) = \beta_1 I_1$, where, $\beta_1 = 1.4$. The face value of debt, $B = 140$. 
Figure 8: Relationships Between Asset Liquidity, Cash, and Credit Spreads

- Higher Asset Liquidity
- Lower Cash Holdings
- Higher Credit Spread

- Secured Debt
- Unsecured Debt
This table reports mean, median, standard deviation, minimum and maximum of the variables of interest for the sample. Credit spread, $CSRD_{i,t}$, is the difference between yield-to-maturity of $i$th bond and the maturity-matched Treasury rate at time $t$. Asset liquidity, $AssetLiq_{i,t}$, is the natural log of the firm’s book value of assets. Leverage, $LEV_{i,t}$, is the ratio of the book value debt to the sum of the book value of debt plus the market value of equity (i.e., the number of shares outstanding times price per share). Asset volatility, $VOL_{i,t}$, the standard deviation of implied daily asset returns over each year using the iterated process of Bharath and Shumway (2008) which utilizes Merton (1974) model to infer the market value of assets each day. Distance to default, $DD_{i,t}$, is defined as $d_2$ in the Merton (1974) option pricing model using the iterative procedure of Bharath and Shumway (2008). Credit rating, $CRD_{i,t}$, is COMPUSTAT numerically translated version of the S&P letter ratings. This numeric rating takes values from 1-23 such that AAA=1, AA+=2, ..., CCC+=17, ..., C=20. Maturity, $MAT_{i,t}$, is the years-to-maturity of $i$th bond at time $t$. The risk free rate, $RF_{i,t}$, is the 10-year constant-maturity Treasury yield obtained for the Federal Reserve Bank of St. Louis (FRED). The slope of the term structure, $TS_{i,t}$, is the difference between the 10- and 2-year constant maturity Treasury yields. The market volatility, $VIX_{i,t}$, is the monthly level of the implied market level volatility obtained from the Chicago Board Options Exchange (CBOE). The business climate, $SP_{i,t}$, is the S&P 500 index monthly return as reported by CRSP. The data for corporate bonds comes from FISD (pre-2006) and TRACE (post-2005). The data for interest rates is from FRED database at the St. Louis Fed. The data for firm characteristics are based COMPUSTAT. Credit Spread is the difference between the yield-to-maturity and maturity-matched Treasury rate.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>Credit Spread ($CSRD_{i,t}$)</td>
<td>2.065</td>
<td>1.334</td>
<td>2.588</td>
<td>0.001</td>
<td>39.997</td>
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<tr>
<td>Asset Liquidity ($AssetLiq_{i,t}$)</td>
<td>0.009</td>
<td>0.006</td>
<td>0.009</td>
<td>0.000</td>
<td>0.213</td>
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<tr>
<td>Leverage ($LEV_{i,t}$)</td>
<td>0.269</td>
<td>0.224</td>
<td>0.190</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Size ($SZ_{i,t}$)</td>
<td>9.083</td>
<td>9.077</td>
<td>1.206</td>
<td>6.021</td>
<td>13.649</td>
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<td>Distance to Default ($DD_{i,t}$)</td>
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<td>6.635</td>
<td>4.842</td>
<td>-6.652</td>
<td>40.427</td>
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<td>0.260</td>
<td>0.157</td>
<td>0.010</td>
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<td>6.060</td>
<td>1.000</td>
<td>29.995</td>
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<td>Risk-free ($RF_{i,t}$)</td>
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<td>4.610</td>
<td>1.201</td>
<td>1.510</td>
<td>6.960</td>
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<td>Slope ($TS_{i,t}$)</td>
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<td>0.700</td>
<td>0.969</td>
<td>-0.470</td>
<td>2.840</td>
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<td>Market Volatility ($VIX_{i,t}$)</td>
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<td>0.211</td>
<td>0.075</td>
<td>0.104</td>
<td>0.599</td>
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<tr>
<td>Business climate ($SP_{i,t}$)</td>
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<td>0.010</td>
<td>0.045</td>
<td>-0.169</td>
<td>0.108</td>
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<tr>
<td>Rating ($CRD_{i,t}$)</td>
<td>7.864</td>
<td>8.000</td>
<td>2.995</td>
<td>1.000</td>
<td>20.000</td>
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</table>
Table 2: Credit Spreads by Asset Liquidity

This table reports mean, median, standard deviation, minimum and maximum of the credit spreads ($CSPRD_{i,t}$) for the entire sample period as well as pre- and post-crisis periods. Crisis refers to the 2008 global financial crisis. Our measure of real asset liquidity is an industry based index of asset turnover (Schlingemann et al., 2002; Sibilkov, 2009; Ortiz-Molina and Phillips, 2014). The index is motivated by the notion that firm assets tend to be industry specific as shown in both the theoretical and empirical literature (Shleifer and Vishny, 1992; Ramey and Shapiro, 2001; Benmelech and Bergman, 2009). We then use quartiles of our real asset liquidity index for sample comparisons in this table. The data for corporate bonds comes from FISD (pre-2006) and TRACE (post-2005). The data for interest rates is from FRED database at the St. Louis Fed. The data for firm characteristics are based COMPSTAT.

<table>
<thead>
<tr>
<th>Panel A: Full Sample</th>
<th>Asset Liquidity Quartiles</th>
<th>Mean</th>
<th>Median</th>
<th>25%-ile</th>
<th>75%-ile</th>
<th>Std. Dev.</th>
<th>N. Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st (Lowest)</td>
<td></td>
<td>2.097</td>
<td>1.296</td>
<td>0.772</td>
<td>2.233</td>
<td>2.797</td>
<td>11439</td>
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<tr>
<td>2nd</td>
<td></td>
<td>2.101</td>
<td>1.456</td>
<td>0.840</td>
<td>2.588</td>
<td>2.179</td>
<td>6406</td>
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<tr>
<td>3rd</td>
<td></td>
<td>1.904</td>
<td>1.255</td>
<td>0.708</td>
<td>2.180</td>
<td>2.274</td>
<td>8642</td>
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<tr>
<td>4th (Highest)</td>
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<td>2.170</td>
<td>1.396</td>
<td>0.792</td>
<td>2.506</td>
<td>2.892</td>
<td>7554</td>
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<td>Highest – Lowest</td>
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<td>0.072</td>
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<table>
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<tr>
<th>Panel B: Pre Crisis</th>
<th>Asset Liquidity Quartiles</th>
<th>Mean</th>
<th>Median</th>
<th>25%-ile</th>
<th>75%-ile</th>
<th>Std. Dev.</th>
<th>N. Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st (Lowest)</td>
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<td>1.894</td>
<td>1.185</td>
<td>0.731</td>
<td>1.953</td>
<td>2.634</td>
<td>9827</td>
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<tr>
<td>2nd</td>
<td></td>
<td>1.735</td>
<td>1.157</td>
<td>0.737</td>
<td>1.912</td>
<td>2.062</td>
<td>4537</td>
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<td>3rd</td>
<td></td>
<td>1.695</td>
<td>1.116</td>
<td>0.664</td>
<td>1.896</td>
<td>2.086</td>
<td>7274</td>
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<td>4th (Highest)</td>
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<td>1.944</td>
<td>1.220</td>
<td>0.730</td>
<td>2.034</td>
<td>2.874</td>
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<td>Highest – Lowest</td>
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<td>0.051</td>
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<table>
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<tr>
<th>Panel C: Post Crisis</th>
<th>Asset Liquidity Quartiles</th>
<th>Mean</th>
<th>Median</th>
<th>25%-ile</th>
<th>75%-ile</th>
<th>Std. Dev.</th>
<th>N. Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st (Lowest)</td>
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<td>3.340</td>
<td>2.326</td>
<td>1.465</td>
<td>3.918</td>
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<td>2.989</td>
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<td>1.695</td>
<td>3.494</td>
<td>2.202</td>
<td>1869</td>
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<tr>
<td>3rd</td>
<td></td>
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<td>3.634</td>
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<td>4th (Highest)</td>
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<td>Highest – Lowest</td>
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<td>-0.168</td>
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</table>
### Table 3: Effects of Asset Liquidity on Credit Spreads

This table presents coefficient estimates from two models:

(1) \( \text{CSPRD}_{i,t} = \alpha + \beta_1 \text{AssetLiq}_{i,t} + \beta_2 \text{AssetLiq}^2_{i,t} + \Phi \mathbf{X}_{i,t} + \varepsilon_{i,t}; \) and,  

(2) \( \text{CSPRD}_{i,t} = \alpha + \sum_{i=4}^{3} \beta_i \text{AssetLiq}_{i,t} + \Phi \mathbf{X}_{i,t} + \varepsilon_{i,t}, \) where \( \text{AssetLiq}_{i,t}, i \in 1, 2, 3, 4 \) are a series of piece-wise linear transformed variations of asset liquidity index, \( \text{AssetLiq}_{i,t}; \) and, \( \mathbf{X}_t \) is a vector of control variables. All estimates include time fixed effects and industry fixed effects. \( t \)-statistics computed using robust standard errors clustered at the firm level.

<table>
<thead>
<tr>
<th></th>
<th>(1) Full Sample</th>
<th>(2) Pre-Crisis</th>
<th>(3) Post-Crisis</th>
<th>(4) Full Sample</th>
<th>(5) Pre-Crisis</th>
<th>(6) Post-Crisis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-2.701***</td>
<td>-2.114***</td>
<td>-3.271***</td>
<td>-2.718***</td>
<td>-1.638***</td>
<td>-3.170***</td>
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<tr>
<td></td>
<td>(-9.16)</td>
<td>(-6.58)</td>
<td>(-4.87)</td>
<td>(-9.11)</td>
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<td>(-4.68)</td>
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<tr>
<td>( \text{AssetLiq} )</td>
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<td>25.94***</td>
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<td></td>
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<tr>
<td></td>
<td>(5.50)</td>
<td>(4.86)</td>
<td>(0.40)</td>
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<tr>
<td>( \text{AssetLiq}^2 )</td>
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<td>-370.5***</td>
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<tr>
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<td>(-3.48)</td>
<td>(1.31)</td>
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<td>( \text{AL}_1 )</td>
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<td>-63.60***</td>
<td>50.32*</td>
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<td>(1.69)</td>
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<td>( \text{AL}_4 )</td>
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<td>5.924***</td>
<td>3.888***</td>
<td>3.831***</td>
<td>5.970***</td>
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<tr>
<td>Size</td>
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<td>-0.0216</td>
<td>-0.162***</td>
<td>-0.0233*</td>
<td>-0.0313**</td>
<td>-0.164***</td>
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<tr>
<td></td>
<td>(-1.97)</td>
<td>(-1.61)</td>
<td>(-4.05)</td>
<td>(-1.74)</td>
<td>(-2.32)</td>
<td>(-4.07)</td>
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<tr>
<td>Dist. to Default</td>
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<td>0.0333***</td>
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<td>(3.87)</td>
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<td>Asset Volatility</td>
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<td>2.537***</td>
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<td>(6.18)</td>
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<td>-0.338***</td>
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<td></td>
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<td>(1.14)</td>
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<td>Treasury Slope</td>
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<td>0.100***</td>
<td>-0.640***</td>
<td>0.0670***</td>
<td>0.0550***</td>
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<tr>
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<td>(4.83)</td>
<td>(3.44)</td>
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<tr>
<td>S&amp;P500</td>
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<td>6.923***</td>
<td>1.430***</td>
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<td>(9.64)</td>
<td>(4.30)</td>
<td>(2.05)</td>
<td>(9.45)</td>
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<td>0.271***</td>
<td>0.385***</td>
<td>0.317***</td>
<td>0.270***</td>
<td>0.381***</td>
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<td></td>
<td>(31.52)</td>
<td>(23.86)</td>
<td>(19.30)</td>
<td>(31.47)</td>
<td>(24.05)</td>
<td>(18.82)</td>
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<tr>
<td>Log(Maturity)</td>
<td>0.0932***</td>
<td>0.0623***</td>
<td>0.149***</td>
<td>0.103***</td>
<td>0.0702***</td>
<td>0.156***</td>
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<td>(7.91)</td>
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<td>(8.57)</td>
<td>(5.83)</td>
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<td>0.665</td>
<td>0.507</td>
<td>0.449</td>
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</table>
Table 4: Effects of Asset Liquidity on Credit Spreads: The Impact of Leverage

For various leverage categories, this table presents coefficient estimates from two models: (1) $CSPRD_{i,t} = \alpha + \beta_1 AssetLiq_{i,t} + \beta_2 AssetLiq^2_{i,t} + \Phi X_{i,t} + \varepsilon_{i,t}$; and, (2) $CSPRD_{i,t} = \alpha + \sum_{j=4}^{4} \eta_j AL_{j,i,t} + \Phi X_{i,t} + \varsigma_{i,t}$, where $AL_{j,i,t}, j \in 1, 2, 3, 4$ are a series of piece-wise linear transformed variations of asset liquidity index, $AssetLiq_{i,t}$; and, $X_{i,t}$ is a vector of control variables. All estimates include time fixed effects and industry fixed effects. Leverage is measured as the the ratio of the book value debt to the sum of the book value of debt plus the market value of equity. Each year, firms are assigned a low, medium or high leverage rank depending on whether their leverage ratio is in the lowest, middle, or top-most tertiles (33%iles). For brevity, coefficient estimates for these control variables and fixed effects are not reported. $t$-statistics computed using robust standard errors clustered at the firm level.

<table>
<thead>
<tr>
<th>Panel A. Nonlinear (convex) specification of asset liquidity</th>
<th>Full Sample Period</th>
<th>Pre-2008 Crisis Period</th>
<th>Post-2008 Crisis Period</th>
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<td></td>
<td>Low (1)</td>
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<td>High (3)</td>
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<tr>
<td>Constant</td>
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<td>1.630***</td>
<td>-5.085***</td>
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<td>(-2.42)</td>
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<td>(-9.37)</td>
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<td>1.638</td>
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<td>(4.49)</td>
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<td>-27.77</td>
<td>-279.0*</td>
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<tr>
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<td>(-0.67)</td>
<td>(-0.45)</td>
<td>(-1.79)</td>
</tr>
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<td>Observations</td>
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<td>8238</td>
<td>7955</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.474</td>
<td>0.570</td>
<td>0.525</td>
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</table>

<table>
<thead>
<tr>
<th>Panel B. Piece-wise linear specification of asset liquidity</th>
<th>Full Sample Period</th>
<th>Pre-2008 Crisis Period</th>
<th>Post-2008 Crisis Period</th>
</tr>
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<td>High (3)</td>
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<td>-4.371***</td>
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<td>(3.71)</td>
<td>(1.64)</td>
<td>(-6.53)</td>
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<td>AL_2</td>
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<td>10.88</td>
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<td>(6.43)</td>
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<td>(2.10)</td>
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<td>AL_4</td>
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<td>-0.953</td>
<td>16.79***</td>
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<td>Adjusted $R^2$</td>
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<td>0.570</td>
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Table 5: Effects of Asset Liquidity on Credit Spreads: The Impact of Growth Options

For various profitability categories, this table presents coefficient estimates from two models:

\( \text{CSPRD}_{i,t} = \alpha + \beta_1 \text{AssetLiq}_{i,t} + \beta_2 \text{AssetLiq}^2_{i,t} + \Phi X_{i,t} + \varsigma_{i,t} \)
and, \( \text{CSPRD}_{i,t} = \alpha + \sum_{j=1}^{4} \eta_j \text{AL}_j_{i,t} + \Phi X_{i,t} + \varsigma_{i,t} \), where \( \text{AL}_j_{i,t}, j \in 1, 2, 3, 4 \) are a series of piece-wise linear transformed variations of asset liquidity index, \( \text{AssetLiq}_{i,t} \); and, \( X_t \) is a vector of control variables. All estimates include time fixed effects and industry fixed effects. Profitability is measured as the average of the ratio of EBITDA to total assets over the preceding 8 quarters. Each year, firms are assigned a low, medium or high profitability rank depending on whether their profitability ratio is in the lowest, middle, or top-most tertiles (33%iles). For brevity, coefficient estimates for these control variables and fixed effects are not reported. \( t \)-statistics computed using robust standard errors clustered at the firm level.

<table>
<thead>
<tr>
<th></th>
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<th>Post-2008 Crisis Period</th>
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<tr>
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<td>(3)</td>
</tr>
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<td><strong>Panel A. Nonlinear (convex) specification of asset liquidity</strong></td>
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<td></td>
<td></td>
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<td>-0.761***</td>
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<td>(-8.83)</td>
<td>(-3.08)</td>
<td>(-0.17)</td>
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<td>AssetLiq</td>
<td>47.02***</td>
<td>20.99***</td>
<td>15.34***</td>
</tr>
<tr>
<td></td>
<td>(5.87)</td>
<td>(3.58)</td>
<td>(2.98)</td>
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<tr>
<td>AssetLiq^2</td>
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<td>-188.8</td>
<td>-235.0***</td>
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<td>(-1.50)</td>
<td>(-3.11)</td>
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<td>7295</td>
<td>8649</td>
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<tr>
<td>Adjusted R²</td>
<td>0.528</td>
<td>0.535</td>
<td>0.449</td>
</tr>
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</table>

|                  |                  |                      |                      |
| **Panel B. Piece-wise linear specification of asset liquidity** |
| Constant         | -5.114*** | -0.785*** | -0.125 | -3.267*** | -0.379 | 0.837** | -5.506*** | 0.874  | -0.777*  |
|                  | (-8.35)   | (-3.16)   | (-0.34) | (-4.83)   | (-1.37) | (2.08)  | (-4.48)   | (1.53) | (-1.70)  |
| AL1              | -43.87**  | 19.17*    | 31.51*** | -122.5*** | -41.04*** | -43.88*** | -307.7*** | 123.1*** | 112.9*** |
|                  | (-2.25)   | (1.76)    | (2.84)   | (-5.52)   | (-3.23) | (-2.76) | (-3.39)   | (3.98) | (3.14)   |
| AL2              | 145.7***  | 36.68***  | 14.24    | 221.0***  | 102.4*** | 55.23*** | -357.4*** | -67.39 | 100.7**  |
|                  | (7.22)    | (3.31)    | (1.04)   | (10.36)   | (8.95)   | (3.69)  | (-2.64)   | (-1.27) | (1.97)   |
| AL3              | 18.77     | 21.79***  | 8.792**  | 35.36*    | 0.0806   | -7.961* | 20.40     | 24.76* | 10.57    |
|                  | (1.26)    | (3.08)    | (2.01)   | (1.71)    | (0.01)   | (-1.74) | (0.78)    | (1.94) | (1.21)   |
|                  | (0.58)    | (1.33)    | (-0.62)  | (-2.22)   | (1.19)   | (-1.01) | (0.71)    | (2.28) | (2.60)   |
| Observations     | 6745      | 7295      | 8649     | 5441      | 5694     | 6753   | 1304      | 1601   | 1896     |
| Adjusted R²      | 0.531     | 0.535     | 0.449    | 0.490     | 0.452    | 0.353  | 0.665     | 0.741  | 0.670    |
Table 6: Intermediating Effects of Cash

This table presents coefficient estimates from the model: \( C_{SPRD_{i,t}} = \alpha + \beta_1 AssetLiq_{i,t} + \beta_2 Cash_{i,t} + \beta_3 AssetLiq_{i,t} \times Cash_{i,t} + \Phi X_{i,t} + \varepsilon_{i,t} \), where \( X_t \) is a vector of control variables. The coefficients for the controls are omitted for brevity. All estimates include time fixed effects and industry fixed effects. \( t \)-statistics computed using robust standard errors clustered at the firm level.

<table>
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<td>OLS</td>
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<td>IV</td>
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<td>0.508</td>
<td>0.442</td>
<td>0.478</td>
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</table>

Table 7: Asset Liquidity, Cash, and Credit Spreads

This table presents coefficient estimates from the model: \( C_{SPRD_{i,t}} = \alpha + \beta_1 HiLiq_{i,t} + \beta_2 LoLiq_{i,t} + \beta_3 Cash_{i,t} + \beta_4 HiLiq_{i,t} \times Cash_{i,t} + \beta_5 LoLiq_{i,t} \times Cash_{i,t} + \Phi X_{i,t} + \varepsilon_{i,t} \), where \( X_t \) is a vector of control variables. All estimates include time fixed effects and industry fixed effects. \( HiLiq \) is a dummy variable that takes on a value of 1 if the firm is ranked in the top 25% based on asset liquidity and 0 otherwise. \( LoLiq \) is a dummy variable that takes on a value of 1 if the firm is ranked in the lowest 25% based on asset liquidity and 0 otherwise. All estimates include time fixed effects and industry fixed effects. \( t \)-statistics computed using robust standard errors clustered at the firm level.

<table>
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<td>Low Asset Liquidity</td>
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