Cash Holdings and Risky Access to Future Credit

Abstract

I quantify a new motive of holding cash through the channel of financing risk. I show that if the access to future credit is risky, firms may issue long-term debt now and save funds in cash to secure the current credit capacity for the future. I structurally estimate the model and find that this motive explains about 30% of cash holdings in the data. Counterfactual experiments indicate that the value of holding cash is around 8% of shareholder value.

Introduction

Holding cash is costly. But, in the data, U.S. public firms on average hold as high as 19% cash in their assets, particularly when they also hold 10% unused lines of credit which could be substitutes for cash. Moreover, during the 2008 financial crisis firms became increasingly cautious about their access to future credit, and they drew down existing credit lines and held the proceeds in cash even if there were no immediate financing needs (e.g., Ivashina and Scharfstein, 2009). So, why do firms stockpile cash?

In this paper, I qualify a new motive of holding cash by developing a dynamic model of long-term debt with financing risk. I show that if the access to future credit is risky, firms may want to issue long-term debt right now and save the funds in cash, and they do so in order to secure the current credit capacity for the future. Further, I structurally estimate the model using a sample of U.S. public firms and find that this motive explains about 30% of total cash holding in the data, even after controlling for transactional cash and unused lines of credit.

An innovation of the paper is that I study firms' cash behaviors jointly with their capital structure decisions. Recent studies show that financial flexibility in the form of unused debt capacity plays an important role in the choice of the capital structure (e.g., DeAngelo, DeAngelo, and Whited, 2011; Denis and McKeon, 2012). According to these studies, firms choose to borrow less (low leverage) to maintain the option to borrow in the future. In this paper, I show that under uncertain financing conditions, the unused debt capacity can disappear before the firm taps it. As a result, the risk of losing unused debt capacity would induce firms to borrow more now (high leverage) and keep the funds in cash.

The central assumption of the paper is that firms have risky access to future credit. Specifically, I assume that the firm's total borrowing limit is captured by the value of its collateral assets, while the value of collateral depends stochastically on credit market conditions. Since the total borrowing limit may shrink in the future, the unused credit could disappear also. Thus, to hedge the risk that the option to borrow may go away in the future,

the firm would execute the borrowing option earlier and save the proceeds in cash. This is the primary motivation in the paper that firms want to hold cash buffers.

In the paper's quantitative analysis, I interpret the option to borrow, the difference between the potential borrowing limit and the actual debt, as unused lines of credit.[1] In that case, the model's assumption that unused credit is risky receives considerable support in the data. First, credit lines are short-term. The rollover of credit lines is not guaranteed upon expiration. Second, the access to lines of credit is contingent on the lender's ability or willingness to supply funds. Third, most credit lines come with a borrowing base formula which imposes a mark-to-market borrowing limit. The amount of available credit is directly linked to the market value of the firm's collateral assets. If the value of collateral assets fluctuates, so does the availability of credit lines.[2]

The model is an extension of the standard framework with investment and financing frictions (e.g., Gomes, 2001; Cooley and Quadrini, 2001). I add three new ingredients. The first is to add a liquidity constraint to capture the mismatch between financing and investing. I assume that the firm's cash flows are realized at the end of the period, which implies that the firm needs to hold liquidity (cash or unused credit) for inter-period payments associated with capital expenditures, expiring credit market liabilities, and dividend payout. Because of the stochastic nature of payments, the liquidity constraint is occasionally binding and generates a precautionary motive to hold liquid funds.

The second extension is to allow for long-term debt, which is important for distinguishing cash from negative debt. With only one-period debt, there is no reason to borrow and hold cash since cash gives a lower direct return than the cost of debt. Firms will simply use all the available cash to reduce the liabilities that are due in the next period. With long-term debt, however, firms have incentives to borrow and temporarily hold cash to secure the current

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[1]The precise difference between the borrowing limit and the actual debt is unused debt capacity. However, in the data, we observe the amount of unused lines of credit, but not the total unused debt capacity. Thus, I use unused lines of credit as a lower-bound approximation of unused debt capacity.

[2]According to the data of a random sample of 600 Compustat firms hand-collected by Berrospide and Meisenzahl (2013), the average ratio of available credit to total credit is about 89%, and it declines significantly during the 2008 financial crisis.

availability of credit for the future. This is possible because the long-term debt does not need to be repaid in full in the next period, even if the firm loses access to new credit.

The third extension is the consideration of shocks that affect the financial condition of firms, that is, their access to credit. This is in addition to a standard productivity/investment shock.

The model is solved numerically by a non-linear approach, the projection method, and most model parameters are estimated by the simulated method of moments. After the estimation, I conduct two counterfactual exercises. First, I examine the impact of each shock on firms' cash holdings. Since the model has two shocks, I can turn off one to study the impact of the other. In this counterfactual experiment, I find that financing risk is the key to understand firms' cash behaviors: it explains about 90% of precautionary cash in the benchmark model. The investment risk, however, explains only 10%. The second counterfactual exercise is to shut down the channel of precautionary cash. In that case, I find that the shareholder value decreases by 8%, and I interpret this 8% as the value of holding precautionary cash.

I also use the model to study the impact of shocks that affect the financing conditions of firms and compare the prediction of the model to the real data. I find that in response to a credit crisis, firms reduce precautionary cash and unused lines of credit dramatically, while they do not cut investment much. This result is consistent with Duchin, Ozbas, and Sensoy (2010) who show that firms used their cash holdings as buffers to smooth investment at the onset of the 2007-2008 credit crisis. In response to a credit boom, instead, firms not only keep most new credit as unused lines, but also save cash out of borrowing. Such behavior demonstrates the precautionary motive of holding liquidity: even if firms are in favorable market conditions, they are still cautious about the possibility of future adverse financing conditions.

Another exercise conducted is to study the implications of an increase in credit uncertainty, or the volatility of the financial shock. In response to an increase in credit uncertainty,

firms draw down credit lines and keep the proceeds in cash, that is, they shift the composition of liquidity from risky credit lines to safer cash holdings. This prediction is consistent with the finding of Ivashina and Scharfstein (2009) that firms increasingly drew down their credit lines in the second half of 2008, but draw-downs were not driven by firms' investment opportunities since they were held largely in cash.

This paper relates to several strands of literature. The first strand of literature tries to explain why cash is different from negative debt. A feature shared by many dynamic corporate finance models is that holding cash is dominated by the use of cash to repay the outstanding debt.[3] To explain why cash is not negative debt, there are generally two approaches in the literature. The first is to impose debt issuance costs such as in Gamba and Triantis (2008), and Boileau and Moyen (2009). Although those studies provide testable implications on firms' choices between debt and cash holdings, the economic interpretation of the reduced-form debt issuance cost is controversial.

The other approach is to allow different maturities between cash and debt. Chaderina (2012) develops a model with two-period defaultable debt in which firms hold precautionary cash to hedge shocks that affect their future profitability prospects. The main difference between this paper and Chaderina (2012) is that I consider multi-period debt with enforcement constraints. Further, instead of studying the role of shocks that affect firms' future profitability prospects, I focus on the financing risk, i.e., the risk of losing access to future credit.

The paper contributes to the recent literature studying the impacts of financial shocks on firms' investment and financing decisions. Jermann and Quadrini (2012) study the macroeconomic effects of financial shocks and show that standard productivity shocks can only partially explain the movements in real and financial variables. The addition of financial shocks brings the model closer to the data. Instead of focusing on the aggregate economy,

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[3]For example, Cooley and Quadrini (2001), Hennessy and Whited (2005, 2007), Moyen (2004), DeAngelo, DeAngelo, and Whited (2011), Bolton, Chen, and Wang (2011), Nikolov and Whited (2011), Hugonnier, Malamud, and Morellec (2012), and Eisfeldt and Muir (2012). Acharya, Almeida, and Campello (2007) develop a three-period model to explain why cash is not negative debt.

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this paper focuses on individual firms with special attention paid to publicly listed U.S. corporations. This allows me to show from a micro prospective, as opposed to a macro approach, that financial shocks do play important roles in explaining firms' financing and investment decisions, especially for liquidity management policies.

This paper is also closely related to Bolton, Chen, and Wang (2012) and Eisfeldt and Muir (2012), who consider stochastic financing opportunities, and to Hugonnier, Malamud, and Morellec (2012) who adopt a similar interpretation of the credit supply shocks.

1   A Three-Period Model

To illustrate the central idea of the paper, I start presenting a simple three-period model. The timing of the firm's decisions is summarized in the top panel of Figure 1.1. There are three days: day 1, day 2, and day 3. On day 1, a firm makes borrowing and saving decisions and it has access to external financing up to a fixed borrowing limit $\bar{\xi}$. On day 2, the firm faces an investment opportunity of size i and still has access to the external financing but with a stochastic borrowing limit ξ.

The value of ξ is revealed at the beginning of day 2. On day 1, the firm knows that there are two possible realizations: ξ_H and ξ_L, with probabilities p_H and $1 - p_H$, respectively. The expected credit limit is $\bar{\xi} = p_H \xi_H + (1 - p_H) \xi_L$. To create a possible liquidity shortage on day 2, I assume that under adverse financing conditions the firm cannot borrow enough funds to finance investment, that is, $\xi_L < i$. However, the expected credit limit is always greater than the investment, that is, $\bar{\xi} > i$.

On day 2, the firm faces two situations. In the first case, the total available funds (cash plus unused credit) are larger than the investment. Therefore, the firm is able to make the investment. In the second situation, the available funds are insufficient to fund the investment and the firm is unable to make the investment. On day 3, the firm receives the revenue R_H if it invested on day 2, or receives R_L otherwise. Then, the firm pays off the debt. The

remaining funds are paid out as dividends.

In this simple model I assume that the discount factor is 1 and the gross interest rate of one-period debt is also 1. The gross interest rate of two-period debt is $1 + r$. I also assume that the revenue R_H is sufficiently larger than R_L so that if the firm has enough liquid funds on day 2 it would always take the investment project.

Let's first consider the scenario that cash and debt have the same maturity. In this case cash is equivalent to negative one-period debt. The middle panel in Figure 1.1 illustrates the timing of short-term borrowing.

I use backward induction to study the firm's decisions. Consider the firm's choices on day 2: to take advantage of the investment opportunity, the firm has to satisfy the cash-in-advance constraint (liquidity constraint) such that: $\xi - b_1 \geq i$. Here, the variable b_1 denotes the firm's net debt position on day 1. Given that ξ is the maximum amount the firm can borrow on day 2 and that b_1 is the amount of debt that needs to be repaid, the available funds for investment are $\xi - b_1$. Thus, the firm makes the investment only if $\xi - b_1 \geq i$.

Now, consider the firm's borrowing and saving decisions on day 1. On day 1, the borrowing limit ξ of day 2 is unknown. However, the firm knows there are only two realizations: $\xi \in \{\xi_H, \xi_L\}$. Thus, given the assumption that the investment project is sufficiently profitable, on day 1 the firm wants to ensure that it will always have enough funds to finance the investment project on day 2, irrespective of the borrowing conditions it will encounter on day 2. As a result, to hedge the worst financing condition ξ_L on day 2, the firm would like to borrow negatively on day 1 ($b_1 < 0$) so that the cash-in-advance constraint on day 2 will always be satisfied ($\xi_L - b_1 \geq i$).

In the three-period model considered here, the state variables at the beginning of day 1 are not specified. In the dynamic model I will consider later, the firm also holds debt outstanding at the beginning of day 1. Thus, in a dynamic framework the model would imply that the firm will choose to reduce its debt balances on day 1 to hedge the adverse financing conditions on day 2.

invest i, credit shock ξ

borrow or save   liquidity constraint   revenue

day 1   day 2   day 3

R_H

$\xi - b_1 \geq i$

short-term debt

$b_1 \downarrow$

$\xi - b_1 < i$

repay debt on day 2 R_L

$R_H - (1+r)b_2$

$\max\{\xi - b_2, 0\} + m_1 \geq i$

long-term debt

$m_1 \uparrow$

$\max\{\xi - b_2, 0\} + m_1 < i$

$R_L - (1+r)b_2$

repay debt on day 3

Figure 1.1: **Timing of Short-Term and Long-Term Borrowing**. The top graph shows the sequences of investing and financing decisions. The middle graph shows the timing of short-term borrowing, and the bottom graph shows the timing of long-term borrowing.

To sum up, with only one-period debt, although the firm can access $\bar{\xi}$ amount of external finance on day 1, it chooses not to tap it. Instead, the firm keeps $\bar{\xi} - b_1$ amount of unused credit. This is the *later-borrowing* motive which induces firms to hold unused lines of credit. In other words, the firm does not borrow now in order to be able to borrow later when the investment opportunity becomes available.

Consider now the scenario in which the firm can borrow with two-period debt. The bottom panel of Figure 1.1 illustrates the timing. In this scenario, if the firm borrows on day 1, it does not need to pay back the debt on day 2. Instead, it repays the debt on day 3 with interest rate r. Now, to take advantage of the investment opportunity on day 2, the firm would tap the credit market on day 1 and save the proceeds in cash. Denote by b_2 the amount of two-period debt that the firm borrows on day 1 and by m_1 the amount of cash that the firm carries from day 1 to day 2. The cash-in-advance constraint on day 2 becomes: $\max\{\xi - b_2, 0\} + m_1 \geq i$, where the term $\max\{\xi - b_2, 0\}$ is unused credit on day 2. To satisfy this cash-in-advance constraint even in the worst financing condition ξ_L, the firm would borrow positively and save cash on day 1: $b_2 = m_1 = i$. Notice that this is possible because of the assumption that $\bar{\xi} > i$. That is, the borrowing limit on day 1 is sufficient to finance the investment on day 2.

To sum up, when there is access to two-period debt, the firm has the incentive to borrow earlier and save the proceeds in cash to hedge against adverse future credit conditions. This is the *pre-borrowing* motive that induces firms to borrow now and save the cash for the later period when investment opportunities become available. The goal of borrowing now is to secure enough funds in the later period, something that would not be guaranteed if the debt was only for one-period.

The full dynamic model I describe in the next section will feature both the later-borrowing motive and the pre-borrowing motive. The presence of these two motives allows the model to generate the coexistence of cash and unused lines of credit in the optimal liquidity policies of firms.

2 The Dynamic Model

Figure 2.1 provides a sketch of the dynamic model. Consider a non-financial firm's balance sheet: on the assets side, it contains physical capital, cash holdings, and unused lines of credit;[4] on the liabilities side, it has equity and debt. In the model, equity is sticky and debt is subject to enforcement constraints. The goal of the model is to understand how does a credit shock affect a firm's investment decisions and how does the firm manage its liquidity to hedge against the credit shock. In the following subsections, I discuss the elements of the balance sheet one by one.
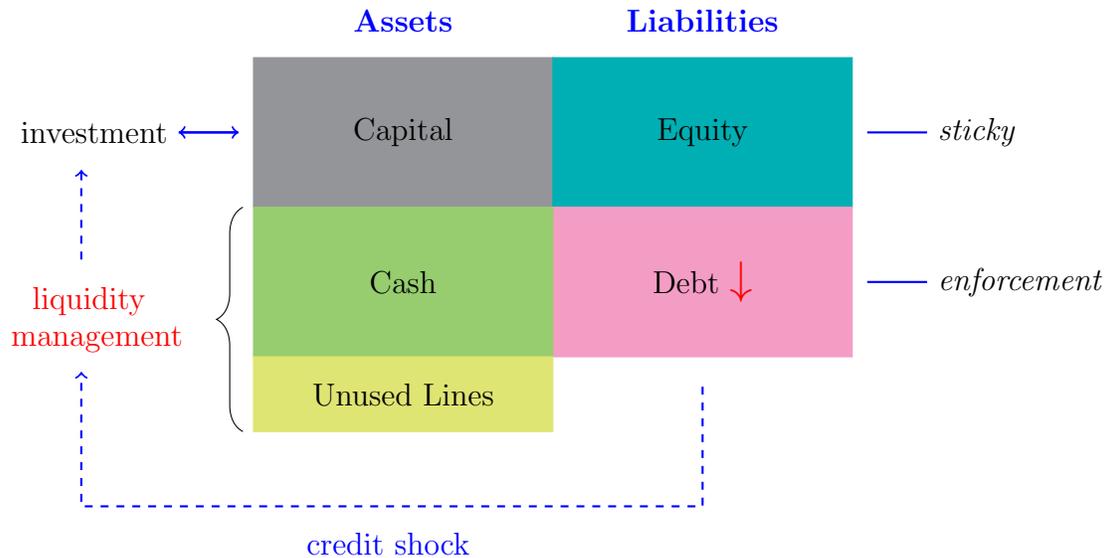

Figure 2.1: **A Sketch of the Dynamic Model**

2.1 Equity

Each firm is run by a manager who behaves in the interests of incumbent shareholders and maximizes the expected discounted present value of dividends. The firm's objective function is

$$V_t = Max : d_t + \mathbb{E}_t[\Lambda_{t+1} V_{t+1}]. \tag{1}$$

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[4]In the data, used lines of credit are debt obligations, whereas unused lines of credit remain off the balance sheet.

The variable V_t represents the firm's equity value at the beginning of time t, d_t is dividend payout during time t, and $\Lambda_{t+1} = \beta$ is the shareholders' discount factor from time t to $t+1$.

2.2 Capital

The firm does not employ labor to produce goods. Capital is the only input. At each period t, the firm can access a production technology $F(z_t, k_t)$, in which k_t is capital and z_t is a productivity shock. In line with DeAngelo, DeAngelo, and Whited (2011), I refer to z_t as investment shock to capture the idea that variations in z_t reflect the marginal productivity of capital and therefore the profitability of investment opportunities.

Capital evolves according to

$$k_{t+1} - (1-\delta)k_t = \phi(\frac{i_t}{k_t})k_t. \tag{2}$$

The variable δ is capital depreciation rate, and the function $\phi(\frac{i_t}{k_t})$ specifies the capital adjustment costs.

2.3 Long-Term Debt

The firm borrows in the form of long-term debt. I use a version of the exponential model introduced in Leland and Toft (1996), and recently used by Hackbarth, Miao, and Morellec (2006), Gourio and Michaux (2012), and among others. In each period, the firm first repays a fixed proportion of its existing debt, and then it issues new debt with repayment rate δ_b and price $p_t(\delta_b)$. Specifically, with repayment rate δ_b, one unit of debt issued at time t receives a payment δ_b at time $t+1$, a payment $\delta_b(1-\delta_b)$ at time $t+2$, and a payment $\delta_b(1-\delta_b)^2$ at time $t+3$, and so on.

As in the literature, I assume that the economy only contains a single type of maturity structure δ_b and all debtholders have the same seniority without regard to when the debt was issued. Thus, in each period t, I only need to keep track of the total amount of debt instead

of the distribution of debt with different maturity dates. Denote b_t as the debt balances at the beginning of period t, then the total amount of repayment is $\delta_b b_t$.

The dynamics of long-term debt are given by

$$b_{t+1} = (1 - \delta_b)b_t + n_t, \tag{3}$$

where, the variable b_t represents the debt balances at the beginning of period t, n_t represents the debt issuance during period t, and b_{t+1} denotes the debt balances at the end of period t. When $n_t > 0$, the firm issues new debt after repayment; when $n_t < 0$, the firm chooses to repay more than δ_b percent of existing debt.

Firms do not default in the model. However, in each period t firms are subject to the following enforcement constraints:

$$p_t b_{t+1} \leq \max \left\{ \xi_t k_{t+1}, (1 - \delta_b)p_t b_t \right\}. \tag{4}$$

The variable ξ_t represents the collateral rate of capital and it also reflects the market price of capital (credit market conditions). This enforcement constraint implies that the maximum amount of debt the firm holds at the end of period t should be either less than the value of collateral assets at the end of period t or be less than the value of non-paid debt of period t. In Appendix A, I provide a micro-interpretation for this enforcement constraint.

If debt is one-period $\delta_b = 1$, the equation (4) becomes $p_t b_{t+1} \leq \xi_t k_{t+1}$, which is the collateral constraint in Kiyotaki and Moore (1997). However, if debt is multiple-period $\delta_b < 1$, the firm may hold debt more than the value of collateral assets *occasionally*, i.e., $p_s b_{s+1} \geq \xi_s k_{s+1}$, for some s. This is due to the arrangement of long-term debt: in each period t, the firm is only obligated to repay δb_t amount of existing debt. After that, the lender cannot force the firm to repay more, even if the credit market condition (ξ_t) or the firm's credit quality ($\xi_t k_{t+1}$) decreases.

2.3.1 Pricing of Long-Term Debt

The pricing of long-term debt is straightforward. Define the debtholders' discount factor as Λ_{t+1}, the same as the shareholders', then the price of long-term debt before the tax shield is

$$\hat{p}_t = \mathbb{E}_t[\Lambda_{t+1}\delta_b + \Lambda_{t+1}(1 - \delta_b)\hat{p}_{t+1}]. \tag{5}$$

The current price of long-term debt is the sum of discounted future repayment and discounted value of non-paid debt.

Denote τ as the corporate tax rate, then the price of long-term debt after the tax shield is

$$p_t = \frac{1}{1 + (1 - \tau)(\hat{p}_t^{-1} - 1)}. \tag{6}$$

Thus, the final price of long-term debt depends on the debt repayment rate δ_b, the corporate tax rate τ, and the debtholders' discount factor Λ_{t+1}.

2.4 Unused Lines of Credit

The definition of unused lines of credit is based on the following assumption:

Assumption 2.1 *The lender honors the firm's outstanding debt, but it cannot fully commit to the unused portion of credit lines.*

In the model, the enforcement constraint (4) is occasionally binding. I define the firm's unused lines of credit as the difference between the right side and the left side of the enforcement constraint: *the total borrowing capacity minus the actual borrowing.* Denote l_t as the amount of unused lines of credit during the period t, then

$$l_t = \omega_{t+1} - p_t b_{t+1}, \tag{7}$$

where the variable ω_{t+1} is the firm's total debt capacity defined as $\omega_{t+1} = \max\{\xi_t k_{t+1}, (1 - \delta_b)p_t b_t\}$. Notice that although the second term $(1 - \delta_b)p_t b_t$ in the parentheses is pre-

committed, the first term $\xi_t k_{t+1}$ is contingent on the current credit market condition ξ_t and the size of the firm's capital assets k_{t+1}. Thus, the amount of unused credit during the period t is not fully committed, and the actual availability of credit depends on the firm's credit quality $\xi_t k_{t+1}$.
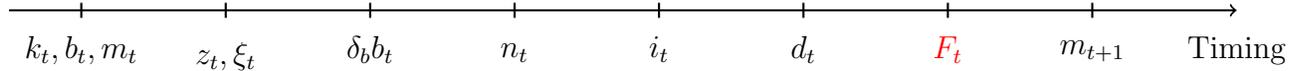
This definition of unused lines of credit is designed to capture the following lending procedures in practice. First, the firm applies for a loan. Then, the bank evaluates the firm's collateral assets. After that, the bank issues a credit line to the firm based on the collateral assets. Given the credit line, the firm decides how much to borrow now and how much to save as unused lines. Finally, on the top of above steps, the bank reevaluates the firm's collateral assets period by period and adjusts the credit limit accordingly.

The definition of unused lines of credit in this paper is not exactly the same as the one used in the literature (e.g., Holmstrom and Tirole, 1998; and Acharya, Almeida, and Campello, 2013). First, in the current setting, for simplicity, firms do not pay a commitment fee to secure a credit line, although introducing a fixed fee will not change the results. Second, credit line is not a pre-commitment contract in the sense that the availability of credit line is contingent on the firm's credit quality as well as the lender's financial health (credit market conditions). The bank only commits to the existing credit, but not to the future credit. Third, to avoid high-dimensional computation problems and to highlight the risk of losing unused credit, I do not model lines of credit as state-contingent claims as suggested by Rampini and Viswanathan (2010). Instead, I focus on the timing of credit line usage: given the access to a credit line with its limit depends on the firm's credit quality and the bank's willingness to supply funds, the firm makes choices about how much to draw down right now and how much to save as unused credit for future needs.

2.5 Cash

The timing of a firm's decision is as follows. In each period t, the firm starts with capital assets k_t, debt outstanding b_t, and cash holdings m_t. Then the firm observes the period t's

investment condition z_t, and credit condition ξ_t. After that, the firm first repays δ_b percent of its debt outstanding b_t, and then decides the amount of new debt issuance n_t, investment i_t, dividend payout d_t, and finally cash savings m_{t+1}.

$$
\begin{array}{ccccccccc}
k_t, b_t, m_t & & z_t, \xi_t & & \delta_b b_t & & n_t & & i_t & & d_t & & F_t & & m_{t+1} & & \text{Timing}
\end{array}
$$

However, the firm's revenues $F(z_t, k_t)$ are realized at the end of period t, while payments need to be made at the beginning of the period. Thus, at the beginning of period t the firm faces a cash-in-advance constraint (liquidity constraint): the sources of funds must be sufficient to support the uses of funds,

$$
\underbrace{m_t}_{\text{cash holdings}} + \underbrace{p_t n_t}_{\text{debt issuance}} \geq \underbrace{\delta_b b_t}_{\text{debt repayment}} + \underbrace{i_t}_{\text{investment}} + \underbrace{d_t}_{\text{payout}}. \tag{8}
$$

The left side of equation (8) includes the financing sources: cash holdings and debt issuance; and the right side of equation represents the financing needs: debt repayment, investment, and dividend payout. In this section, I assume that the firm cannot issue equity (or pay negative dividend). That is, $d_t \geq 0$. But I will relax this assumption in the quantitative studies.

To sum up, given the rigidities of adjusting the financing needs: mandatory debt repayment, non-negative dividend payout, and capital adjustment costs, to satisfy the period t's cash-in-advance constraint, in period $t - 1$ the firm has two choices: either to accumulate cash or to reserve unused credit.

2.5.1 Precautionary Cash

All the firm's decisions are subject to the budget constraint:

$$
F(z_t, k_t) + m_t + p_t n_t = p_t^m m_{t+1} + \delta_b b_t + i_t + d_t, \tag{9}
$$

where the variable p_t^m is the price of cash. After combining this budget constraint with the cash-in-advance constraint, the cash-in-advance constraint can be rewritten as

$$p_t^m m_{t+1} \geq F(z_t, k_t). \tag{10}$$

This cash-in-advance constraint is occasionally binding in the model, and when it does not bind, I define the precautionary cash as

$$c_t = p_t^m m_{t+1} - F(z_t, k_t). \tag{11}$$

When the precautionary cash $c_t > 0$, the cash balances carried into the next period are larger than the cash generated from cash flows in the current period.

2.6 The Firm's Optimization Problem

To sum up the model, recall a firm's balance sheet.

Assets	Liabilities
Capital k_{t+1}	Equity V_t
Cash m_{t+1}	Debt b_{t+1}

The firm considers three tradeoffs. (1) On the assets side of the balance sheet, the firm makes choices between cash and capital. Although cash earns a lower rate of return than capital, cash is more liquid than capital since the firm faces capital adjustment costs. (2) On the liabilities side, the firm prefers debt finance to equity finance given the tax shield of debt. However, debt finance is limited by the enforcement constraints. (3) Between the assets side and the liabilities side, cash is not negative debt because of the maturity differences. While cash helps to smooth the funds from long-term borrowing between periods, holding cash incurs an opportunity cost.

The above three tradeoffs imply two motivations of holding liquidity. (a) Later-borrowing

motive: given the rigidities of adjusting the financing needs, the firm chooses to keep distances from the borrowing limit and to save unused credit to hedge future credit contractions. (b) Pre-borrowing motive: given the maturity mismatch between cash and debt, the firm also chooses to borrow more with long-term debt and save funds in cash, and it does so also as insurance against future credit contractions.

Let $V(k, m, b; s)$ be the firm's equity value at the beginning of period t, where s represents the exogenous state variables z and ξ. The firm's problem $\mathcal{P}$ can be written down recursively:

$$V(k, m, b; s) = \max_{k', m', b', d} \left\{ d + \mathbb{E}[\Lambda' V(k', m', b'; s')] \right\}$$

subject to:

$$p^m m' \geq F(z, k) \tag{12}$$

$$F(z, k) + m + pn = p^m m' + \delta_b b + i + d \tag{13}$$

$$d \geq 0 \tag{14}$$

$$k' - (1 - \delta)k = \phi\left(\frac{i}{k}\right)k \tag{15}$$

$$b' = (1 - \delta_b)b + n \tag{16}$$

$$pb' \leq \max\left\{ \xi k', (1 - \delta_b)pb \right\} \tag{17}$$

The manager maximizes the equity value of the firm subject to six constraints: the cash-in-advance constraint, the budget constraint, the non-negative dividend constraint, the capital accumulation equation, the dynamics of long-term debt, and the enforcement constraint. I summarize two propositions of the firms' problem and their proofs are in Appendix B.

Proposition 2.1 *If the debt repayment rate $\delta_b = 1$, the cash-in-advance constraint is always binding and precautionary cash $c_t = 0$.*

Proposition 2.2 *There exists a cutoff $\delta_b^* < 1$ such that: if $\delta_b < \delta_b^*$, the cash-in-advance constraint is occasionally binding and precautionary cash $c_t > 0$.*

The economic intuition of these two propositions is as follows. When the debt repayment rate $\delta_b = 1$, cash is the same as negative debt. As a result, firms do not hold precautionary cash because they can always save interest expenses by using cash to reduce debt. However, when the repayment rate $\delta_b < \delta_b^*$, the benefit of holding cash can be larger than the direct costs holding cash. This is because, if the firm borrows with long-term debt today and saves the funds in cash, it can ensure itself from future credit contractions.

3 Model Solution

The model is solved numerically by the projection method, and the numerical procedures are discussed in Appendix C.

3.1 Normalized Optimization Problem

To keep the model computation tractable, I detrend all firm-level variables by capital k, using the assumption of linear technology $F(z, k) = zk$. After detrending, the firm's optimization problem becomes:

$$\tilde{V}(\tilde{m}, \tilde{b}; s) = \max_{g', \tilde{m}', \tilde{b}', \tilde{d}} \left\{ \tilde{d} + g' \mathbb{E}[\Lambda' \tilde{V}(\tilde{m}', \tilde{b}'; s')] \right\}$$

subject to:

$$p^m \tilde{m}' g' \geq z \tag{18}$$

$$z + \tilde{m} + p\tilde{n} = p^m \tilde{m}' g' + \delta_b \tilde{b} + \tilde{i} + \varphi(\tilde{d}) \tag{19}$$

$$g' - (1 - \delta) = \phi(\tilde{i}) \tag{20}$$

$$p\tilde{b}' g' = (1 - \delta_b) p\tilde{b} + p\tilde{n} \tag{21}$$

$$p\tilde{b}' g' \leq \eta \xi g' + (1 - \eta)(1 - \delta_b) p\tilde{b} \tag{22}$$

where, $g' = k'/k$ is the growth rate of capital, $\tilde{m} = m/k$, $\tilde{b} = b/k$ are detrended state variables, and $\tilde{x} = x/k$ are other detrended variables. In this normalized optimization problem, there are only two state variables left, the cash-to-capital ratio $\tilde{m}$ and the debt-to-capital ratio $\tilde{b}$, and this makes the numerical computation much easier.

To make the model closer to explaining the real data, in the quantitative analysis I relax the assumption of non-negative dividend payout. Instead of imposing the non-negative dividend constraint (14), I introduce a smooth equity adjustment cost function $\varphi(\tilde{d})$ in the budget constraint (19) to capture the frictions in adjusting equity. For numerical purposes, I also replace the debt enforcement constraint (17) with its stochastic version, the equation (22), in which I take away the term 'max' and introduce a refinancing probability η. In Appendix A, I show that these two enforcement constraints (17) and (22) are equivalent.

3.2   Functional Forms

In this section, I discuss the functional forms of capital and equity adjustment cost, and also the assumptions on the process of the shocks.

The capital adjustment cost function $\phi(\frac{i_t}{k_t})$ is given by

$$\phi(\frac{i_t}{k_t}) = \frac{a_1}{(1 - \zeta)}(\frac{i_t}{k_t})^{1-\zeta} + a_2. \tag{23}$$

This function is concave in i_t and decreasing in k_t. The concavity of $\phi(\cdot)$ captures the idea that it is more costly to change the capital stock quickly. The value $1/\zeta$ is the elasticity of investment-capital ratio with respect to the marginal q. The parameters $a_1 = \delta^\zeta$ and $a_2 = \frac{-\zeta}{1-\zeta}\delta$ are set so that in the steady state the capital adjustment cost is zero and the marginal q is equal to one. This adjustment cost function has been widely used in the investment and production-based asset pricing literature. See, for example, Jermann (1998).

As in Jermann and Quadrini (2012), the equity adjustment cost function $\varphi(\tilde{d})$ is given by

$$\varphi(\tilde{d}) = \tilde{d} + \kappa(\tilde{d} - \tilde{d}_{target})^2, \tag{24}$$

where κ is a parameter measuring the rigidities of adjusting equity, and $\tilde{d}_{target}$ is a long-term targeted dividend payout ratio calibrated to match the average dividend payout ratio in the data. This equity adjustment cost function implies: if the firm pays dividend at its long-term target ratio, it does not occur any cost; however, if the firm deviates from its long-term target ratio, it needs to pay an additional cost; and particularly, if the firm wants to pay negative dividend, that is, to issue equity, it needs to pay a cost that is convex in the amount of issuance.[5]

3.2.1 Shocks

The productivity shock z_t follows a first order autoregressive process

$$\log(z_t) = \mu_z + \rho_z \log(z_{t-1}) - \sigma_z^2/2 + \sigma_z u_t, \tag{25}$$

where u_t is $i.i.d$ innovation with standard normal distribution $N(0,1)$. The variable μ_z refers to the drift of the process $\log(z_t)$, ρ_z refers to the persistence, and σ_z refers to the volatility. The model allows large-scale shocks. Thus, given the log-normal specification, the impact of volatility σ_z on the conditional expectation of the productivity shock z_t can not be ignored. Following Gilchrist, Sim, and Zakrajsek (2010), I subtract the term $\sigma_z^2/2$ in equation (25) to remove this second-order impact. Since u_t is distributed normally, simple algebra shows $E(e^{-\sigma_z^2/2+\sigma_z u_t} \mid \sigma_z) = 1$. Thus, increases in the volatility σ_z represent a mean-preserving spread to the conditional distribution of productivity z_t. For numerical purposes, I approximate the AR(1) process in equation (25) with a finite-state Markov chain.

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[5]There are several interpretations for why there are rigidities through equity adjustment costs. (1) Equity issuance cost. The firm pays an additional cost when it issues equity to shareholders. And the cost is convex in the sense that underwriting fees display increasing marginal cost in the size of the offering, e.g., Altinkilic, and Hansen (2000). (2) Dividend smoothing. The firm has a long-term targeted payout ratio, and it actively adjusts the payout ratio when the ratio was deviated from the target. (3) Dividend tax. Shareholders need to pay income tax on dividends they received.

The refinancing probability η_t in equation (22) is stochastic, and I refer to it as financing shock or credit shock. Similar to the productivity shock, the financing shock η_t follows a AR(1) process:

$$\eta_t = \overline{\eta} + \rho_\eta(\eta_{t-1} - \overline{\eta}) + v_t, \tag{26}$$

where the variables $\overline{\eta}$ and ρ_η are respectively the mean and the persistence of process η_t. The variable v_t is $i.i.d$ innovation with distribution $N(0, \sigma_\eta^2)$, and σ_η refers to the volatility of the financing shock. Also, I approximate this AR(1) process with a finite-state Markov chain in the quantitative analysis.

4 Estimation

In this section I conduct a structural estimation of the model. I start by describing the data, and then discuss the estimation procedures and results.

4.1 Data

I obtain data from the Compustat annual files except for the variable unused lines of credit. Data about unused lines of credit are not available in Compustat, and most existing research manually collects the credit line data from firms' SEC 10-K files (e.g., Sufi, 2009; Yun, 2009). For this study, I use the data from the Capital IQ database, which contains a large sample of unused lines of credit from 2002 to 2010. In Capital IQ, the variable unused lines of credit refers to *total undrawn credit*, which includes undrawn revolving credit, undrawn commercial paper, undrawn term loans, and other undrawn credit. See Filippo and Perez (2012) for a detailed description of total undrawn credit in the Capital IQ database.

Following the literature, I exclude financial firms and utilities with SIC codes in the intervals 4900-4949 and 6000-6999, and firms with SIC codes greater than 9000. I also exclude firms with a missing value of book value of assets, debt, cash, unused line, investment, payout, and cash flow. I winsorize all variables at the 2.5% and 97.5% percentiles to limit

the influence of outliers. All variables are deflated by the Consumer Price Index. The final sample for the structural estimation is a balanced panel of 1,999 firms over 9 years from 2002 to 2010. Table 1 provides the definitions and sources of the variables used in the structural estimation.

4.2 Parameters and Target Moments

The choice of model parameters is done by the simulated method of moments (SMM). The basic idea of SMM is to choose the model parameters so that moments generated by the model are as close as possible to the corresponding real data moments. The detailed estimation steps and identification strategies are discussed in Appendix D.

The first panel in Table 2 lists the 14 target moments used in the estimation. The choice of target moments is based on the following principle: First, to estimate most of the parameters in the model, I choose the mean and the standard deviation of all six key variables in the model, except the standard deviation of investment which is replaced by the autocorrelation of investment.[6] Second, to identify the persistence of shocks, I also include the autocorrelation of cash and the autocorrelation of cash flows.

The second panel in Table 2 lists the 10 parameters estimated by the simulated method of moments. They are the drift, the persistence, and the standard deviation of productivity shock μ_z, ρ_z, σ_z; the persistence and the standard deviation of credit shock ρ_η, σ_η; the capital depreciation rate δ; the collateral rate ξ; the equity rigidity parameter κ; the capital adjustment parameter ζ; and the price of cash p^m.

The third panel in Table 2 lists the 3 parameters that are calibrated directly form the data. I set the subjective discount rate $\beta = 0.97$ such that the implied one-period interest rate is approximately equal to the average of the real interest rate 1.03 over sample period 2002-2010. I use the effective corporate tax rate $\tau = 0.15$. The debt repayment rate $\delta_b = 0.31$

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[6]The model is unable to match the standard deviation of investment. However, as shown in the robustness check of the model, including the moment of the standard deviation of investment does not change the main estimation results.

is set to match the average long-term debt retirement rate in the data.

4.3   Estimation Results

Table 2 reports the estimation results. The model matches the data quite well, except for three moments: the mean of unused lines of credit, the standard deviation of cash, and the standard deviation of cash flows. The model is unable to match those three moments for the following reasons: To generate a higher standard deviation of cash or cash flows, the model requires a lower capital adjustment cost. However, on the other hand, the model needs a higher capital adjustment cost to match the level of unused lines of credit. There is thus a tension between matching the level of the firm's liquidity holdings and matching the standard deviation of the firm's real decisions.

The second panel in Table 2 shows the estimated value of model parameters. The estimated standard deviation of productivity shock is 0.466, and the persistence is 0.421. Compared to the literature (e.g., DeAngelo, DeAngelo, and Whited, 2011), the estimated standard deviation of productivity shock is higher while the persistence is lower. The reason is that the data I considered includes the recent financial crisis. Thus, it is reasonable to find that firms' decisions are more volatile in my estimation.

The estimated standard deviation of credit shock is 0.457, and the persistence is 0.410. Since these two estimates of credit shocks are new in the literature, it is useful to explain the magnitude of the shocks. Suppose that during normal periods the firm can refinance its debt with a probability of 50%, then the estimated magnitude means that: if the firm is hit by the worst credit shock, it cannot refinance its debt anymore; if the firm receives the best credit shock, it can refinance its debt with probability 100%.

The estimated collateral rate is 0.456, which implies that the firm can borrow up to 45.6% of its capital assets. The equity rigidity parameter κ is 0.533, which means that for a firm with $10 book value of assets, if the firm issues $1 in equity, its issuance cost is 5% of the proceeds; if the firm issues $2 in equity, its issuance cost doubles to 10% of the proceeds.

That is, the equity issuance cost is convex. The capital adjustment cost ζ is 0.779, which implies that the elasticity of investment-capital ratio with respect to the marginal q is 1.28.

The estimated price of cash p^m is 0.975, which is higher than the price of one-period debt 0.97. The difference between the price of cash and the price of one-period debt can be interpreted as the opportunity cost of holding cash, or the liquidity premium. In terms of return, the interest rate earned on cash is $1/0.975 \approx 1.026$, while the interest rate paid on debt is 1.03. Thus, the estimated liquidity premium is about 40bps.

4.4 Counterfactual Exercises

Given the estimated model, I conduct a counterfactual exercise to identify which types of risks are better in explaining the firm's liquidity policies: financing risk or investment risk. I first simulate the model using the estimated parameters to generate benchmark moments, and then I remove the productivity/investment shock from the model and simulate a new set of moments as a comparison. Similarly, I also remove the financing shock from the model and simulate another set of moments.

Table 3 shows the results of the experiment. First, compared to the data (column one), the benchmark model (column two) explains 67% precautionary cash and 47% unused lines of credit as observed in the data.[7] Second, the model with only financing shock (column three) generates 63% precautionary cash and 33% unused lines of credit as observed in the data. Third, the model with only productivity shock (column four) generates 4% precautionary cash and 10% unused lines of credits as observed in the data. Thus, this counterfactual exercise implies that the financing risk is the driving force for firms to hold liquidity, particularly for the precautionary cash. Furthermore, the precautionary cash generated by the financing risk accounts for $\frac{0.057}{0.189} \approx 30\%$ of total cash holdings in the data.

A second counterfactual exercise I conduct is to examine the value of holding liquidity. I run the following three experiments. In the first experiment, I shut down both the channel

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[7] According to the model, the precautionary cash of period t is defined as cash holdings at the beginning of period $t + 1$ minus cash flows at the end of period t.

of holding precautionary cash and the channel of holding unused lines of credit. That is, I assume that both the cash-in-advance constraint and the debt enforcement constraint are always binding in the model. In the second experiment I shut down only the channel of holding unused lines of credit, and in the third experiment I shut down only the channel of holding precautionary cash. Finally, I compare the firm's performances under these three experiments to the benchmark model.

When comparing the firm's performances under those three experiments, I set the value of capital and the value of debt in the experimental models to be the same as in the benchmark model.[8] Thus, firms in those experiments are identical expect for having different channels of holding liquidity.

Table 4 shows the results of the above experiments. Compared to the benchmark model, in the model without any liquidity holdings (Model 1), the equity value decreases by $(0.755 - 0.553)/0.755 \approx 27\%$. The economic explanation behind this result is simple: in the case of no liquidity holdings, the firm needs to adjust equity or capital very frequently, which in turn causes large value losses in the presence of adjustment costs.

In the second model (Model 2), the channel of holding unused lines of credit is closed, and therefore the firm holds more precautionary cash as substitutes for unused lines. However, the equity value barely changes. This implies that the firm is doing a good job in substituting unused lines of credit by cash holdings.

In the third model (Model 3), the firm is not allowed to hold precautionary cash. Intuitively, in this case the firm increases unused lines of credit as substitutes for cash. Interestingly, however, the shareholder value decreases by $(0.755 - 0.692)/0.746 \approx 8\%$, which is smaller than that of Model 1, but larger than that of Model 2. Thus, this experiment suggests that unused lines of credit cannot be perfect substitutes for cash holdings.

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[8]This can be done by re-calibrating the mean of productivity shock and financing shock such that the simulated mean of capital and debt are the same as in the benchmark model. However, the persistence and the volatility of shocks remain the same.

4.5   Comparative Statics of Debt Maturity

In this section, I study the comparative statics of the firm's cash holdings and financing dynamics with respect to the exogenous changes of debt maturity.

The top panel in Figure 1 shows the firm's cash-to-assets ratio as a function of debt maturity. The solid line represents the model, while the dashed line represents the data. As can be seen from the graph, the firm's cash-to-assets ratio decreases with the maturity of debt, both in the data and in the model. This is because long-term debt provides more stable funds than short-term debt, and hence, when the maturity of debt is long, firms need less liquidity to hedge against refinancing risks. Thus, this result is consistent with the finding of Harford, Klasa, and Maxwell (2014) that firms had increased their cash holdings to mitigate the refinancing risk caused by shortening debt maturity over the 1980-2008 period.

Moreover, the model-predicted cash-to-asset ratio is quite close to the one observed in the data. Notice that in the model there is only a single type of debt maturity, while in the data there are multiple structures of debt maturity; thus, the comparison here between the model and the data can be taken as an out-of-sample test.

A key implication of the model is that firms have incentives to issue long-term debt and save funds in cash to hedge against future credit contractions. Further, this motive of holding cash increases with the maturity of debt. Thus, the model predicts that the correlation between cash accumulation and debt issuance is positive, and the strength of the correlation increases with the maturity of debt.

The bottom panel in Figure 1 depicts the correlation between cash accumulation and debt issuance as a function of debt maturity. The solid line represents the model, while the dashed line represents the data. As shown in the figure, both in the data and in the model, the correlation is positive and increases in the maturity of debt. Thus, the model's key mechanism is supported by the data.

However, the predicted correlation is much higher than the one observed in the data. The explanation for this discrepancy is as follows: In the model there are no frictions to prevent

firms from saving cash out of debt issuance and therefore the correlation between cash saving and debt issuance is strong, while in the data there are restrictions on the use of the proceeds from debt issuance. Another caveat is that, in the data, I use the maturity of outstanding debt to approximate the maturity of new issued debt, but in the model those two are the same given that there is only a single type of debt structure.

5   Model Implications

In this section, I simulate the model to investigate the firm's response to different types of shocks. I simulate three types of shocks to mimic three hypothetical scenarios: credit crisis, credit boom, and credit uncertainty. Since the model allows for large-scale shocks, the firm's responses to shocks are not linearized around the steady state; instead, they are the actual nonlinear transition paths after the shocks. When calculating the transition paths, I use the previous estimated structural parameters.

5.1   Credit Crisis

Figure 2 shows the firm's transition paths after a negative credit shock/financing shock. Panel A plots the process of the negative credit shock. During the first 10 periods, the firm can access a lender with probability 0.5. At the period of 11, there is a negative credit shock, which reduces the probability of financing to zero. Here, the size of the shock is taken from the previous estimated value of the shock. From period 12 and so on, the financing opportunity recovers according to the estimated AR(1) process of the shock.

Panel B depicts the transition paths of the debt-to-assets ratio and cash-to-assets ratio, and Panels C to F describe the transition paths of the unused line-to-assets ratio, precautionary cash-to-assets ratio, investment-to-assets ratio, and net payout-to-assets ratio, respectively.

As can be seen in Panel B, after a negative credit shock, the firm reduces debt as well as

cash holdings. This is because a negative credit shock temporally freezes the firm's access to credit markets. The firm needs to reduce external borrowing and to rely on internal finance. At the same time, as shown in Panels C and D, the firm reduces its liquidity holdings dramatically: both unused lines of credit and precautionary cash hit the zero bound when the firm has trouble accessing the credit market.

However, as shown in Panel E, the firm does not cut much of its investment because of its sizable liquidity holdings. This is consistent with the finding of Duchin, Ozbas, and Sensoy (2010) that firms used their cash holdings as buffers to smooth investment at the onset of the credit crisis of 2007-2008. Finally, the firm also reduces its net payout after the negative credit shock, which is shown in Panel F.

Figure 3 shows the sensitivity of the firm's transition paths with respect to the debt repayment rate δ_b, after a negative credit shock. I consider three cases of debt repayment rate: $\delta_b = 0.10$, $\delta_b = 0.20$, and $\delta_b = 0.33$, which represent 10-Year, 5-Year, and 3-Year debt maturity. As shown in Figure 3, firms with 10-Year debt maturity respond relatively less to the negative credit shock than firms with 5-Year or 3-Year debt maturity. This implies that long-term debt (with cash) provides insurance against credit shocks.

5.2   Credit Boom

Figure 4 shows the firm's transition paths after a positive credit shock. Panel A plots the process of the positive credit shock. Panel B depicts the transition paths of debt and cash, and Panels C to F depict the transition paths of unused lines of credit, precautionary cash, investment, and net payout, respectively.

Two take-away results from Figure 4 are (1) although a credit boom provides better financing opportunities, the firm does not choose to borrow all the available credit. Instead, the firm keeps most new credit as unused lines, which is shown in Panel C; (2) within the amount of debt the firm has borrowed during the credit boom, the firm saves some of the proceeds as precautionary cash. To draw a comparison between the new borrowing and the

new cash savings, I also plot the changes in borrowing (solid line) in Panel D. As can be seen from Panel D, some of the new borrowing has been saved as precautionary cash.

Those two results demonstrate the precautionary motive of holding liquidity: even if firms are in favorable market conditions, they are still cautious about the possibility of future adverse financing conditions.

5.3 Credit Uncertainty

Figure 5 depicts the firm's transition path after a credit uncertainty shock, that is, after an increase in credit volatility. In this exercise, I change only the second moment of credit shock, while leaving the expected level of credit shock unchanged. Panel A plots the change of the credit volatility. Panels B to F depict the transition path for each variable.

As shown in Panel B, when credit volatility increases, the firm increases cash holdings immediately, but cuts debt one period after the shock. This is because under the setting of long-term debt, reducing the current debt would shrink the next period's borrowing capacity and hence the firm is hesitant to cut debt.

Panel C shows that after the credit uncertainty shock, the firm first reduces unused lines of credit and then rebuilds them. Panel D shows that the firm increases precautionary cash immediately after the shock. The economic interpretation is as follows. When credit uncertainty increases, the firm wants to prepare more liquidity for the future, through either cash or unused lines of credit. However, the increase in credit uncertainty also raises the chance that very bad credit conditions will prevail in the future, which in turn makes reserving unused credit lines less reliable than stockpiling cash since the access to future credit lines depends on future credit conditions. As a result, when credit uncertainty increases, the firm wants to shift the funds under risky credit lines into safer cash holdings. This offers a plausible explanation for why firms wanted to draw down credit lines and stockpile cash during the recent financial crisis (e.g., Ivashina and Scharfstein, 2009) — because of the increases in credit uncertainty.

Panel E shows that the level of investment declines after the credit uncertainty shock, and Panel F shows that the firm temporally cuts dividend payout to help build up cash reserves.

6   Model Robustness

In this section, I check the model robustness by adding the investor's stochastic discount factor. Following the literature, I specify the investors' stochastic discount factor as[9]

$$\Lambda_{t+1} = \beta(\frac{z_{at+1}}{z_{at}})^{-\gamma}, \tag{27}$$

where the variable β is the subjective discount rate, γ is the risk aversion coefficient, and z_{at} denotes aggregate productivity level at time t.

This discount factor implies that the investors have a higher valuation on firms that pay out dividends (repay debt) in an economic downturn. To capture the aggregate business cycle fluctuations in the data, as in Warusawitharan and Whited (2013), I specify two aggregate states, an expansionary state $z_{aH} = 1.01$ and a recessionary state $z_{aL} = 0.97$, with transition matrix $\Gamma = \begin{bmatrix} 0.71 & 0.29 \\ 0.75 & 0.25 \end{bmatrix}$. I set the investor's risk aversion coefficient $\gamma = 2$. I also assume that the aggregate productivity shock z_{at} is independent of the firm-level productivity shock z_t specified in Section 2.2. Thus, the firm's total productivity can be written as $\hat{z}_t = z_{at}z_t$.

6.1   Estimation Results with Stochastic Discount Factor

Table 6 reports the estimation results when the stochastic discount factor is included. Compared to the results in Table 2, the model-predicted cash-to-assets ratio in Table 6 becomes lower while the unused lines-to-assets ratio is higher. This is because under the setting of stochastic discount factor, firms are more risk averse toward borrowing and hence they bor-

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[9]See, for example, Zhang (2005). If the consumer side of the economy can be described by one representative agent with power utility and a risk aversion coefficient γ, then the pricing kernel can be written as $\Lambda_{t+1} = \beta(\frac{C_{t+1}}{C_t})^{-\gamma}$. Moreover, if the aggregate consumption C_t is linear in the aggregate productivity z_{at}, I have the pricing kernel in the Equation (27).

row less and hold more unused lines of credit. Further, since the firm borrows less, the cash savings out of borrowing become less too. And this explains why the cash-to-assets ratio decreases.

Table 7 reports the results of the counterfactual exercise of examining the role of shocks. As can be seen from the second and third column of the table, conditional on the stochastic discount factor, financing risk is still the driving force for the firm's liquidity holdings. The fourth column shows that without the stochastic discount factor, cash increases while unused lines of credit decrease. This is consistent with the above observations that higher risk aversion increases unused lines of credit but reduces precautionary cash.

To sum up, the two take-away results are (i) a higher degree of the shareholders' risk aversion implies a relatively stronger later-borrowing motive of holding unused lines of credit but a relatively weaker pre-borrowing motive of saving precautionary cash; (ii) conditional on the stochastic discount factor, financing risk is still the driving for firms to hold liquidity.

7   Conclusion

In this paper, I quantify a new motive of holding cash through the channel of financing risk. I show that if the access to future credit is risky, firms want to issue long-term debt right now and save the funds in cash, and they do so in order to secure the current credit capacity for the future. The main results are (i) the liquidity premium of holding cash is about 40bps; (ii) the value of holding cash is around 8% of shareholder value; (iii) financing risk, instead of investment risk, is the driving force for firms to hold liquidity; (iv) increases in credit uncertainty induce firms to draw down credit lines and to hold the proceeds in cash.

An implication of the model is that firms manage liquidity jointly with capital structure decisions: On the one hand, to maintain the option to borrow in the future, firms borrow less in the current period and hold unused credit lines. On the other, to hedge the risk of losing the option to borrow, firms increase leverage today and save cash for future needs.

A A Micro-Interpretation of the Enforcement Constraint

In this appendix, I provide a micro-interpretation of the enforcement constraint (4) used in Section 2.3:

$$p_t b_{t+1} \leq \max \left\{ \xi_t k_{t+1}, (1 - \delta_b) p_t b_t \right\}. \tag{4}$$

I will keep the variable ξ_t as a constant collateral rate and introduce a new variable η_t to capture the credit risk. I assume that firms need to search for lenders when they decide to tap the credit market. The probability of finding a lender depends on the financing condition. When the financing condition is η_t, the firm can find a lender with probability η_t, and with probability $1 - \eta_t$ the firm cannot get financed. Here, the inverse of the financing condition $1/\eta_t$ can be interpreted as a measure of credit market tightness. Thus, the probability of finding a lender decreases with the credit market tightness. The variable η_t can also be interpreted as a measure of the lender's financial health.

In the case that the firm finds a lender, it can issue new debt. However, due to the firm's limited commitment on its debt obligations, the issuance of debt is subject to collateral constraints: when the lender provides loans to the firm in the current period, it wants to make sure that in the next period the liquidation value of the firm's assets is larger than the value of the firm's outstanding debt so that the firm does not default. To be specific, if the firm has capital assets k_{t+1} at the end of period t, its total credit limit during period t would be ξk_{t+1}, in which I assume that the assets in place $(1 - \delta) k_t$ and the new investments i_t have the same collateral rate ξ. As a result, the firm's debt outstanding b_{t+1} at the end of period t should satisfy: $p_t b_{t+1} \leq \xi k_{t+1}$. The value of total debt should be less than or equal to the value of collateral assets.

In the case that the firm does not find a lender, it cannot issue new debt. However, according to the arrangement of long-term debt, the lender cannot force the firm to repay more than δ_b percent of its debt outstanding, without regard to the financing conditions. In this case, the borrowing constraint would be $p_t b_{t+1} \leq (1 - \delta_b) p_t b_t$, where $(1 - \delta_b) p_t b_t$ is the

value of non-paid debt.

To sum up, during the period t the firm is subject to the following revised enforcement constraint, which is a stochastic version of the constraint (4):

$$p_t b_{t+1} \leq \omega_{t+1}, \tag{28}$$

where $p_t b_{t+1}$ is the value of debt outstanding and ω_{t+1} is the firm's total debt capacity as follow:

$$\underbrace{\omega_{t+1}}_{\text{debt capacity}} = \underbrace{\eta_t}_{\text{refinancing prob.}} \underbrace{\xi k_{t+1}}_{\text{collateral asset}} + (1 - \eta_t)\underbrace{(1 - \delta_b)p_t b_t}_{\text{non-paid debt}}. \tag{29}$$

The firm's debt capacity depends on the financing condition η_t, the value of collateral assets ξk_{t+1}, and the value of non-paid debt $(1 - \delta_b)p_t b_t$.

Accordingly, the firm's unused lines of credit during period t would be defined as:

$$l_t = \eta_t \xi k_{t+1} + (1 - \eta_t)(1 - \delta_b)p_t b_t - p_t b_{t+1}. \tag{30}$$

A.1 The Feature of Enforcement Constraint

There are three remarks on the enforcement constraint (28). First, as can be seen from equation (29), a better financing condition η_t eases the enforcement constraint, a lower repayment rate δ_b relaxes the enforcement constraint, and a larger the last period's debt outstanding b_t also relaxes the current period's enforcement constraint.

Second, if the repayment rate $\delta_b = 1$, the enforcement constraint (28) becomes $p_t b_{t+1} \leq \eta_t \xi k_{t+1}$. In this case, consider the constraint in period $t + 1$: $p_{t+1} b_{t+2} \leq \eta_{t+1} \xi k_{t+2}$. Suppose there is a decline of the financing opportunity η_{t+1}. Then, as a result, the firm has to reduce its debt outstanding b_{t+2}, which in turn forces the firm to cut either investment or dividend. Thus, if it is costly for the firm to adjust capital or equity quickly within a period, concerns about period $t+1$'s credit contractions would induce the firm to borrow less and save unused debt capacity in period t.

Third, if the repayment rate $\delta_b < 1$, the second term $(1 - \eta_t)(1 - \delta_b)p_t b_t$ on the right side of equation (29) comes up. In this case, the firm would have incentives to borrow more to hedge against future credit contractions. This is because an additional unit of borrowing Δb_t in period $t - 1$ would relax the enforcement constraint in period t by $(1 - \eta_t)(1 - \delta_b)p_t\Delta b_t$ dollars. Further, if it is costly to adjust capital or equity quickly, the firm would temporally save the funds from the long-term borrowing in cash.

A.2 The Trade-off Between Cash and Unused Lines of Credit

Let's compare the efficiency of cash and unused lines of credit in providing future liquidity. Denote p_t^m by the price of cash at period t, then one additional dollar of cash in period $t - 1$ leads to $\frac{1}{p_{t-1}^m}$ dollars of available funds in period t. Similarly, suppose the price of debt at period t is p_t, then one additional dollar of unused lines of credit in period $t - 1$ leads to $\frac{\eta_t(1-\delta_b)p_t+\delta_b}{p_{t-1}}$ dollars of available funds in period t. The term $\frac{\eta_t(1-\delta_b)p_t+\delta_b}{p_{t-1}}$ depends on the credit market condition η_t, and it contains two parts. The first part $\frac{\eta_t(1-\delta_b)p_t}{p_{t-1}}$ represents the increase in debt issuance, and the second part $\frac{\delta_b}{p_{t-1}}$ is the reduction in debt repayment.

The firm makes a trade-off between low-return cash $\frac{1}{p_{t-1}^m}$ and contingent unused lines of credit $\frac{\eta_t(1-\delta_b)p_t+\delta_b}{p_{t-1}}$. And this trade-off depends on the maturity of debt ($\frac{1}{\delta_b}$), the opportunity cost of holding cash ($p_{t-1}^m - p_{t-1}$), and the future financing condition (η_t).

If $\delta_b = 1$, $\frac{\eta_t(1-\delta_b)p_t+\delta_b}{p_{t-1}} = \frac{1}{p_{t-1}} > \frac{1}{p_{t-1}^m}$, which means that unused lines of credit are less costly than cash holdings in providing liquidity. However, if $\delta_b < 1$, unused lines of credit become contingent, and cash can be more efficient than credit lines in accumulating liquidity in some states, particularly when future credit market conditions become worse: it is more likely that $\frac{1}{p_{t-1}^m} > \frac{\eta_t(1-\delta_b)p_t+\delta_b}{p_{t-1}}$ when η_t becomes smaller.

The above results can also be explained by the features of long-term debt. With long-term debt, one unit of debt issuance in period $t - 1$ not only brings in p_{t-1} dollars of proceeds in period $t - 1$, but also relaxes the period t's enforcement constraint by $(1 - \eta_t)(1 - \delta_b)p_t$ dollars. The relaxation of enforcement constraint then increases the available credit the firm

can use in period t. On the other hand, one unit of debt retirement in period $t-1$ only leads to $\eta_t(1-\delta_b)p_t + \delta_b$ dollars of available funds in period t. This is because that the financing opportunity is stochastic, if the firm does not borrow now, it may lose the chance to borrow in the future.

B   Proofs

The firm's problem after detrending is (I remove the tilde on the detrended variables):

$$V(m, b; s) \; = \; \max_{g', m', b', d} \left\{ d + \beta g' \mathbb{E}[(\frac{z_a'}{z_a})^{-\gamma} V(m', b'; s')] \right\}$$

subject to:

$$p^m m' g' \geq z_i z_a \tag{31}$$

$$z_i z_a + m + pn = p^m m' g' + \delta_b b + i + \varphi(d) \tag{32}$$

$$g' = (1 - \delta) + \pi \phi(i) \tag{33}$$

$$pb'g' = (1 - \delta_b)pb + pn \tag{34}$$

$$pn \geq 0 \tag{35}$$

$$pn \leq \eta[\xi g' - (1 - \delta_b)pb] \tag{36}$$

Let μ be the multiplier on the cash-in-advance constraint (31), λ_0 be the multiplier on the budget constraint (32), q be the multiplier on the investment equation (33), λ_1 be the multiplier on the debt dynamics equation (34), λ_2 be the multiplier on non-negative debt issuance constraint (35), and λ_3 be the multiplier on the enforcement constraint (36).

The Lagrangian equation is:

$$L = d + \beta g' \mathbb{E}[(\frac{z_a'}{z_a})^{-\gamma} V(m', b'; s')]$$

$$+ \mu\left(p^m m' g' - z_i z_a\right)$$

$$+ \lambda_0\left(z_i z_a + m + pn - p^m m' g' - \delta_b b - i - \varphi(d)\right)$$

$$+ q\left(1 - \delta + \pi\phi(i) - g'\right)$$

$$+ \lambda_1 p\left(b' g' - (1 - \delta_b)b - n\right)$$

$$+ \lambda_2 pn$$

$$+ \lambda_3\left(\eta[\xi g' - (1 - \delta_b)pb] - pn\right)$$

where $\lambda_2 \equiv 0$ and η is the probability of having a financing opportunity.

First Order Conditions for d, i, m', b', g', n are:

$$\lambda_0 - \frac{1}{\varphi'(d)} = 0$$

$$q - \frac{\lambda_0}{\pi\phi'(i)} = 0$$

$$\beta g' \mathbb{E}[(\frac{z_a'}{z_a})^{-\gamma} V_{m'}'] - \lambda_0 p^m g' + \mu p^m g' = 0$$

$$\beta g' \mathbb{E}[(\frac{z_a'}{z_a})^{-\gamma} V_{b'}'] + \lambda_1 p g' = 0$$

$$\beta \mathbb{E}[(\frac{z_a'}{z_a})^{-\gamma} V'] + \mu p^m m' - \lambda_0 p^m m' - q + \lambda_1 p b' + \lambda_3 \xi \eta = 0$$

$$\lambda_0 p - \lambda_1 p + \lambda_2 p - \lambda_3 p = 0$$

Envelope Conditions are:

$$V_m = \lambda_0$$

$$V_b = -\lambda_0 \delta_b - \lambda_1 (1 - \delta_b)p - \lambda_3 (1 - \delta_b)p\eta$$

Proof of Proposition 3.1: If $\delta_b = 1$, then $\mu = \lambda_0 - \lambda_1 \frac{p}{p^m} > 0$, by using $\lambda_0 - \lambda_1 = \lambda_3 \geq 0$

and $p^m > p$. Thus, the cash-in-advance constraint is always binding.

Proof of Proposition 3.2: When $\delta_b < 1$, $\mu = \lambda_0 - \frac{p}{p^m}\frac{\lambda_1}{\delta_b + (1-\delta_b)p\eta} + \frac{p}{p^m}\beta\mathbb{E}_s\left[\left(\frac{z'_a}{z_a}\right)^{-\gamma}\frac{(1-\eta)(1-\delta_b)\lambda'_1}{\delta_b + (1-\delta_b)p\eta}\right]$.

The size of lagrangian multiplier μ depends on the state s. Thus, it is possible that in some states $\mu = 0$ and therefore the cash-in-advance constraint can be occasionally non-binding. Appendix C.2 demonstrates all the possible cases of non-binding constraints.

C   Numerical Methods

After writing down the first-order conditions and the envelope conditions, the firm's problem can be summarized by a system of non-linear equations associated with three expectation terms. Thus, by solving the non-linear equations, I get the solution of the firm's problem.

The numerical solution takes three steps. First, I approximate the three conditional expectation functions as follows:

$$\Phi_V(m, b; s) = \mathbb{E}_s\left[(z'_a)^{-\gamma}V(m', b'; s')\right]$$

$$\Phi_m(m, b; s) = \mathbb{E}_s\left[(z'_a)^{-\gamma}V_{m'}(m', b'; s')\right]$$

$$\Phi_b(m, b; s) = \mathbb{E}_s\left[(z'_a)^{-\gamma}V_{b'}(m', b'; s')\right]$$

Second, given the parameterized expectations, I solve the system of non-linear equations on each grid. I discreterize each shock on five grid points and each state variable on ten grid points. I also do robust check by increasing the number of grids. I interpolate linearly between grids when calculating the expectations. Finally, I iterate on the approximation functions until convergence.

C.1   Main Programming Routine

The main numerical routine contains two loops:

The outside loop: given states (m, b, s), solve policies (m', b') and update the approxi-

mation functions (Φ_V, Φ_m, Φ_b).

The inside loop: solve a non-linear equation system with four unknowns.

The four unknowns are: m', b', i, V, and the four equations are:

$$EQ1 : \mu(p^m m'g' - z_i z_a) = 0$$

$$EQ2 : \lambda_2 pn = 0$$

$$EQ3 : \lambda_3\big[\eta\big(\xi g' - (1 - \delta_b)pb\big) - pn\big] = 0$$

$$EQ4 : d + \beta g'(z_a)^\gamma \Phi_V - V = 0$$

where,

$$g' = (1 - \delta) + \pi\phi(i)$$

$$n = b'g' - (1 - \delta_b)b$$

$$d = \varphi^{-1}(z_i z_a + m + pn - p^m m'g' - \delta_b b - i)$$

$$\lambda_0 = \frac{1}{\varphi'(d)}$$

$$q = \frac{\lambda_0}{\pi\phi'(i)}$$

$$\lambda_1 = \frac{-\beta(z_a)^\gamma \Phi_b}{p}$$

$$\mu = \lambda_0 - \frac{\beta(z_a)^\gamma \Phi_m}{p^m}$$

$$\lambda_3 = \frac{\lambda_0 p^m m' + q - \lambda_1 pb' - \mu p^m m' - \beta(z_a)^\gamma \Phi_V}{\xi\eta}$$

$$\lambda_2 = \lambda_3 - \lambda_0 + \lambda_1$$

C.2 Occasionally Binding Constraints

I first solve the equation system by assuming that the two constraints (31) and (36) are both binding, and then check the Lagrangian multipliers μ and λ_3. According to the sign of μ and λ_3, I specify four cases and resolve the system case by case.

Case A, both binding, neither precautionary cash nor unused lines of credit:

$$EQ1 : \eta\big(\xi g' - (1 - \delta_b)pb\big) - pn = 0$$

$$EQ3 : p^m m' g' - z_i z_a = 0$$

Case B, one non-binding, only has precautionary cash:

$$EQ1 : \eta\big(\xi g' - (1 - \delta_b)pb\big) - pn = 0$$

$$EQ3 : p^m m' g' - z_i z_a > 0$$

Case C, one non-binding, only has unused lines of credit:

$$EQ1 : \eta\big(\xi g' - (1 - \delta_b)pb\big) - pn > 0$$

$$EQ3 : p^m m' g' - z_i z_a = 0$$

Case D, both non-binding, precautionary cash *coexists* with unused lines of credit:

$$EQ1 : \eta\big(\xi g' - (1 - \delta_b)pb\big) - pn > 0$$

$$EQ3 : p^m m' g' - z_i z_a > 0$$

D   Simulated Method of Moments

The choice of model parameters is done by the simulated method of moments (SMM). The basic idea of SMM is to choose the model parameters such that the moments generated by the model are as close as possible to the corresponding real data moments.

The real data is a panel of heterogeneous firms, but the simulated data is generated by a representative firm. To keep consistency between the actual data and the simulated data, I estimate the parameters of an *average* firm in the data. To be specific, given the panel structure of the data, I first calculate moments for each firm, and then compute the average of moments across firms and use it as the target moment. I use the bootstrap method to calculate the variance-covariance matrix associated with the target moments.

The estimation procedure is as follows.[10] First, for each firm i, I choose moments $h_i(x_{it})$, where x_{it} is a vector representing variables in the actual data, and subscript i and t indicates firm and year respectively. Second, for each firm i, I calculate the within-firm sample mean of moments as $f_i(x_i) = \frac{1}{T}\sum_{t=1}^{T}h_i(x_{it})$, where T is the number of fiscal years in the data. Third, I compute the average of the within-firm sample mean as $f(x) = \frac{1}{N}\sum_{i=1}^{N}f_i(x_i)$, where N is the number of firms in the data.

Correspondingly, I use the model to simulate a panel data of N number of firms and S periods. I set $S = 100T$ to make sure that the representative firm would visit all the states in the model. I calculate the average sample mean of moments in the model as $f(y,\theta) = \frac{1}{NS}\sum_{i=1}^{N}\sum_{s=1}^{S}h(y_{is},\theta)$, where y_{is} is the simulated data from the model, and θ represents the parameters to be estimated.

The estimator $\widehat{\theta}$ is the solution to

$$\min_{\theta} : [f(x) - f(y,\theta)]^T\Omega[f(x) - f(y,\theta)].$$

The weighting matrix Ω is defined as $\widehat{\Sigma}^{-1}$, where $\widehat{\Sigma}$ is the variance-covariance matrix associated with the average of sample mean $f(x)$ in the data. I use the bootstrap method to calculate the variance-covariance matrix $\widehat{\Sigma}$. First, given the population of N number of firms from the real data, I draw J random samples with size $\frac{N}{2}$. Second, for each draw j, I compute the statistics of the drawn sample, denote by $f(x)^j$. Third, I approximate the variance-covariance matrix by the variance of $f(x)^j$, i.e., $\widehat{\Sigma} \approx \frac{1}{J}\sum_{j=1}^{J}\left(f(x)^j - \frac{1}{J}\sum_{j=1}^{J}f(x)^j\right)^T\left(f(x)^j - \frac{1}{J}\sum_{j=1}^{J}f(x)^j\right)$. Finally, I set J=50,000 to have enough accuracy of the bootstrap method.

D.1   Identification

In the estimation, parameters are jointly identified by moments, and the number of moments is larger than the number of parameters. Thus, there is no one-to-one mapping between

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[10]I also use the estimation procedure described in DeAngelo, DeAngelo, and Whited (2011), and the estimation results are robust.

moments and parameters. To have a clear idea about the identification of the model parameters, I conduct comparative statics exercises to find out the relationship between the target moments and the model parameters. In the comparative statics study, I first use the estimated parameters as benchmark parameters to compute the moments. Then, I adjust the parameters one by one to examine the sensitivity of each moment with respect to the change of parameters. Table 5 reports the results of the comparative statics exercises.

According to the comparative statics exercises, the main identification of parameters is as follows. First, consider the identification of two shocks in the model. The drift of productivity shock μ_z can be identified by the mean of investment. This is because increases in μ_z raise the marginal profit of investment, and therefore the level of investment. The persistence of productivity shock ρ_z is mainly identified by the autocorrelation of cash flows, and the standard deviation σ_z is identified by the standard deviation of cash flows. Similarly, the persistence of the credit shock ρ_η is mainly identified by the autocorrelation of cash, and the standard deviation of credit shock σ_η is identified by the standard deviation of debt.

The change of capital deprecation rate δ affects the level of cash, the level of debt, the level of investment, and the level of cash flows, and therefore the parameter δ is pinned down by those four moments. The collateral rate ξ is mainly identified by the level of debt since increases in ξ raise the level of debt uniquely.

The next set of parameters are about frictions. The equity rigidity parameter κ measures the rigidities of adjusting equity. It is mainly identified by the standard deviation of payout. The second friction parameter, the capital adjustment cost parameter ζ, is identified by autocorrelation of investment.

The price of cash p^m measures the opportunity cost of holding cash. Increases in the price of cash reduces the level of cash, but raise the level of unused lines. Thus, the parameter p^m can be jointly identified by two moments: the level of cash and the level of unused lines.

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Table 1: **Variable Definitions in the Structural Estimation**

Variable	Model	Detrended Model	Data
Cash/Assets	$\frac{p^m m_{t+1}}{k_t+m_t}$	$\frac{p^m \tilde{m}_{t+1} g_{t+1}}{1+\tilde{m}_t}$	(Cash and Short-Term Investments (CHE_t) $-$ Debt in Current Liabilities-Total (DLC_t)) / Assets-Total (AT_{t-1}). From Compustat.
Debt/Assets	$\frac{p_t b_{t+1}}{k_t+m_t}$	$\frac{p_t \tilde{b}_{t+1} g_{t+1}}{1+\tilde{m}_t}$	Long-Term Debt-Total $(DLTT_t)$ / Assets-Total (AT_{t-1}). From Compustat.
Investment/Assets	$\frac{i_t}{k_t+m_t}$	$\frac{\tilde{i}_t}{1+\tilde{m}_t}$	Capital Expenditures $(CAPX_t)$ / Assets-Total (AT_{t-1}). From Compustat.
Payout/Assets	$\frac{d_t : d_t > 0}{k_t+m_t}$	$\frac{\tilde{d}_t : \tilde{d}_t > 0}{1+\tilde{m}_t}$	(Purchase of Common and Preferred Stock $(PRSTKC_t)$ + Dividends-Preferred/Preference (DVP_t) + Dividends Common/Ordinary (DVC_t)) / Assets-Total (AT_{t-1}). From Compustat.
Cash Flow/Assets	$\frac{z_t k_t}{k_t+m_t}$	$\frac{z_t}{1+\tilde{m}_t}$	Operating Income Before Depreciation $(OIBDP_t)$ / Assets-Total (AT_{t-1}). From Compustat.
Unused Line/Assets	$\frac{l_t}{k_t+m_t}$	$\frac{\tilde{l}_t}{1+\tilde{m}_t}$	Total Undrawn Credit$_t$ / Assets-Total (AT_{t-1}). From Capital IQ and Compustat.

Table 2: **Moments and Parameters**

	Data	Model
TARGET MOMENTS		
Mean of Cash/Assets	0.189	0.154
Mean of Unused Line/Assets	0.100	0.047
Mean of Debt/Assets	0.162	0.184
Mean of Investment/Assets	0.050	0.053
Mean of Payout/Assets	0.029	0.041
Mean of Cash Flow/Assets	0.098	0.093
Std of Cash/Assets	0.116	0.046
Std of Unused Line/Assets	0.055	0.074
Std of Debt/Assets	0.082	0.091
Std of Payout/Assets	0.027	0.025
Std of Cash Flow/Assets	0.070	0.033
Auto-Corr of Cash/Assets	0.188	0.191
Auto-Corr of Investment/Assets	0.205	0.220
Auto-Corr of Cash Flow/Assets	0.297	0.315

ESTIMATED PARAMETERS	Estimates	SE
The drift of productivity shock, μ_z	0.041	(0.007)
Persistence of productivity shock, ρ_z	0.466	(0.086)
Volatility of productivity shock, σ_z	0.421	(0.077)
Persistence of credit shock, ρ_η	0.410	(0.063)
Volatility of credit shock, σ_η	0.457	(0.054)
Capital depreciation rate, δ	0.087	(0.012)
Collateral rate, ξ	0.456	(0.041)
Equity rigidity parameter, κ	0.533	(0.118)
Capital adjustment cost, ζ	0.779	(0.199)
Price of cash, p^m	0.975	(0.023)

CALIBRATED PARAMETERS		
Subjective discount factor, β		0.97
Corporate effective tax rate, τ		0.15
Debt repayment rate, δ_b		0.31

Empirical moments are based on a balanced panel of non-financial, unregulated firms from Compustat annual files 2002-2010. Estimation is done by the simulated method of moment, which chooses model parameters such that the moments generated by the model are as close as possible to the corresponding real data moments. The first panel reports the target moments in the estimation, and the second panel lists point estimates and standard errors (in parentheses). The third panel reports parameters estimated directly from the data.

Table 3: **Counterfactual Exercises (I): The role of shocks**

	Data	Benchmark Model	Financing Shock	Productivity Shock
MOMENTS				
Mean of PrecautionaryCash/Assets	0.091	0.061	0.057	0.004
Mean of Unused Line/Assets	0.100	0.047	0.033	0.010
Mean of Cash/Assets	0.189	0.154	0.151	0.103
Mean of Debt/Assets	0.162	0.184	0.204	0.258
Mean of Investment/Assets	0.050	0.053	0.056	0.057
Mean of Payout/Assets	0.029	0.041	0.038	0.033
Mean of Cash Flow/Assets	0.098	0.093	0.094	0.098
Std of Cash/Assets	0.116	0.046	0.039	0.031
Std of Unused Line/Assets	0.055	0.074	0.054	0.017
Std of Debt/Assets	0.082	0.091	0.084	0.025
Std of Payout/Assets	0.027	0.025	0.024	0.021
Std of Cash Flow/Assets	0.070	0.033	0.004	0.035
Auto-Corr of Cash/Assets	0.188	0.191	0.115	0.207
Auto-Corr of Investment/Assets	0.205	0.220	-0.053	0.020
Auto-Corr of Cash Flow/Assets	0.297	0.315	0.258	0.256

The first column reports the moments observed in the data. The second column reports the benchmark moments of the model with both the financing shock and the productivity shock. The third column reports the moments of the model with only the financing shock. The fourth column reports the moments of the model with only the productivity shock.

Table 4: **Counterfactual Exercises (II): The value of liquidity**

	Benchmark Model	Model (1) Neither	Model (2) NoLines	Model (3) NoPcash
Normalized Value of Cash Flow	0.110	0.110	0.110	0.110
Normalized Value of Debt	0.245	0.245	0.245	0.245
Normalized Value of Precautionary Cash	0.063	0.000	0.103	0.000
Normalized Value of Unused Credit Line	0.077	0.000	0.000	0.138
Normalized Value of the Firm	1.000	0.798	0.996	0.937
Normalized Value of Equity	0.755	0.553	0.751	0.692
Normalized Costs of Adjusting Capital	0.101	0.322	0.117	0.108
Normalized Costs of Adjusting Equity	0.023	0.219	0.069	0.014
Normalized Value of Equity Payout	0.042	0.044	0.041	0.036
Normalized Volatility of Equity Payout	0.034	0.110	0.061	0.020

The first column reports the moments of the benchmark model. The second to fourth column report the moments of the experimental models. Model (1) refers to the model without any liquidity holdings, Model (2) refers to the model without the channel of holding unused lines of credit, and Model (3) refers to the model without the channel of holding precautionary cash. To draw comparisons between different models, I normalize the value of the firm in the benchmark model to 1. Also, I set the value of capital and the value of debt to be the same in those models so that firms in different models are identical expect for having different channels of holding liquidity.

Table 5: **Comparative Statics of Estimated Parameters**

	Bench	μ_z	ρ_z	σ_z	ρ_η	σ_η	δ	ξ	κ	ζ	p^m
Mean of Cash/Assets	0.154	0.156	0.149	0.147	0.156	0.172	0.173	0.168	0.152	0.155	**0.107**
Mean of Unused Line/Assets	0.047	0.044	0.044	0.049	0.053	0.066	0.045	0.068	0.061	0.047	**0.129**
Mean of Debt/Assets	0.184	0.189	0.184	0.180	0.170	0.146	0.179	**0.229**	0.167	0.184	0.088
Mean of Investment/Assets	0.053	**0.056**	0.040	0.052	0.052	0.052	0.067	0.052	0.053	0.056	0.055
Mean of Payout/Assets	0.041	0.038	0.044	0.045	0.041	0.044	0.046	0.040	0.041	0.038	0.046
Mean of Cash Flow/Assets	0.093	0.093	0.088	0.086	0.092	0.091	**0.112**	0.091	0.094	0.092	0.098
Std of Cash/Assets	0.046	0.047	0.046	0.046	0.046	0.056	0.045	0.054	0.042	0.046	0.032
Std of Unused Line/Assets	0.074	0.073	0.073	0.078	0.085	0.105	0.074	0.102	0.086	0.075	0.124
Std of Debt/Assets	0.091	0.093	0.092	0.093	0.103	**0.128**	0.090	0.112	0.089	0.093	0.071
Std of Payout/Assets	0.025	0.024	0.027	0.027	0.026	0.029	0.026	0.026	**0.022**	0.024	0.025
Std of Cash Flow/Assets	0.033	0.034	0.035	**0.041**	0.033	0.033	0.040	0.033	0.034	0.034	0.035
Auto of Cash/Assets	0.191	0.199	0.219	0.174	**0.256**	0.174	0.172	0.185	0.175	0.191	0.146
Auto of Investment/Assets	0.220	0.213	0.393	0.257	0.264	0.164	0.249	0.203	0.280	**0.190**	0.095
Auto of Cash Flow/Assets	0.315	0.312	**0.445**	0.304	0.310	0.292	0.292	0.317	0.305	0.309	0.262

This table shows the results of comparative statics exercises of the estimated parameters. The first column lists the benchmark moments simulated by the parameters estimated in Table 2. The second to the twelfth column shows the results of the sensitivity test by changing the value of one parameter each time. The parameters are: the drift of productivity shock μ_z, the persistence of productivity shock ρ_z, the volatility of productivity shock σ_z, the persistence of credit shock ρ_η, the volatility of credit shock σ_η, the capital depreciation rate δ, the collateral rate ξ, the equity rigidity parameter κ, the capital adjustment cost ζ, and the price of cash p^m. I increase each parameter by 33% to test its sensitivity, except increasing price of cash p^m from 0.975 to 0.98.

Table 6: **Estimation with Stochastic Discount Factor**

	Observed	Simulated
TARGET MOMENTS		
Mean of Cash/Assets	0.189	0.129
Std of Cash/Assets	0.116	0.070
Auto of Cash/Assets	0.188	0.463
Mean of Debt/Assets	0.162	0.143
Std of Debt/Assets	0.082	0.121
Auto of Debt/Assets	0.226	0.780
Mean of Investment/Assets	0.050	0.047
Std of Investment/Assets	0.025	0.003
Auto of Investment/Assets	0.205	0.229
Mean of Payout/Assets	0.029	0.029
Std of Payout/Assets	0.027	0.019
Auto of Payout/Assets	0.136	0.226
Mean of Cash Flow/Assets	0.098	0.076
Std of Cash Flow/Assets	0.070	0.022
Auto of Cash Flow/Assets	0.297	0.230
Mean of Unused Line/Assets	0.100	0.072
Std of Unused Line/Assets	0.055	0.130
Auto of Unused Line/Assets	0.194	0.438

	Estimates	SE
ESTIMATED PARAMETERS		
The drift of productivity shock, μ_{z_i}	0.021	(0.004)
Persistence of productivity shock, ρ_{z_i}	0.399	(0.050)
Volatility of productivity shock, σ_{z_i}	0.342	(0.041)
Persistence of credit shock, ρ_{η_i}	0.302	(0.012)
Volatility of credit shock, σ_{η_i}	0.477	(0.016)
Capital depreciation rate, δ	0.061	(0.008)
Collateral rate, ξ	0.389	(0.046)
Equity rigidity parameter, κ	0.742	(0.101)
Capital adjustment cost, ζ	0.801	(0.049)
Price of cash, p^m	0.977	(0.042)

This table reports the estimation results when the stochastic discount factor is included. The first panel reports the target moments, and the second panel lists point estimates and standard errors (in parentheses).

	Benchmark Model	Financing Shock	Productivity Shock	Without Discount Factor
TARGET MOMENTS				
Mean of Cash/Assets	0.129	0.117	0.088	0.135
Std of Cash/Assets	0.070	0.050	0.025	0.055
Auto of Cash/Assets	0.463	0.536	0.542	0.428
Mean of Debt/Assets	0.143	0.146	0.232	0.187
Std of Debt/Assets	0.121	0.122	0.050	0.089
Auto of Debt/Assets	0.780	0.844	0.870	0.715
Mean of Investment/Assets	0.047	0.047	0.049	0.045
Std of Investment/Assets	0.003	0.002	0.004	0.003
Auto of Investment/Assets	0.229	0.240	0.757	0.135
Mean of Payout/Assets	0.029	0.030	0.026	0.029
Std of Payout/Assets	0.019	0.012	0.011	0.015
Auto of Payout/Assets	0.226	0.322	0.603	0.364
Mean of Cash Flow/Assets	0.076	0.077	0.079	0.076
Std of Cash Flow/Assets	0.022	0.004	0.023	0.022
Auto of Cash Flow/Assets	0.230	0.533	0.216	0.263
Mean of Unused Line/Assets	0.072	0.069	0.024	0.041
Std of Unused Line/Assets	0.130	0.123	0.034	0.085
Auto of Unused Line/Assets	0.438	0.534	0.815	0.436

This table reports results of counterfactual exercises when the discount factor is included. The first column summarizes the benchmark moments simulated by the model using the estimated parameters. The second column reports moments simulated by the model with the financing shock and the stochastic discount factor. The third column reports the moments simulated by the model with the productivity shock and the stochastic discount factor, and the fourth column reports the moments simulated by the model with both the financing and the productivity shock, but *without* the stochastic discount factor.
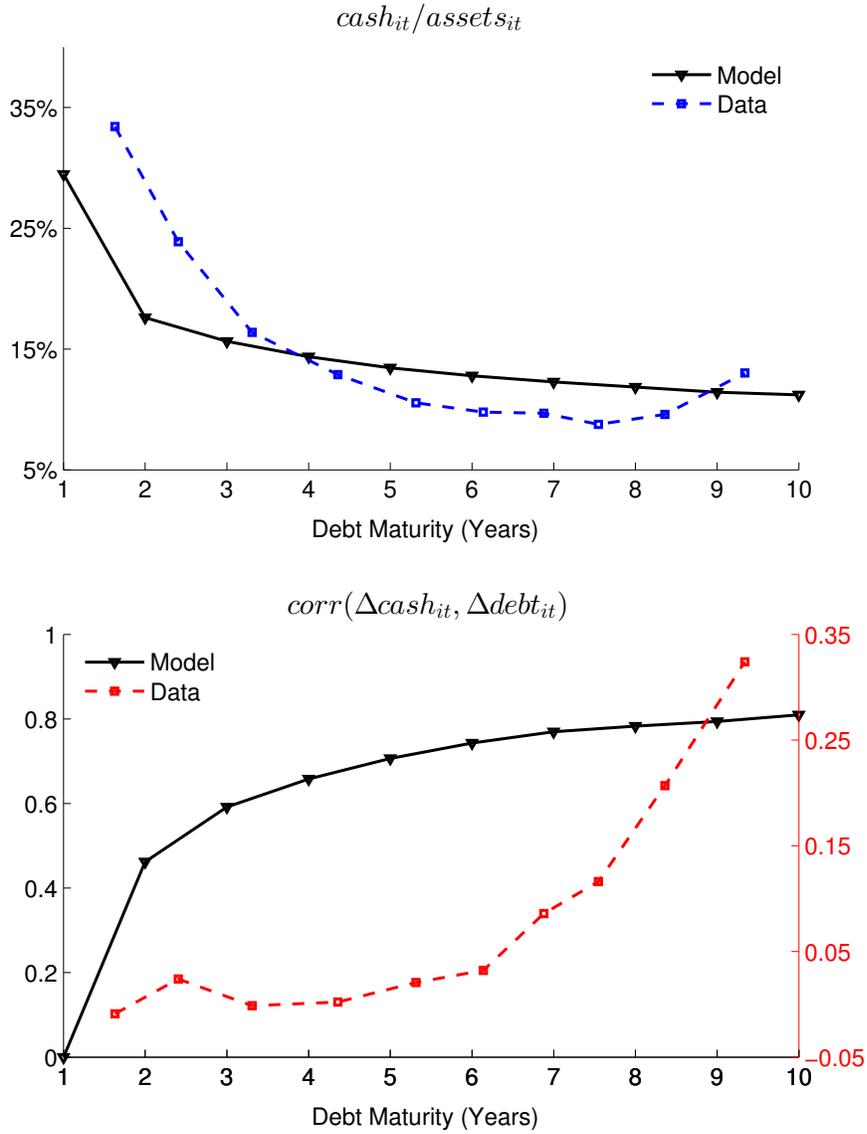
Figure 1: **Comparative Statics of Debt Maturity**. This figure shows the comparative statics of debt maturity. The solid lines represent the model prediction, and the dash lines represent the real data. The top panel depicts the cash-to-assets ratio, and the bottom panel depicts the correlation between cash accumulation and net long-term debt issuance. I classify firms into ten groups based on the maturity of outstanding debt. In the data, I define the maturity of debt as: $maturity = (0.5dd1 + 1.5dd2 + 2.5dd3 + 3.5dd4 + 4.5dd5 + 10(dltt - dd2 - dd3 - dd4 - dd5))/(dltt + dd1)$, where Compustat items $dd1$, $dd2$, $dd3$, $dd4$, and $dd5$ represent, respectively, the dollar amount of long-term debt maturing during the first year after the annual report, during the second year after the report, and so on; item $dltt$ represents the dollar amount of long-term debt that matures in more than one year. In the model, the maturity of debt is defined as the inverse of debt repayment rate. However, in the model, when the maturity of debt equals one there would be no difference between cash and unused credit lines, and in that case I treat unused credit lines as cash.
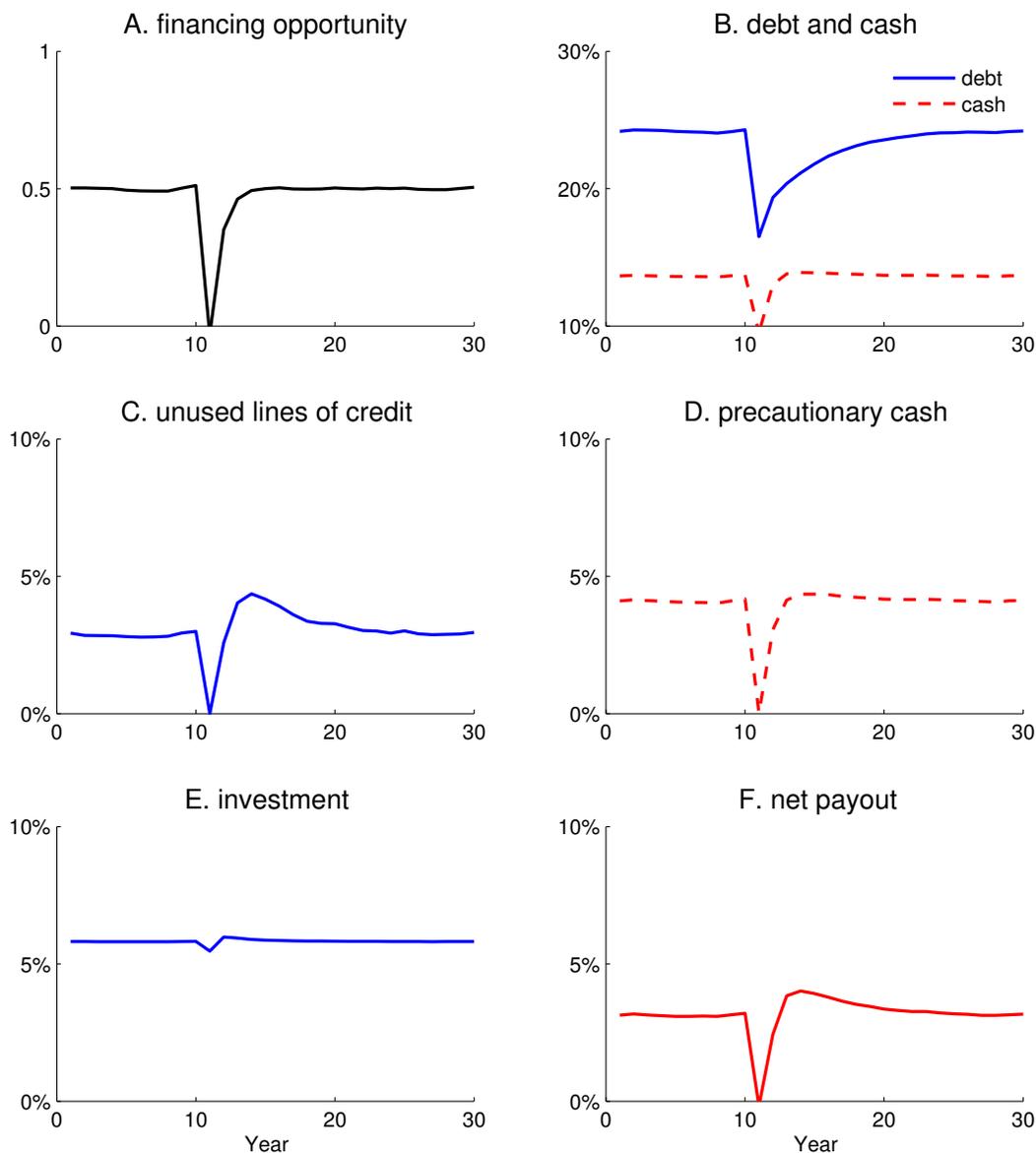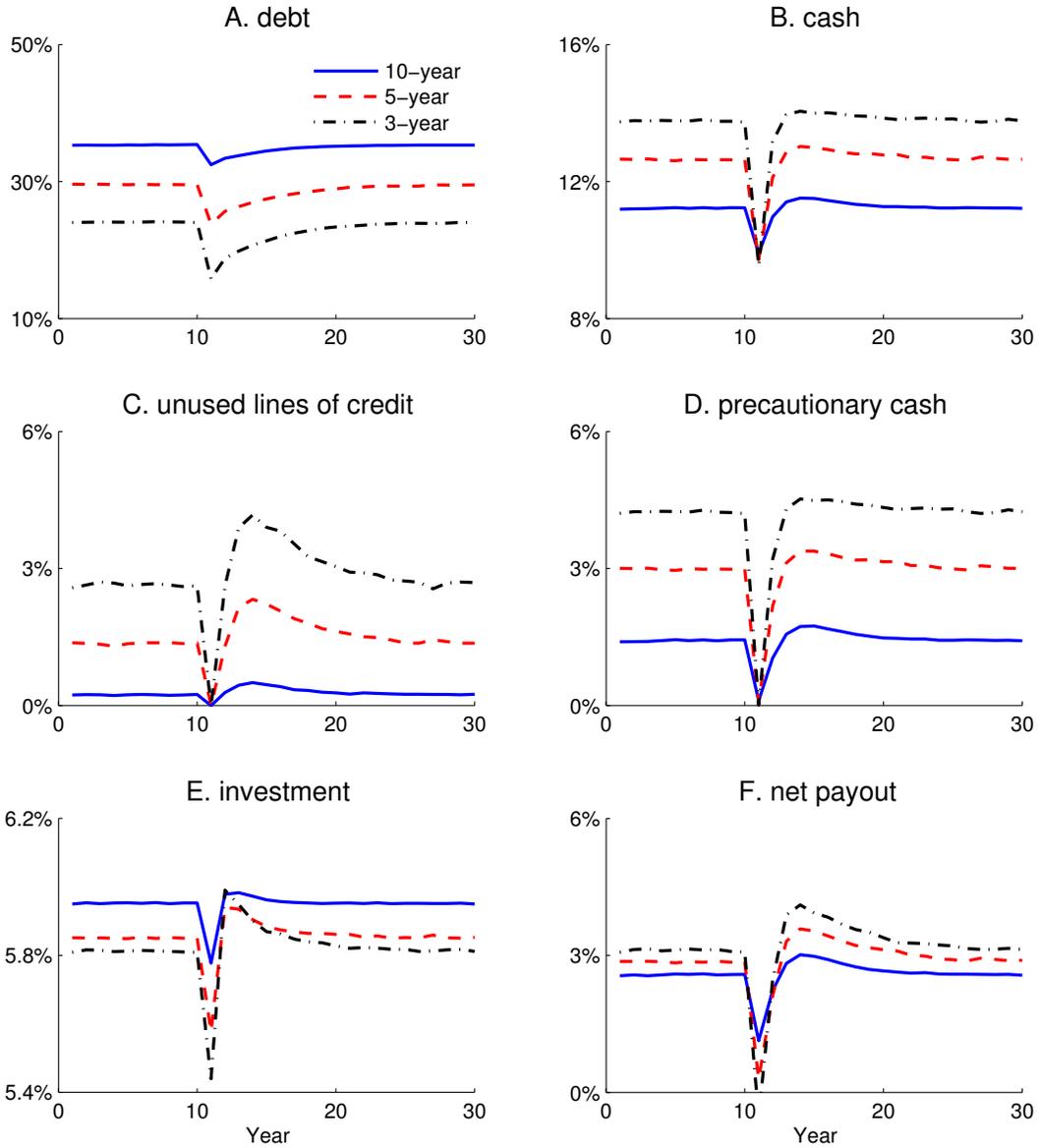
Figure 2: **Credit Crisis**. This figure depicts the firm's transition path after a negative credit shock. The x-axis indicates time (year) and the y-axis represents the value of each variable (to assets ratio). Since the model is non-linear and it features large-scale shocks, I depict the actual transition path instead of showing the percent deviations around the steady state. To get the transition paths, I simulate 10,000 firms with each firm has 30 periods. For the first 10 periods, I simulate the firm using the estimated parameters. At period 11, I add an additional negative financing shock. From period 11 and so on, I simulate each firm's transition paths and calculate the average of transition paths across the 10,000 simulated firms.

Figure 3: **Long-term debt (with cash) provides financial flexibility**. This figure shows the sensitivities of the firm's transition paths with respect to debt repayment rate δ_b. I consider three cases of debt repayment rate: $\delta_b = 0.10$, $\delta_b = 0.20$, and $\delta_b = 0.33$, which represent 10-Year, 5-Year, and 3-Year debt maturity. The x-axis indicates time (year) and the y-axis represents the value of each variable (to assets ratio). Since the model is non-linear and it features large-scale shocks, I depict the actual transition path instead of showing the percent deviations around the steady state. To get the transition paths, I simulate 10,000 firms with each firm has 30 periods. For the first 10 periods, I simulate the firm using the estimated parameters. At period 11, I add an additional positive financing shock. From period 11 and so on, I simulate each firm's transition paths and calculate the average of transition paths across the 10,000 simulated firms.
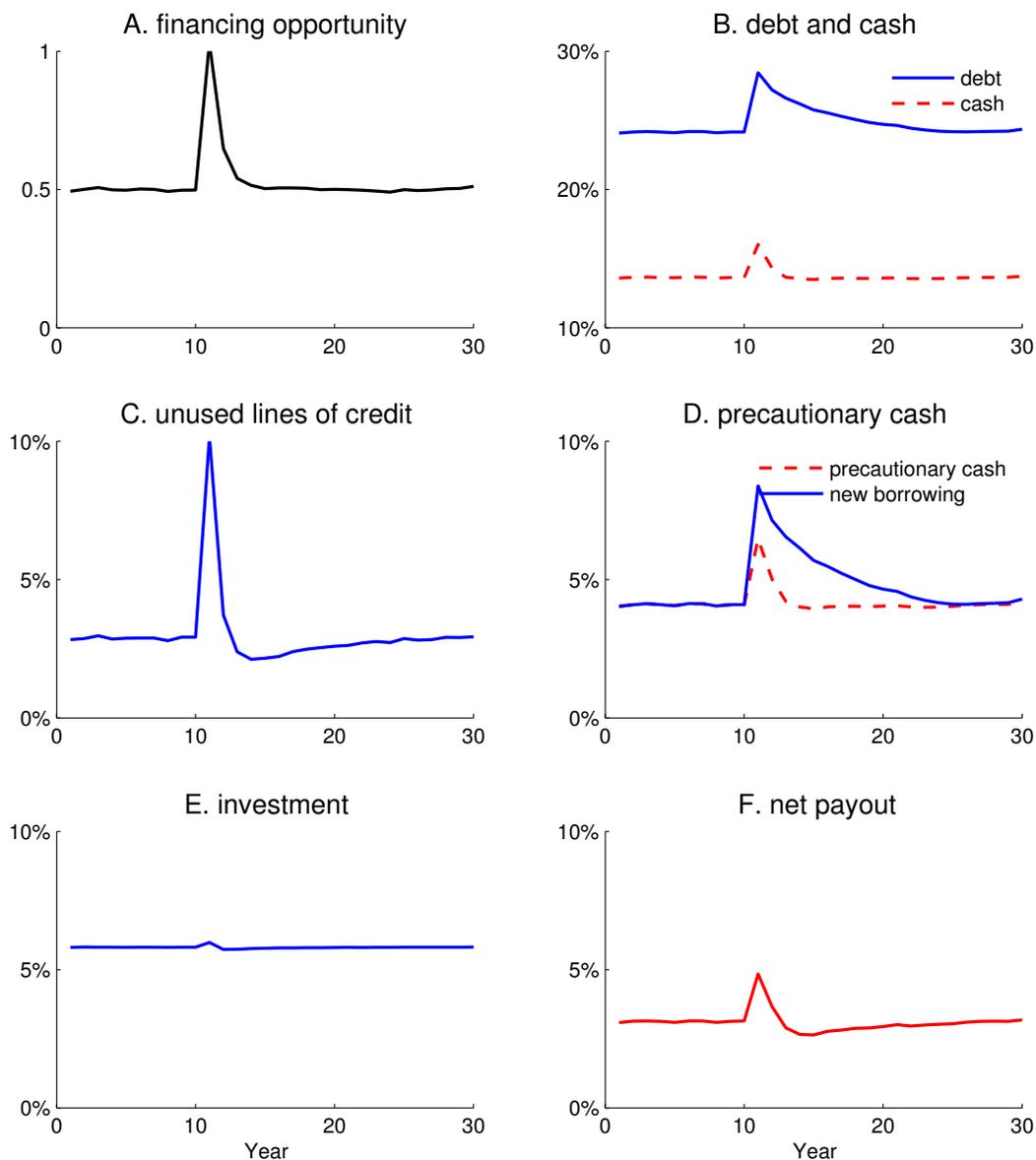
Figure 4: **Credit Boom**. This figure depicts the firm's transition path after a positive credit shock. The x-axis indicates time (year) and the y-axis represents the value of each variable (to assets ratio). Since the model is non-linear and it features large-scale shocks, I depict the actual transition path instead of showing the percent deviations around the steady state. To get the transition paths, I simulate 10,000 firms with each firm has 30 periods. For the first 10 periods, I simulate the firm using the estimated parameters. At period 11, I add an additional positive financing shock. From period 11 and so on, I simulate each firm's transition paths and calculate the average of transition paths across the 10,000 simulated firms.
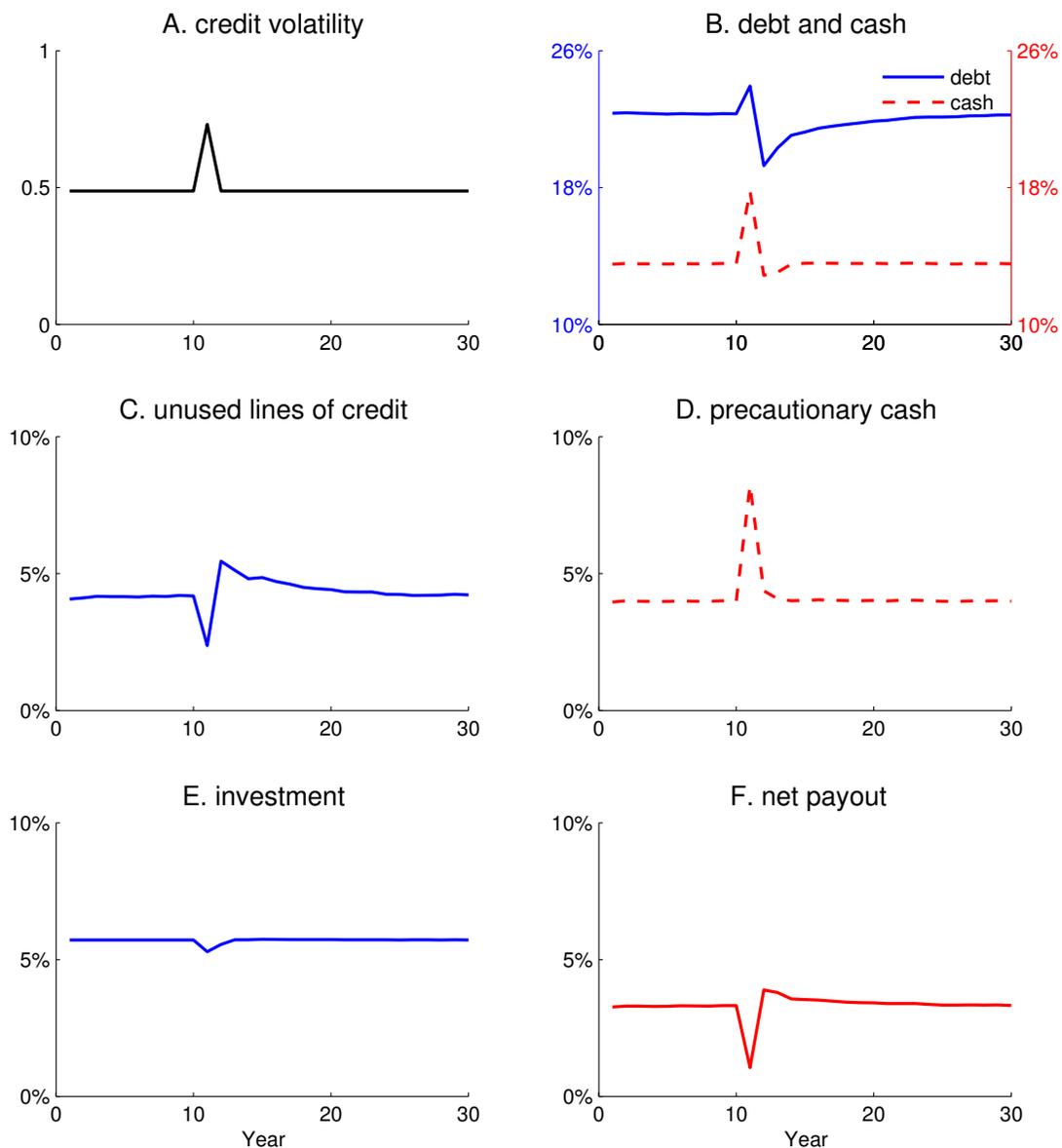
Figure 5: **Credit Uncertainty**. This figure depicts the firm's transition path after a credit uncertainty shock. The x-axis indicates time (year) and the y-axis represents the value of each variable (to assets ratio). Since the model is non-linear and it features large-scale shocks, I depict the actual transition path instead of showing the percent deviations around the steady state. To get the transition path, I simulate 10,000 firms with each firm has 30 periods. For the first 10 periods, I simulate the firm using the estimated value of credit volatility. From period 11 and so on, I increase the credit volatility by 50% percent. I simulate each firm's transition paths and calculate the average of transition paths across the 10,000 simulated firms.