How Do Financial Frictions Affect Self-financing Firms?

Zhifeng Cai* and Kai Ding†

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Abstract

Standard models of financial frictions impose collateral or borrowing constraints on firms. However, firms with sufficiently high net worth don't have to borrow externally to finance their investment, hence are unaffected by the tightening of collateral constraints. This is inconsistent with the fact that even the largest corporations in the US reduced their capital expenditure by 24.4% after the bankruptcy of Lehman Brothers. We argue that financial frictions affect these firms through the liquidity channel. We develop a model where bank credit lines and liquid assets are substitutes for financing liquidity shocks. In the model, a tightening of the bank credit lines forces firms to hold more liquid assets, increasing the effective cost of capital expenditure and hence reducing corporate investment. The calibrated model also matches the fact that after the collapse of Lehman firms increased their liquid assets holdings and bonds issuance.

JEL Classification: G31, G32

Keywords: Liquidity Shock, Cash Holding, Financial Frictions, Great Recession, Corporate Finance

*University of Minnesota and Federal Reserve Bank of Minneapolis (e-mail: caixx162@umn.edu)
†University of Minnesota and Federal Reserve Bank of Minneapolis (e-mail: dingx203@umn.edu)

1 Introduction

Our study of the Great Recession is motivated by three key observations about the investment and financing behavior of firms.

1. *Capital investment by self-financing firms fell significantly.* By self-financing firms we refer to firms that consistently generate more internal funds than capital expenditure. The green and blue lines in Figure 1 are the average capital expenditure and cash flow from operating activities of the largest 20% of COMPUSTAT firms in terms of asset level[1]. These large firms generate higher net cash flows from operating activities than their capital expenditure, and hence are capable of financing their investment without resorting to external funds. However, during the 2008 recession, their investment dropped by 24 percent. This pattern was also documented in Chari and Kehoe (2009) and Shourideh and Zetlin-Jones (2012).

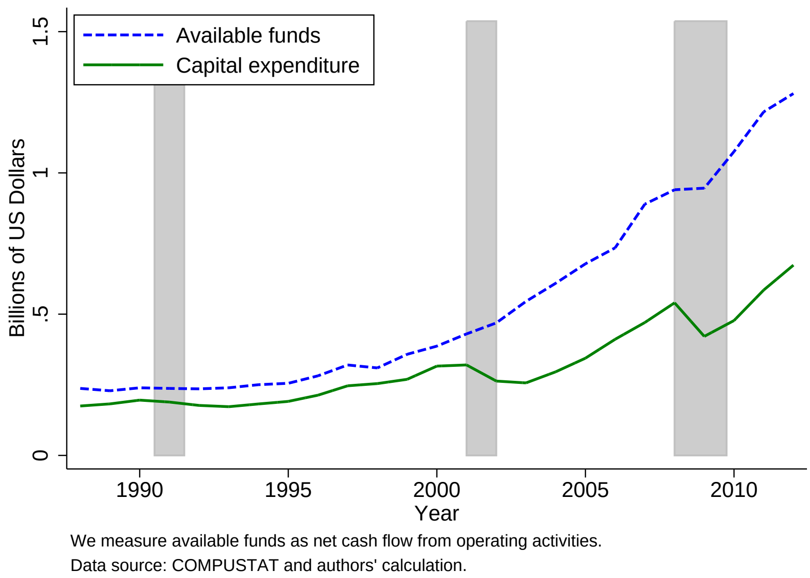

Figure 1: Capital expenditures and available funds for the largest 20% of COMPUSTAT firms.

2. *Liquid assets holdings by self-financing firms increased during the Great Recession, especially after the collapse of Lehman.* Figure 2 plots the time series of average liquid assets holdings of self-financing firms. Liquid assets refer to the balance sheet item "cash

[1]These firms account for more than 30% of the civilian employment. Variables are taken from balance sheet and cash flow statements from COMPUSTAT.

and cash equivalents".[2] This surge in liquid assets holdings during the Great Recession is robust across sectors and firm sizes.

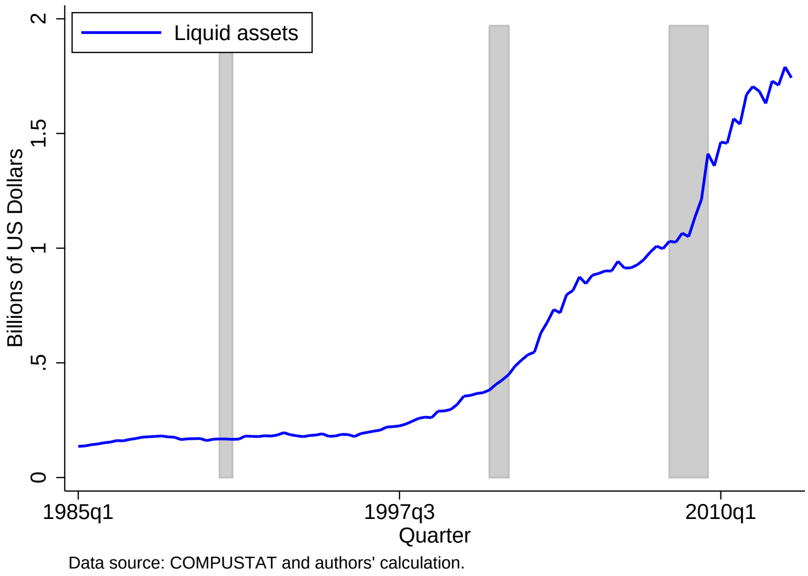

Figure 2: Liquid assets holdings for the largest 20% of COMPUSTAT firms. Liquid assets refer to the item "cash and cash equivalents (CHE)" from COMPUSTAT balance sheet data.

3. *Issuance of bank loans shrank while issuance of corporate bonds expanded.* Figure 3 is taken from Adrian et al. (2012). It plots the total issuance of bank loans and corporate bonds for all the COMPUSTAT firms (except financial and utility firms). We see a decrease in the issuance of bank loans (top panel) and an increase of bonds issuance (bottom panel) from the onset of the recession. This suggests that it may be worthwhile to model bank loans and corporate bonds as different debt instruments. An important distinction between the two is that bank loans are mainly in the form of revolving credit lines[3].

These three facts cannot be simultaneously accounted for in models with collateral constraints or productivity shocks:

- A tightening of the collateral constraint in a standard model with financial frictions forces firms with binding constraints to reduce their capital investment. However, self-financing

[2] Henceforth, we use liquid assets and cash interchangeably.

[3] Survey of Terms of Business Lending conducted by Federal Reserve Board reveals that 77% of C&I loans are made under commitment according to survey conducted on May 2014.

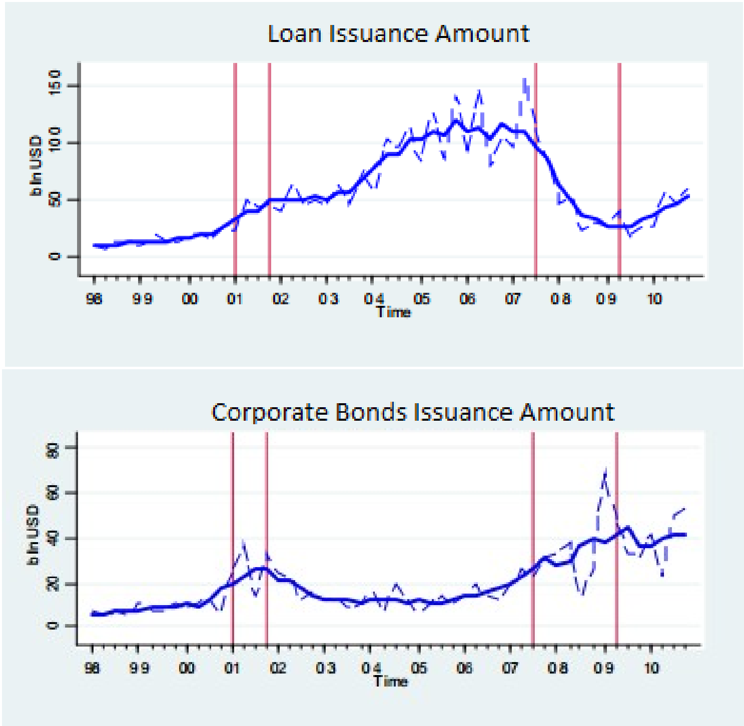

Figure 3: New issuance of debt: top for bank loans, bottom for corporate bonds.
Source: Adrian et al. (2012)

firms have enough internal funds to finance their capital expenditure, and do not have to resort to external funds. Thus it is not clear how a tightening of the collateral constraint will reduce investment of these firms.

- A negative productivity shock in a standard RBC model generates a drop in corporate investment. However, it doesn't give clear predictions about corporate liquid assets holdings. In fact, we show later that a negative productivity shock *reduces* firms' liquid assets holdings under the assumption that liquidity shocks are proportional to the level of capital stock, as in Holmstrom and Tirole (1998).

- Macroeconomic models with corporate borrowing usually ignore heterogeneity in corporate debt structure, hence cannot address the opposite behavior of bank loans and corporate bonds during the Great Recession.

To explain the three facts above, we propose a model where firms' capital stock is subject to *liquidity shocks*, which we model as unexpected cost that firms have to finance right away before their operations can be continued. As in Holmstrom and Tirole (1998), we interpret liquidity shocks as "cost overrun of the initial investment or a shortfall of revenue relative to operating expense during the intermediate period". Liquidity shocks have to be financed by either drawing down credit lines or selling liquid assets. In this environment we study how an exogenous reduction of the credit lines available to firms (henceforth credit line shock) impacts their investment and cash holdings decisions.

The *intuition* why a credit line shock can simultaneously account for firms' investment and liquid assets holdings behavior is as follows. Bank credit lines and liquid assets are substitutes for insuring against liquidity shocks and safeguarding capital investment. Given the amount of credit lines available, firms have to bundle one unit of capital with certain units of liquid assets to cover the remaining liquidity risk. When banks tighten the credit lines, firms have to bundle extra units of liquid assets with each unit of capital to cover the increased liquidity risk. Holding liquid assets, however, is costly because of their low return. This increases the marginal cost of capital investment. Hence, firms optimally reduce their capital investment.

The assumption that credit lines serve as substitutes to cash holdings against liquidity shocks during the Great Recession is supported by the empirical finding in Campello et al. (2011). In particular, they showed that at firm level "there is a strong negative correlation between cash holdings and credit lines in the crisis".

The exogenous tightening of bank credit during the Great Recession is supported by the Senior Loan Officer Opinion Survey conducted by the Federal Reserve Board. As shown in Figure 4, the net percentage of domestic banks that have tightened their lending standards of commercial and industrial loans to large and middle-market firms increased from 25% at the beginning of 2008 to more than 75% at the peak of the recession.

We calibrate the model to firm-level balance sheet information from COMPUSTAT and compare the transition dynamics of the model economy after a standard credit shock, a productivity shock, and a credit line shock. We find that:

1. A standard credit shock does not affect high net worth (hence unconstrained) firms, leaving their capital expenditure and cash holdings unchanged.

2. A productivity shock generates a decrease of capital expenditure across firm sizes. But it implies a counter-factual reduction in firms' liquid assets holdings.

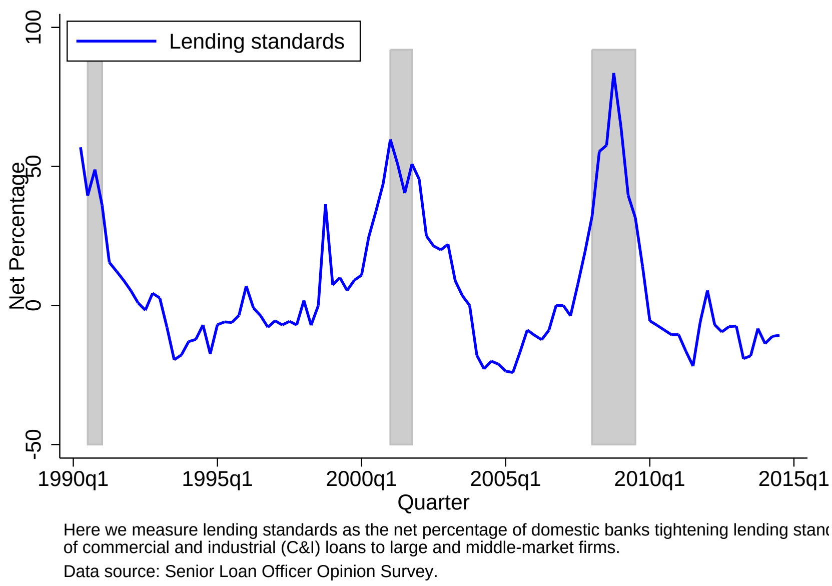

Figure 4: Net Percentage of domestic banks tightening lending standards.

3. A credit line shock generates a decrease in capital expenditure as well as an increase in liquid assets holdings across firm sizes.

4. A credit line shock also generates a compositional change between loans and bonds as in the data.

The paper is structured as follows. Section 2 reviews literature. Section 3 presents a simple two-period example to illustrate our model tradeoffs. Section 4 sets up the full-fledged recursive model. Section 5 studies the quantitative properties of our model. Section 6 concludes.

2 Related Literature

Our empirical findings are novel as we are the first to jointly document corporate financing, liquid assets holdings and corporate investment behavior for self-financing firms. Chari and Kehoe (2009) and Shourideh and Zetlin-Jones (2012) document that a large fraction of US corporations are able to self-finance their investment. There is also a large and growing literature studying why large corporations choose to hold more cash from 1980 on. For recent study on this issue, see for example Pinkowitz et al. (2012).

Our model is also related to the literature on financial frictions such as Khan and Thomas

(2013) and Jermann and Quadrini (2012), or earlier ones like Bernanke and Gertler (1989) and Kiyotaki and Moore (1997b). This literature focuses on the role of bank debt as a source of external financing for investment. We focus instead on its role as revolving credit lines that provides firms with the flexibility of financing liquidity shocks. We show that adding this more realistic feature into the model helps to improve the model's cross-sectional predictions.

Our paper is also related to the literature on corporate liquidity management practices initiated by Holmstrom and Tirole (1998). We embed firm's liquidity management decision into a quantitative heterogeneous firms framework, and conduct numerical experiments to demonstrate that it can help us to think about corporate investment behavior of firms, especially during the Great Recession.

Lastly, our paper is related to a recent literature studying the implications of corporate debt structure on the macroeconomy, such as Fiore and Uhlig (2011), Uhlig and Fiore (2012) and Crouzet (2013). These papers study how firms choose between bank loans and corporate bonds. We study a different tradeoff between bank loan and corporate bonds from these authors. Specifically, in our model bank loans are a more flexible source of financing that can be used to finance firms' liquidity shocks, as documented in Sufi (2009).

3 Model: Two-Period Example

To illustrate the tradeoffs in our model, we start with a simple two-period example.

Firms in the economy produces output y with capital k using some decreasing returns to scale technology $y = zk^{\alpha}$. This technology is also subject to some liquidity shock. After capital k has been installed but before output y is produced, a random additional cost of ρk has to be paid right away before production could continue. In additional to this risky production technology, firms also have access to a riskless saving technology with return equal to 1. We can think of this technology as checking accounts in the banks. At the end of each period, firms decide how to split their assets between risky investment k and riskless saving m.

Firms can issue bonds at interest rate R. They also have access to credit lines from banks. The credit lines are collateralized to the physical capital of the firms. The credit limit for a firm with capital stock k is ξk for some exogenous parameter ξ. Firms can finance the investment in capital by either issuing bonds b or drawing down their credit line. However, liquidity shocks can only be paid using credit lines or riskless saving m. They cannot be financed using bonds. This is because bond issuance usually involves paperworks and preparations such as SEC filings, which takes relatively long time to complete.

The timing of the model is as follows.

In period 1, firms choose how much capital investment k to make. They also decide how much riskless saving m to make. Firms have 0 net worth (assume this for simplicity). All the investment and saving are financed by either issuing corporate bonds b or drawing down its bank credit line l_k[4].

On the morning of period 2, a liquidity shock[5] ρk is realized. It can be financed either from saving m or by drawing down bank credit line l_ρ[6].

In the afternoon, output y is produced. Firms make payment on corporate bonds and the used portion of their credit lines.

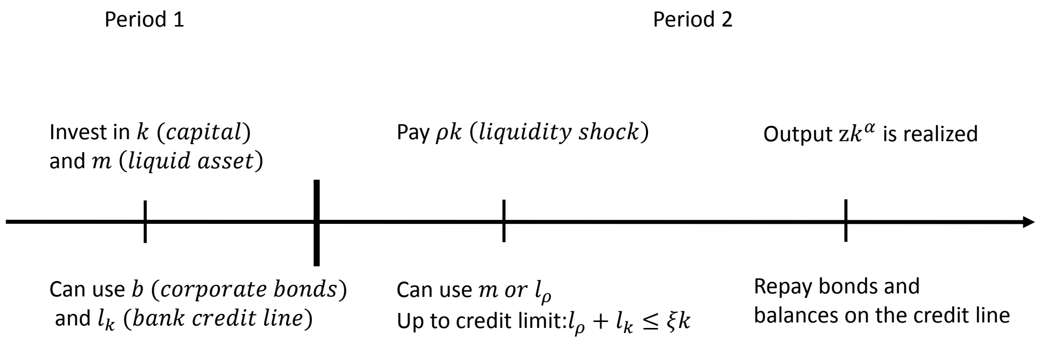

Figure 5: Timing (two-period example)

Inter-period borrowing (borrowed in period 1 and repaid in period 2) carries an interest rate

[4]Here the subscript k in l_k denotes that part of the credit line that is drawn down for capital investment purpose.

[5]A liquidity shock is an unexpected cost that firms have to finance right away before their operations can be continued. As in Holmstrom and Tirole (1998), we interpret liquidity shocks as "cost overrun of the initial investment or a shortfall of revenue relative to operating expense during the intermediate period".

[6]Here the subscript ρ in l_ρ denotes the part of the credit line that is drawn down to finance the liquidity shock ρk.

of R. Intra-period borrowing (borrowed at day 2 and repaid at day 2) carries an interest rate of 1. This implies that:

1. The interest rate on corporate bonds is always R;

2. If a firm draws down part of its credit line in period 1 (for investment purpose) and part of it in period 2 (for liquidity purpose), then the two proportions carry different interest rates, the former being R whereas the latter being 1. This is consistent with the common practices of the credit card industry that interest accrues only if a balance stays on a credit card for sufficiently long time.

The firm's problem can be stated as follows:

$$\pi(\xi) = \max_{k,m,b,l_k,l_\rho} zk^\alpha - R(b+l_k) - l_\rho$$

subject to

$$m + k \leq b + l_k \qquad \text{(Budget Constraint)}$$

$$m + l_\rho \geq \rho k \qquad \text{(Liquidity Constraint)}$$

$$l_k + l_\rho \leq \xi k \qquad \text{(Credit Line Limit)}$$

We make the following assumptions:

Assumption 1. $R > 1$. *Inter-period borrowing rate is higher than intra-period borrowing rate.* $\xi \leq \rho$. *Credit line itself is not sufficient to cover the liquidity shock.*

Lemma 1. *Under assumptions 1, the optimal solution to firm's problem is characterized by:*

$$m > 0, l_k = 0, l_\rho = \xi k$$

$$\alpha z k^{\alpha-1} = R(1+\rho) - (1-R)\xi$$

That is, firm holds positive liquid assets, uses no credit line for financing investment and saves the entire credit line for covering the liquidity shock.

Intuitively, liquidity shock has be to financed through either saving m or credit line l_ρ. Riskless saving m carries an opportunity cost of $(R-1)$ due to its low return. So firms minimize their riskless saving by saving the entire credit line for financing liquidity shock.

Proof. From (Budget Constraint) and (Credit Line Limit) of the problem, we get: $m \geq \rho k - l_\rho \geq \rho k - \xi k + l_k > 0$. Note that $k > 0$ because the marginal return to capital approaches infinity at 0.

Suppose at the optimal solution $l_k > 0$. Consider a perturbation as follows: reduce both m and l_k by $\varepsilon > 0$ and increase l_ρ by ε; keep k, b constant. This is feasible because both m and l_k are strictly positive. One can verify that all constraints are satisfied. This perturbation increases profit by $(R-1)\varepsilon > 0$. Contradiction! So $l_k = 0$.

If at the optimal solution $l_\rho < \xi k$, then a perturbation of increasing l_ρ by $\varepsilon > 0$ and decreasing m by ε increases profit of the firm. □

Proposition 1. *Under assumptions 1 and 2,*

$$\frac{\partial k}{\partial \xi} > 0.$$

That is, a tightening of the credit limit reduces investment level. Also,

$$\frac{\partial b}{\partial \xi} < 0.$$

That is, a tightening of the credit limit increases bond financing.

Proof. From lemma 1 we know that $l_\rho = \xi k$ and $m = (\rho - \xi)k$. Plug them into the objective function of the firm and take the first order condition, we get:

$$\alpha A k^{\alpha-1} = R(\rho - \xi + 1) + \xi = R(\rho + 1) - (R-1)\xi$$

So the marginal cost of capital increases as ξ decreases. Hence k decreases as ξ decreases. Because $b = R(\rho - \xi + 1)k = R(\rho - \xi + 1)[\frac{R(\rho+1)-(R-1)\xi}{\alpha A}]^{1/(\alpha-1)}$ □

The intuition is as follows. As credit limit tightens, firms are forced to hold more cash per unit of capital. This is costly since the return on cash is lower than firm's borrowing cost R. This increases the effective marginal cost of investment and reduces optimal capital stock.

Next, we make several generalizations to the model:

1. We make ρ stochastic. This is consistent with the corporate liquidity management literature and facilitates our calibration;

2. Since ρ is stochastic, firms may fail to finance their liquidity shocks in some states of nature. We allow bondholders to charge a forwarding-looking interest schedule on bonds to account for this default risk;

3. We embed this framework into an infinite period problem with dividends distribution and dynamic net worth accumulation.

4 General Model

4.1 Firms

There is a continuum of firms in the economy of measure 1. Each firm has a production technology $f(k) = zk^{\alpha}$, where k is the capital stock of the firm and z is the economy-wide productivity level (which we assume is a constant). All the firms are producing a homogenous output.

The timing of the model is in Figure 6. (Note: later on, Lemma 2 and Lemma 3 will simplify this timing).

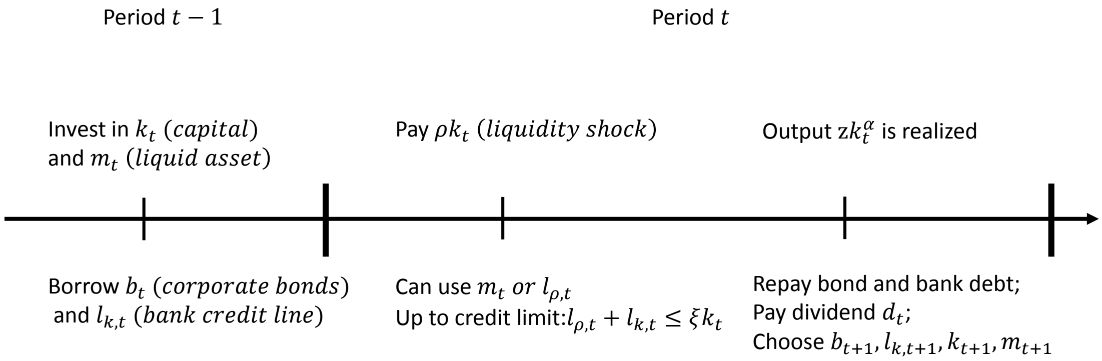

Figure 6: Timing

Firms walk into period t with some predetermined level of capital stock k_t, cash holdings m_t, bond debt outstanding b_t, and credit line debt outstanding l_t^k. Then a liquidity shock ρk_t is realized, where ρ is i.i.d. across firms and over time with distribution $g(\rho) \sim N(\mu_\rho, \sigma_\rho^2)$. The liquidity shock is the amount of money that a firm has to pay right away before the project can be continued. It can be financed by either drawing down the remaining credit line $\left(\xi k_t - l_t^k\right)$ (we will explain in the next subsection 4.2 the interpretations for this credit limit ξk_t), or using cash holdings m_t. We assume that bond issuance is less flexible and hence cannot be contingent on the realization of the liquidity shock. This is motivated by the lengthy SEC filling procedure and the high flotation cost such as underwriting fees, legal fees and registration fees associated with bond issuance, as documented in Krishnaswami et al. (1999).

If a firm manages to finance the liquidity shocks, it proceeds to the production stage and produces $f(k_t)$. Then the firm pays back banks and bondholders, issues new bonds b_{t+1}, draws down next-period credit line l_{t+1}^k, pays out dividends d_t, and makes capital investment k_{t+1} and cash holdings m_{t+1} decisions for the next period. If a liquidity shock isn't financed, the firm will lose all its capital stock k_t and cash holdings m_t. The firm exits the market and is replaced by a new firm.

In order to get a stationary distribution of the net worth of the firms, we assume that there is some exogenous bankruptcy probability θ for each firm in each period.

Firm's optimization problem could be summarized as the following Bellman equation:

$$V(k,m,b,l_k) = \max_{\rho^*, d(\rho), b'(\rho), l_k'(\rho), k'(\rho), m'(\rho)} \int_{\rho \le \rho^*} \left[d(\rho) + \beta\theta V\left(k'(\rho), m'(\rho), b'(\rho), l_k'(\rho)\right)\right] g(\rho) d\rho$$

subject to

$$\rho^* k \le m + (\xi k - l_k) \qquad \text{(Credit Limit Constraint)}$$

$$d(\rho) + k'(\rho) + m'(\rho) + \rho k + b + l_k$$

$$\le q_b \cdot b'(\rho) + q_{l_k} \cdot l_k'(\rho) + f(k) + (1-\delta)k + m, \forall \rho \le \rho^* \qquad \text{(Budget Constraint)}$$

$$q_b = qG\left(\frac{m'(\rho) + \xi k'(\rho) - l_k'(\rho)}{k'(\rho)}\right) \qquad \text{(Bond Interest Schedule)}$$

$$q_{l_k} = qG\left(\frac{m'(\rho) + \xi k'(\rho) - l_k'(\rho)}{k'(\rho)}\right) \qquad \text{(Credit Line Interest Schedule)}$$

where ρ^* is the cutoff level for the liquidity shocks chosen by the firm: a liquidity shock of ρk will be financed if and only if $\rho \le \rho^*$. $d(\rho)$ is the dividend distributed to the households, $k'(\rho), m'(\rho)$ are capital investment and cash holdings for the next period, $b'(\rho)$ is the issuance of new bonds, and $l_k'(\rho)$ is the draw down of the new credit line. (Credit Limit Constraint) is the credit limit on bank credit lines and (Budget Constraint) is the budget constraint of the firm. (Bond Interest Schedule) and (Credit Line Interest Schedule) are interest rate schedules on bonds and credit lines, which are the risk-free rate q adjusted for the probability of going bankruptcy of the firm. Note that the portion of the credit line l_k used for investment purpose is an inter-period loan and carries an interest rate of $\frac{1}{q_{l_k}}$, while the portion l_ρ used for financing the liquidity shock is an intra-period loan and carries an interest rate of 1.

To simplify the optimization problem of the firm, we need the following lemma first:

Lemma 2. *$V(k,m,b,l_k) = V(k, m-\varepsilon, b, l_k - \varepsilon), \forall 0 < \varepsilon < \min(m, l_k)$, i.e., value function V only depends on the difference between m and l_k.*

Proof. From the Bellman equation, m and l_k show up only in the credit limit constraint (Credit Limit Constraint) and the budget constraint (Budget Constraint). In both locations, only $m - l_k$ matters. □

This lemma leads to the following proposition stating that bank credit lines will only be used for financing liquidity shocks when cash holdings are positive.

Proposition 2. *If $m'(\rho) > 0$, then $l_k'(\rho) = 0$*[7]*, i.e. whenever the firm chooses to hold positive cash $m'(\rho)$ for the next period, it won't draw down its credit line $l_k'(\rho)$ for the purpose of capital investment. I.e., it will save all its credit line for financing the liquidity shock in the coming period.*

Proof. Suppose $m'(\rho) > 0$ and $l_k'(\rho) > 0$. Then the following perturbation will make the firm better off:

Reduce both $m'(\rho)$ and $l_k'(\rho)$ by $\varepsilon > 0$.

This perturbation doesn't affect the continuation payoff to the firm which is proved in Lemma 2. It doesn't affect the price schedule of bond and credit line either which we could see from (Bond Interest Schedule) and (Credit Line Interest Schedule).

However, it relaxes the budget constraint of this period since $l_k'(\rho)$ carries an interest rate of $\frac{1}{q_{l_k}} > 1$. Therefore, firms are strictly better off than before. Contradiction. □

Intuitively, credit line is a cheaper instrument to finance liquidity shocks than cash. This is because credit line (used for financing the liquidity shock) is an intra-period loan carrying an interest rate of 1 while cash has to be set aside and carried over from last period and hence carries an inter-period interest rate. A firm will only hold positive cash if its credit line isn't enough to finance the liquidity shock in the intermediate period. In that case, it will optimally not waste any of the credit line for financing capital investment.

Since our model is trying to explain the cash holdings behavior of firms, parameters are calibrated so that firms have positive cash holdings. As a result, we may assume without loss of generality here that cash holdings are positive and none of the credit line is used for capital investment. This simplifies the timing (Figure 7) and firm's Bellman equation to:

[7] Note: m' and l_k' here denote the policy function for the *next period* cash holding and credit line usage. They are NOT derivatives.

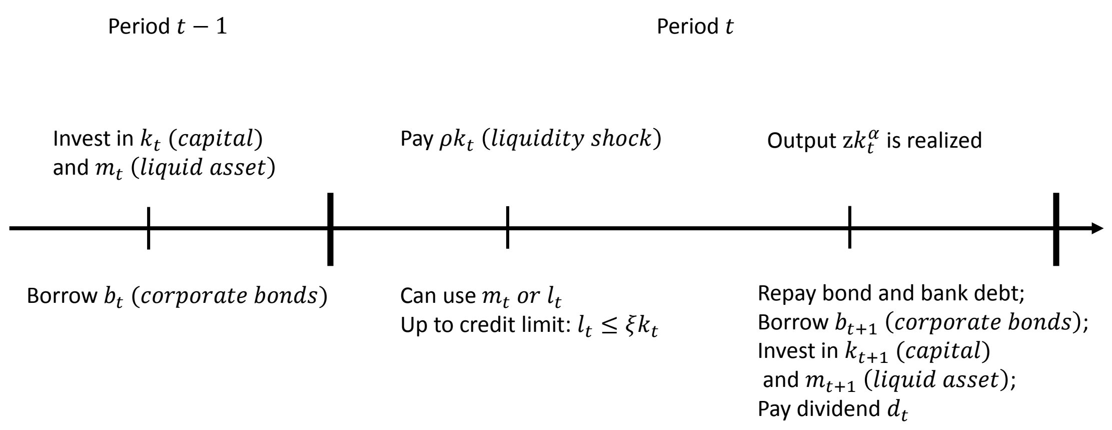

Figure 7: Timing (simplified)

Firm's Bellman equation:

$$V(k,m,b) = \max_{\rho^*, d(\rho), b'(\rho), k'(\rho), m'(\rho)} \int_{\rho \leq \rho^*} \left[d(\rho) + \beta\theta V\left(k'(\rho), m'(\rho), b'(\rho)\right)\right] g(\rho) d\rho$$

subject to

$$\rho^* k \leq m + \xi k$$

$$d(\rho) + k'(\rho) + m'(\rho) + \rho k + b + \leq q_b \cdot b'(\rho) + f(k) + (1-\delta)k + m, \forall \rho \leq \rho^*$$

$$q_b = qG\left(\frac{m'(\rho) + \xi k'(\rho)}{k'(\rho)}\right)$$

4.2 Bonds and Bank Credit Lines

As discussed above in firms' problem, firms issue one-period corporate bonds $b'(\rho)$. Interest schedule on bonds takes into account the bankruptcy probability of the firms:

$$q_b = qG\left(\frac{m'(\rho) + \xi k'(\rho)}{k'(\rho)}\right)$$

Bank loans come in the form of credit lines with credit limits. For a firm with capital stock k_t, its credit limit is ξk_t. We motivate this credit limit as a result of renegotiation process between firms and banks when credit line debt becomes due. To be concrete, we assume that firms cannot commit to pay back their credit lines. When the credit line debt becomes due, firms have the option of renegotiating with banks about how much money they will pay back. If the renegotiation fails, banks will grab firms' capital stock k_t and liquidate it in the market at some exogenous price ξ. Therefore, no matter how much banks lend to the firms during the lending stage, ξk_t is the maximum amount of money banks can get back during the pay-back stage (outside option of the banks). For simplicity, we assume firms make take-it-or-leave-it offers during the renegotiation stage and hence banks will get no more than their outside option. This motivates the credit limit of ξk_t on the credit lines.

4.3 Households

Households' problem is relatively simple. They consume the dividends paid out by the firms and save in the bond market. Households are risk averse and discount future at rate β. In the stationary equilibrium risk free rate $q = \beta$.

$$W(b) = \max_{c,b'} U(c) + \beta W(b')$$

subject to

$$c + b \leq qb' + D$$

where D is the aggregate dividends paid out to the households. Denote the policy functions of the households by c^h, b^h.

4.4 Equilibrium

A stationary equilibrium is a collection of functions $V, W, m', d', k', b', c^h, b^h$ and the risk free rate q such that:

1. Given q, V, m', d', k', b' solve individual firm's problem

2. Given q, W, c^h, b^h solve households' problem

3. Goods market and bonds market clear

5 Quantitative Analysis

To facilitate a comparison of our credit line shocks with shocks to the standard borrowing constraint (henceforth standard credit shocks), we add a standard borrowing constraint (Standard Borrowing Constraint) to the previous analyzed problem. Specifically, we numerically solve the following problem:

$$V(k,m,b) = \max_{d(\rho),b'(\rho),k'(\rho),m'(\rho)} \int_{\rho k \leq m+\xi k} \left[d(\rho) + \beta\theta V\left(k'(\rho), m'(\rho), b'(\rho)\right)\right] g(\rho) d\rho$$

subject to

$$d(\rho) + k'(\rho) + m'(\rho) + (\rho k - m) + b \leq q_b \cdot b'(\rho) + f(k) + (1-\delta)k$$
$$q_b = qG\left(\frac{m'(\rho) + \xi k'(\rho)}{k'(\rho)}\right)$$
$$b \leq \eta k \qquad \text{(Standard Borrowing Constraint)}$$

We simulate a panel of 100,000 firms to the stationary distribution. Then we study the impulse responses of this economy to various shocks.

5.1 Calibration

We choose the following parameters independently of the model equilibrium. Discount factor β is set to 0.96 to match annual interest rate 4%. Depreciation rate is set to 5%, as estimated by Nadiri and Prucha (1996). Curvature of the production function α is set to 0.7, as in Hennessy and Whited (2007) and Cooper and Ejarque (2003)[8]. Productivity z is normalized to 1. Exogenous death rate is set to $0.01 > 0$ to ensure the existence of a stationary equilibrium.

Next we move on to the set of parameters that we estimate using firm-level data from COMPUSTAT. The most important task is to estimate the structure of corporate liquidity shocks. To

[8]For a detailed discussion of choice of α in production functions without labor, see Covas and Haan (2012b).

our knowledge, this has not been done in the literature. Current liabilities are what a firm needs to pay within a relatively short period of time. Hence we use the ratio of current liabilities over total asset as proxy for liquidity shocks of the period. We estimate the mean and variance of liquidity shocks using cross-sectional mean and variance of firms' current liabilities over total asset ratio, respectively. The assumption behind our estimation is that all firms are subject to the same process governing the idiosyncratic liquidity shock.

In our model there are two types of borrowing constraints: standard borrowing constraint and credit line limit. We estimate the former using the leverage ratio and the latter using credit line over capital ratio as documented in Sufi (2009). A summary of our calibration is presented in table 1.

Before explaining the results of our quantitative exercise, it is useful to discuss how well the model does in capturing some of the key moments in data. One way of checking the validity of our estimates is to compare the cash over capital ratio of our model to the data. In our calibrated model, cash over capital ratio is 0.32, while in the data it is 0.31.

Calibrated parameters			Source		
Discount factor	β	0.96	Annual interest rate 4%		
Depreciation rate	δ	0.05	Nadiri and Prucha (1996)		
Technology	α	0.7	Cooper and Ejarque (2003)		
Productivity	z	1	Normalization		
Exogenous death rate	θ	0.01	Guarantee existence of stationary equilibrium		
Estimated parameters			**Target moments**	**Model**	**Data**
Mean of liquidity shocks	μ_c	0.35	Cross-sectional mean of current liabilities/asset ratio	0.26	0.23
Variance of liquidity shocks	σ_c	0.032	Cross-sectional variance of current liabilities/asset ratio	0.018	0.02
Credit line constraint	ξ	0.57	Mean of available credit line/capital ratio	0.56	0.54
Standard borrowing constraint	η	1.1	Mean of leverage ratio	0.73	0.61
			Untargeted moment		
			Mean of cash/capital ratio	0.32	0.31

Table 1: Calibration

5.2 Impulse Response

5.2.1 Key Result

Our key results are illustrated in Figure 8. The top row is for large firms (net worth at top 25% of firms). Standard credit shocks (tightening of bond borrowing constraint) are unable to generate a reduction in capital expenditure, or an increase in liquid assets holdings for large firms, whereas credit line shocks are able to generate both.

The intuition is as follows. Large firms have accumulated enough net worth so that their borrowing constraints are no longer binding. Therefore, standard credit shocks have no effects on their investment decision. However, credit line shocks do have an effect on large firms by forcing them to hold more cash. Costly cash holdings increase the effective marginal cost on capital investment. Therefore, firms optimally choose to reduce investment.

For small firms (net worth at bottom 25% of firms), both standard credit shocks and credit line shocks reduce their capital investment because these firms are both borrowing constrained and liquidity constrained. But their implications on corporate cash holdings are different. Standard credit shocks reduce corporate cash holdings because they reduce corporate investment, whereas credit line shocks force firms to hold more cash per unit of capital.

Finally, productivity shocks lead to a reduction in capital for both large and small firms, consistent with the data. However, productivity shocks also imply a counter-factual reduction in liquid assets holdings.

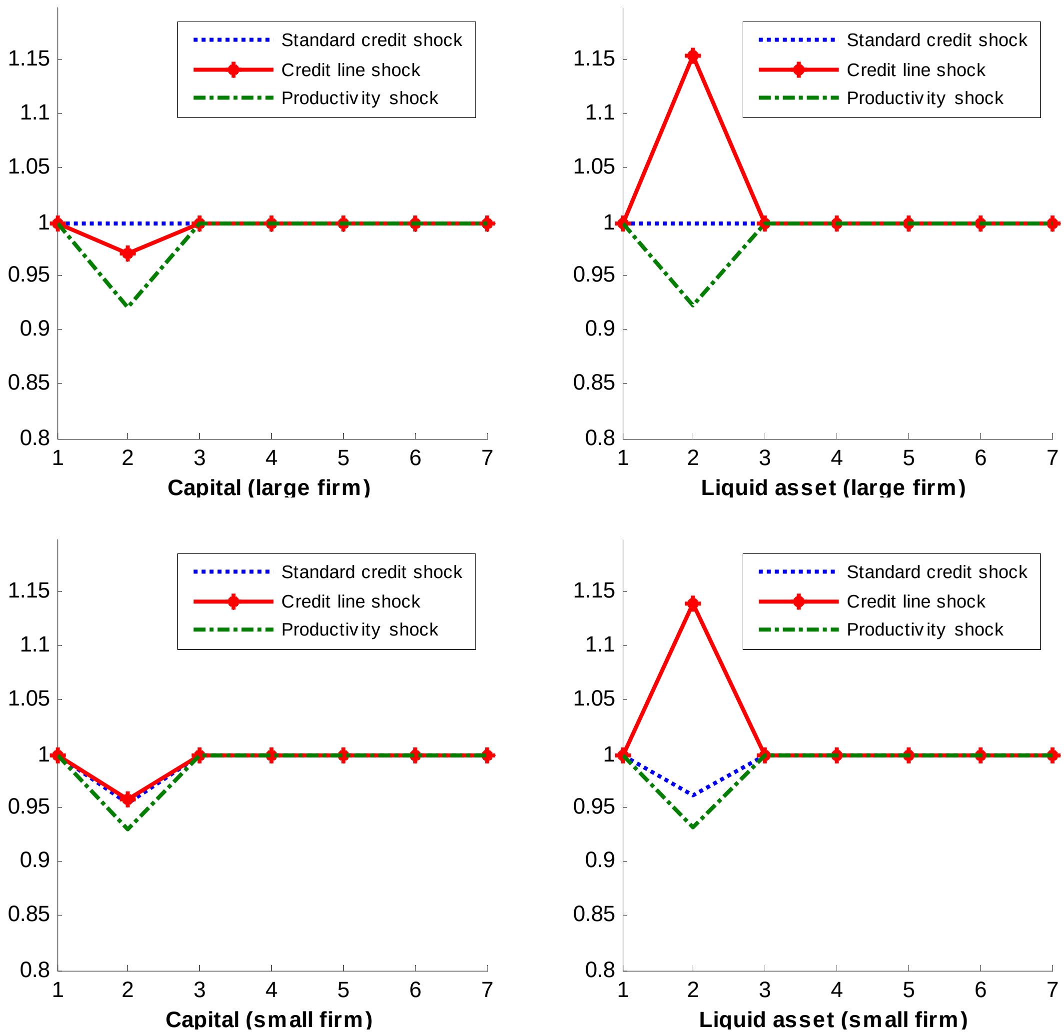

Figure 8: Cross sectional impulse responses to 10% standard credit shock, 10% credit line shock and 5% productivity shock. Large firms refer to the top 25% of firms in terms of net worth. Small firms refer to the bottom 25% of firms. Standard credit shocks have no effect on large firms. Productivity shocks induce firms to hold less liquid assets (not consistent with the data) by inducing them to hold less physical capital. Credit line shocks generate a decrease in capital and an increase in liquid assets holdings for both large and small firms.

5.2.2 Prediction of Loan-Bond Composition

Adrian, Colla and Shin (2013) documents that loan financing collapses whereas bond financing remains strong. Our credit line shocks match that feature in the data, whereas standard credit shocks and productivity shocks do not (Figure 9). As credit line shocks hit, firms' demand for liquid assets rises. This increases the demand for corporate bonds despite a reduction in corporate investment.

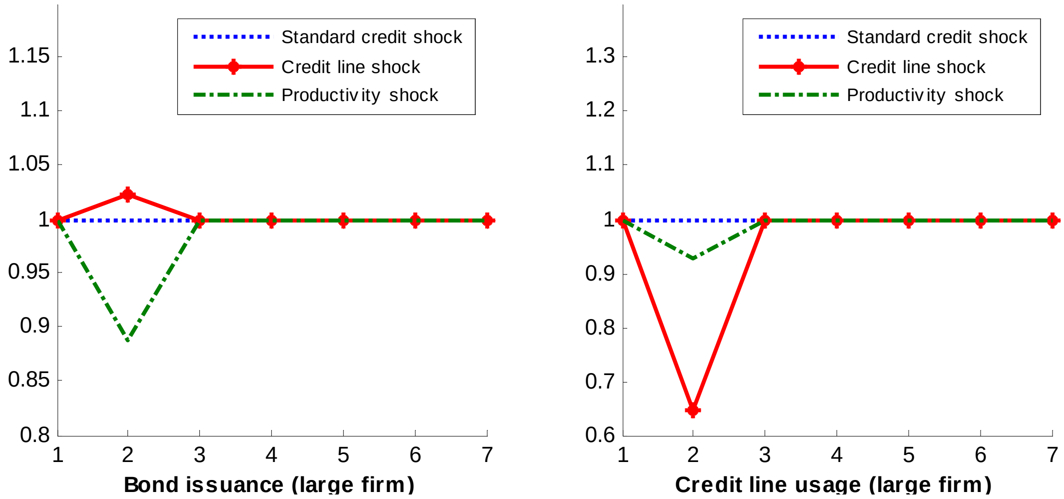

Figure 9: Cross sectional impulse responses to 10% standard credit shock, 10% credit line shock and 5% productivity shock. Large firms refer to the top 25% of firms in terms of net worth. Productivity shock generates a decrease of both bond issuance and credit line usage. Standard credit shock has no effect on large firms. Credit line shock generates an increase in bond issuance as well as a decrease in credit line usage.

6 Conclusion

In this paper, we document a significant reduction in capital investment, an increase in liquid assets holdings, and an increase in relative amount of corporate bonds issuance to bank loans issuance by self-financing firms during the Great Recession.

These three facts cannot be simultaneously accounted for in models with collateral constraints or productivity shocks. To explain the three facts, we propose a model where firms' capital stock is subject to *liquidity shocks*. Bank credit lines and liquid assets are substitutes for insuring against liquidity shocks and safeguarding capital investment. Given the amount of credit lines available, firms have to bundle one unit of capital with certain units of liquid assets to cover the remaining liquidity risk. When banks tighten the credit lines, firms have to bundle extra units of liquid assets with each unit of capital to cover the increased liquidity risk. Holding liquid assets, however, is costly because of their low return. This increases the marginal cost of capital investment. Hence, firms optimally reduce their capital investment.

Then we calibrate our model to firm-level balance sheet information from COMPUSTAT, and compare the predictions of negative productivity shocks in a standard RBC model, tightening of the collateral constraints in a standard model of financial frictions, and credit line shocks in our model. We find that standard credit shocks do not affect self-financing firms, leaving their capital expenditure and cash holdings unchanged; productivity shocks generate a decrease of capital expenditure across firm sizes. But they imply a counter-factual reduction in firms' liquid assets holdings; credit line shocks generate a decrease in capital expenditure as well as an increase in liquid assets holdings across firm sizes. Credit line shocks also generate a compositional change between loans and bonds as in the data.

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