Bank Liquidity Supply and Corporate Investment during the 2008–2009 Financial Crisis

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Abstract

I document a line of credit channel through which bank liquidity supply shocks affect corporate investment during the 2008–2009 financial crisis. By exploiting the predetermined variation in the maturity structure of lines of credit, I find that firms whose last pre-crisis lines of credit become due at the time of the crisis (treated firms) cut investment by more than similar firms whose lines of credit mature after the crisis. Moreover, this effect is stronger for financially constrained firms, bank-dependent firms, and firms whose pre-crisis banks are unhealthy. Within the treated group, firms with unhealthy banks are less likely to obtain lines of credit in the crisis than those with healthy banks. Finally, in the sample of firms with lines of credit before the crisis, I find that those with unhealthy banks experience lower growth in lines of credit and investment, but this effect is restricted only to unrated firms.

Keywords: Bank liquidity supply, lines of credit, corporate investment, financial crisis, matching estimators

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1 Introduction

During the 2008–2009 financial crisis, banks suffered large losses caused by mortgage delinquencies, and bank lending and corporate investment then declined dramatically. An influential view that explains these crisis events holds that a bank credit supply shock originating outside of the corporate loan sector forced banks to reduce credit to firms, which in turn led to investment cuts and the Great Recession (Brunnermeier, 2009). However, some researchers find that the bank credit supply shock had little impact on corporate investment during the crisis (Kahle and Stulz, 2013). In this paper, I study the role of an important source of external liquidity—bank lines of credit—in transmitting the bank credit supply shock to the economy.

Bank lines of credit are one of the main liquidity management instruments for firms and are of similar magnitude to cash holdings (Sufi, 2009; Campello *et al.*, 2011). Firms drew down their credit lines more aggressively during the crisis than they did in normal times, as evidenced by empirical work based on both supervisory data (Ivashina and Scharfstein, 2010; Chodorow-Reich and Falato, 2018) and survey data (Campello *et al.*, 2010; Campello *et al.*, 2011). Firms also report that they use credit lines to exploit future business opportunities (Lins *et al.*, 2010). Hence, it is likely that the bank credit supply shock can affect corporate investment through a line of credit channel.

I employ two empirical strategies to assess the impact of bank lines of credit on firm investment. In the first strategy, I exploit the predetermined variation in the maturity structure of pre-crisis lines of credit (LC) to investigate whether firms with LC maturing at the time of the crisis perform differently from those with LC maturing after the crisis. If the bank credit supply shock affects corporate investment, I would then expect that firms with LC maturing at the time of the crisis face more severe liquidity pressures because of illiquidity in the banking sector than otherwise similar firms with LC maturing after the crisis. As a result, firms' inability to obtain liquidity on demand may lead to a fall in investment if other sources of financing are also costly.

More specifically, the first approach uses Abadie and Imbens (2011) matching estimator of the average treatment effect for the treated (ATT) to compare the change in investment of firms whose last pre-crisis credit lines mature at the time of the crisis period

(treated firms), October 2008 to June 2009 (Chodorow-Reich, 2014), with that of the matched control firms selected from the group of firms whose last pre-crisis credit lines mature after the crisis (non-treated firms). Following Almeida *et al.* (2011), in the baseline matching, I match firms based on size, cash flow, cash, *Q*, leverage, industry, and credit ratings, all measured in 2006.

I find that the maturity structure of pre-crisis LC has an economically large effect on crisis investment. The baseline result shows that treated firms reduce their average quarterly investment by 0.70 percentage point more in the crisis (a 31% lower investment rate compared with the pre-crisis investment level) than matched control firms. The parallel trends assumption seems to be satisfied because treated and control firms exhibit similar investment trends in the pre-crisis period. A placebo test shows that firms that have LC maturing in the first three quarters of 2007, a non-crisis period, perform similarly to control firms that do not have LC maturing in the same non-crisis period. That is, maturing LC in a period without bank liquidity shocks does not affect corporate investment. Overall, the results are consistent with the causal effect of bank liquidity supply on investment outcomes during the crisis.

The key identification assumption in the matching strategy is that the assignment to the treated and non-treated group is exogenous to firm outcome variables, conditional on observable firm characteristics. In the baseline matching, I measure the predetermined variation in whether firms have their last pre-crisis LC maturing at the time of the crisis based on information available right before the Lehman bankruptcy (September 15, 2008).[1] This is subject to the criticism that some smart CEOs may have predicted the 2008 financial crash before the Lehman failure and adjusted their LC beforehand, which undermines the assumption of a predetermined maturity structure of the last pre-crisis LC. To address this issue, I examine the maturity structure of credit lines that were originated prior to the end of 2006, a normal time period when firms were less likely to have anticipated the financial turmoil in late 2008.[2] Based on the information set in 2006, treated firms are defined as those

[1] Chodorow-Reich (2014) also uses this cutoff date to define the last syndication before the crisis, as the TED spread soared to a record-high level right after the Lehman collapse (see Figure 2).

[2] The average household debt default rate is around 3.3% in 2006, similar to the previous five years. It increases to 5% in 2007, 8.5% in 2008, and 11% in 2009. Banks also function normally in 2006. As a reference, an early sign of banks' weak performance points to August 2007, when BNP Paribas froze three investment funds with a high stake in subprime markets.

that have the last *pre-2006* LC maturing in the crisis, whereas non-treated firms are those that do not have *pre-2006* LC maturing in the crisis. The matching estimate of the ATT (−0.48) is slightly smaller than that in the baseline matching (−0.70) but is still statistically significant. The findings based on the more predetermined maturity structure of LC further reinforce the causal effect of bank liquidity supply on investment.

I conduct a series of robustness tests and consistently find similar estimates of ATT, in terms of both economic magnitude and statistical significance. First, I document that the matching results are robust to the choice of control variables. In particular, the results are similar when matching additionally on the maturity of LC at the time of issuance, which excludes the possibility that firms match the maturity of LC to that of investment opportunities.[3] Second, I show that maturing LC is not a proxy for maturing long-term debt that affected investment, as documented in Almeida *et al.* (2011). In particular, the matching results remain unchanged when matching additionally on long-term debt due at the time of the crisis. Last, standard regression tests yield similar results.

I next examine whether the effect of the predetermined maturity structure of LC varies with firms' financial constraint levels. If the bank credit supply shock story explains the investment decline in the crisis, then firms that are *ex ante* more financially constrained or more reliant on external financing should be more adversely affected by maturing LC in the crisis. Consistent with this prediction, I find that treated firms in the financially constrained group (high leverage, non-dividend payer, low payout ratio, high Kaplan-Zingales index, and bank-dependent) or in the high level of external finance dependence group (both firm- and industry-level) are more severely affected by maturing LC in the crisis than treated firms in the financially unconstrained group or in the low level of external finance dependence group. For example, for high Kaplan-Zingales index (financially constrained) treated firms, their investment experiences a fall of 1.66 percentage points relative to control firms, but for low Kaplan-Zingales (financially unconstrained) treated firms, their investment increases by a small and statistically insignificant 0.12 percentage point relative to corresponding control firms.

[3] In other words, both treated and matched control firms have the similar maturity of LC at the time of issuance (e.g., 36 months LC). They only differ in when their pre-crisis credit lines become mature.

Furthermore, I test whether the health of pre-crisis banks matters.[4] If bank liquidity supply affects corporate investment and bank relationships are sticky enough (Chodorow-Reich, 2014), then treated firms that are attached to unhealthy banks in the pre-crisis period should be more adversely affected by expiring LC than those that borrow from healthy banks. That is exactly what I find.

I then investigate the channels through which bank health may affect firm investment. Formal regression tests consistently find that, within treated firms, those attached to unhealthy banks in the pre-crisis period are less likely to obtain bank liquidity during the crisis.[5] Therefore, bank lines of credit play an important role in transmitting bank health to firms.

A valid concern is that the heightened debt rollover risk in the crisis may also explain the effect of maturing LC on corporate investment. I exclude this possibility by showing that that treated firms with healthy lenders are less adversely affected than those with unhealthy lenders.

I also examine the value implications of maturing LC in the crisis to assess whether projects that are cut are value-maximizing. I document that treated firms' *Q* declines by more in the crisis when they cut investment. Looking at firms' adjustment of cash and other policies, I find that treated firms also save more cash but barely adjust other policies, including inventory, dividend, research and development. Treated and control firms also share similar growth in cost of goods sold (COGS), selling, general and administrative expense (SG&A), sales, and employment, suggesting that firms with maturing LC in the crisis may be forced to hoard cash to pay for additional expenses that were partly covered by LC and firms find it hard to adjust.

To sum up, I interpret the matching results as follows. When firms' pre-crisis credit lines mature in the crisis, firms suffer an insufficient supply of bank liquidity and

[4] Bank health is defined as the percentage change in the number of loans to all other firms between the normal and crisis periods (Chodorow-Reich, 2014; see details in Section 4.1). I also use ABX exposure as an IV for bank health, where ABX exposure is defined as the lead bank's exposure to ABX AAA 2006-H1 index. I justify the exogeneity of bank health in Section 4.3.

[5] Summary statistics also tell the same story. Out of the 47 treated firms whose pre-crisis banks have large ABX exposures (firm-level ABX exposure is defined as the lead bank's exposure to ABX AAA 2006-H1 index), only 5 (11%) firms obtain new LC in the crisis, whereas out of the 47 treated firms whose pre-crisis banks have small ABX exposures (healthy), 25 (53%) firms originate LC in the crisis.

consequently are forced to cut investment. Consistent with the bank credit supply shock story, this effect is more pronounced for financially constrained firms, bank-dependent firms, and firms that are attached to unhealthy banks. Notably, treated firms attached to unhealthy banks are less likely to obtain bank liquidity in the crisis. Therefore, bank credit supply shocks are transmitted to firms through a line of credit channel.

The second part of this paper examines whether bank credit supply shocks affect corporate liquidity and investment for more general firms irrespective of the maturity structure of LC. In other words, I focus on the sample of firms that originate credit lines at least once before the crisis. I follow the empirical strategy in Chodorow-Reich (2014), who studies the effect of bank credit supply on employment, to study the effect of bank health on corporate liquidity growth and investment growth in the crisis.

The key identification assumption in the second strategy is that conditional on observable characteristics, bank health is uncorrelated with unobserved credit demand shocks that affect liquidity and investment growth. The fact that the 2008–2009 financial crisis originated outside of banks' corporate loan portfolios makes it suitable to disentangle the credit supply effect from the demand effect. In the formal tests, following Chodorow-Reich (2014), I justify the exogeneity of the bank health measure by showing that, for the subset of firms that originate LC in both the pre-crisis and crisis periods, the effect of bank health on firm-bank level liquidity growth is the same in regressions with and without firm fixed effects, which would not hold if unobserved credit demand shocks are correlated with bank health.

The results of the second strategy are as follows. First, the loan-level regressions show that for the same firms receiving LC from at least two banks in the pre-crisis period, they receive more bank liquidity in the crisis from healthy banks than from unhealthy banks. Such loan-level tests fully control for changes in investment opportunities at the firm level. Second, firm-level regressions indicate that bank health has a large, positive effect on firms' LC liquidity growth and investment growth. In the baseline OLS regression, a one standard deviation increase in bank health boosts investment by 8.2%. Third, the effects of bank health on the growth of LC and investment are restricted only to unrated firms. Fourth, firms with healthy banks use more LC in the crisis when managing their corporate liquidity (LC

plus cash). In other words, bank health affects firms' choice of external liquidity LC and internal liquidity cash. Last, I gauge the aggregate effect of the bank credit supply shock on investment in the full unrated sample (Chodorow-Reich, 2014). I document that for unrated firms with negative investment growth, bank health can explain 22.4% of the aggregate investment drop. For unrated firms with positive investment growth, if there were no bank credit supply shock, their investment would have been boosted by another 21.8%.

Overall, the results of both empirical strategies highlight a line of credit channel through which bank credit supply shocks are transmitted to firms. For the firms with pre-crisis LC maturing in bad times, the tight bank liquidity provision in the crisis forces firms to reduce investment. Importantly, firms that are attached to healthy banks in the pre-crisis period experience higher bank liquidity growth and investment growth in the crisis.

This paper is closely related to the recent literature that examines the effect of the 2008 financial crisis on U.S. firms' financial policies and investment. Kahle and Stulz (2013) argue for a demand shock story based on their finding that bank-dependent firms perform similarly to non-dependent firms. However, most firms have LC (Sufi, 2009), and about 90% of credit lines mature after the crisis (Chodorow-Reich and Falato, 2018).[6] Hence, most firms could potentially draw down their pre-crisis LC to withstand bad times. Almeida *et al.* (2011) show that the maturity structure of long-term debt has a causal effect on firm investment in the crisis. However, their results do not point out whether or not the effect is due to a bank credit supply shock. Existing literature also documents the increased drawdown behavior of firms in the crisis (Ivashina and Scharfstein, 2010; Campello *et al.*, 2010), but they do not study the relation between LC and investment. Campello *et al.* (2011) examine the connection between liquidity management and pro forma planned investment based on survey data, but they do not argue for a bank credit supply shock story. My focus on LC directly traces the effect of firm outcomes to the bank liquidity supply side, and I employ the predetermined maturity structure of LC to establish a causal relation between LC and investment. Chodorow-Reich and Falato (2018) study how bank health is transmitted to

[6] Sufi (2009) documents that 81.7% of firm-years have LC for all the public firms in Compustat from 1996 through 2003. Based on supervisory data (Shared National Credit), Chodorow-Reich and Falato (2018) find that only 10% of bank loans have a remaining maturity of less than one year at the time of the crisis; the remaining 90% of bank loans mature after one year.

firms whose loans mature after the crisis. My paper complements their work in that I focus on the firms that are excluded in their paper—that is, firms that have LC due at the time of the crisis—and I document a line of credit through which bank credit supply shocks are transmitted to firms.

This research also adds to the broader literature studying the transmission of bank credit supply shocks. Recent papers use non-U.S. credit registry data to estimate the effect of bank credit supply (Cingano *et al.* 2016; Iyer *et al.* 2014; Khwaja and Mian 2008; Schnabl, 2012). The detailed loan-level data in the credit registry database greatly enhance the identification strength and better control for both observed and unobserved credit demand shocks by including firm fixed effects in the regression of change in outcome variables. However, the credit registry data often restrict analysis to the effect of bank health on firms' financial policies, with few papers offering real-side implications.[7] The second identification approach in this paper is the same as the one used in the above papers in that I also use loan-level data to better control for credit demand shocks, albeit in a small sample because of limited LC originations in the crisis. This article differs from the above papers in that I focus on U.S. firms and study the effect of bank liquidity supply not only on firms' liquidity but also on their investment.

Finally, this article is related to a strand of literature that examines firms' choice between cash and lines of credit (Sufi, 2009; Yun, 2009; Acharya *et al.*, 2013). All these papers look at how the characteristics of firms affect their corporate liquidity. This paper is the first to show that bank credit supply shocks can affect firms' choice of cash and lines of credit, which supports the prediction in Acharya *et al.* (2013).

The reminder of this paper is organized as follows. Section 2 presents the data and variable definitions. Section 3 introduces the matching strategy and shows the effects of the maturing LC on investment. The results on heterogeneous effects by financial constraints, external finance dependence, and bank health are also presented. Section 4 uses loan- and firm-level regressions to study the effect of bank health on corporate liquidity growth, investment growth, and corporate liquidity choices. Section 5 concludes.

[7] One exception is Cingano *et al.* (2016), who have data on both bank credit and firm investment on Italian firms, most of which are small firms.

2 Data

I begin with loan-level data from Dealscan, which has detailed loan origination data such as loan start date, end date, loan amount, and lenders data. I use such information to identify whether firms have LC maturing in the crisis and to construct bank health measure. I clean Dealscan data mainly following Chodorow-Reich (2014). More specifically, I start collecting all the loans originated in the U.S. and made to U.S. firms with the primary purpose of the loans being "corporate purposes" or "working capital",[8] the most common two types of primary purpose. I also require that at least one of a loan's lead lenders is from the 43 most active lenders in Chodorow-Reich (2014). Based on these loan origination data, I construct a bank health measure in equation (1) as defined later.

Based on Dealscan, I obtain the loan start date of a firm's last pre-crisis syndication and the information on whether that syndication is a LC or term loan. I choose all the firms whose last pre-crisis loan is a LC. The main reason to focus only on LC, instead of term loans, is that firms normally use only a small portion of total LC,[9] whereas term loans are often fully drawn down when loans start. Therefore, when crisis happens, firms whose last pre-crisis syndication is a LC can potentially use such bank liquidity commitment by drawing down cheap LC with predetermined low loan margins relative to prevailing funding cost in the crisis. However, firms whose last pre-crisis facility is a term loan cannot use such loan in the crisis because it has been fully drawn down already. In other words, a pre-crisis LC serves as cheap liquidity to firms in the crisis, but a pre-crisis term loan does not. Another reason not to focus on term loan is that it is more likely to include non-bank financial institutions and more likely to be sold by banks, so the measure of bank health for term loan lenders is likely to have more measurement errors based on the health of commercial banks. The reason to focus on only the last, instead of all the pre-crisis LC, is that Dealscan has good quality data of loan originations but incomplete data on loan amendment and early termination. The focus on last pre-crisis LC will better capture the accuracy of the LC availability during or after crisis and most recent bank relationships. Based on this information, I determine whether firms have last pre-crisis LC due in the crisis.

[8] The next common type is corporate takeover.
[9] On average, firms draw down about one third of total LC in the random sample of Sufi (2009).

I then merge Dealscan data with firm financials data from Compustat's North America Annual and Quarterly data using the Dealscan-Compustat link table from Chava and Roberts (2008). As a result, only public firms are included in the analysis. I then construct the followings firm financial control variables. Cash flow is defined as EBITDA (oibdq) over lagged assets (atq). Cash is cash (cheq) divided by lagged assets. Size is defined as log of assets. Market-to-book ratio is market value of assets (total assets (atq) + market value of equity (cshoq * prccq) – common equity (ceqq) – deferred taxes (txdbq))/book value of assets. Leverage is total debt over book assets. Ratings data are also sourced from Compustat.

In the matching estimation, the outcome variable is the change in average quarterly investment from October 2006 - June 2007 to October 2008 - June 2009. Following Chodorow-Reich (2014), I define the crisis period as the three quarters after Lehman bankruptcy, i.e., October 2008 to June 2009. Corporate investment is quarterly capital expenditures over lagged assets. Similar to Almeida *et al.* (2011), I drop financial firms (SIC 6000s) and utility firms (SIC 4900-4949). I also drop firms with assets growth greater than 100% in a single quarter at some point in my sample period. Firms with assets less than 10 million at the end of 2006 are also dropped because the financials of these small firms are more volatile.[10]

In the baseline matching, I also require that non-treated firms, firms that do not have last LC maturing in the crisis, to have LC available right before crisis, such restriction ensures that both treated firms and non-treated firms rely on bank liquidity before crisis. My results are unchanged without this restriction. Firms with sufficient cash are dropped because firms substitute between internal and external liquidity during the crisis (*Campello, et al*., 2011), and firms with high cash reserves before crisis are less affected (Duchin *et al.*, 2010). More specifically, I drop 62 firms with cash ratio greater than 40%, leading to the final sample of 929 firms. My matching results are similar in the absence of this restriction. In the baseline matching, there are 94 treated firms and 835 non-treated firms.[11] The baseline

[10] This restriction matters little because the average Dealscan syndicate size is much larger than 10 million, so firms with assets less than 10 million normally have no loans in Dealscan. As a result, such firms will be excluded from the final sample.
[11] See the definition in section 3.1.

matching results in 88 unique control firms. As a comparison, in Almeida *et al.* (2011), there are 86 treated firms and 79 unique control firms in their baseline matching.

3 The maturity structure of credit lines and firm investment

In this section, I exploit the predetermined variation in whether firms have LC due in the crisis to investigate whether firms with LC maturing in the crisis perform differently from those without LC maturing in the crisis. Sufi (2009) shows that credit line usage is prevalent. He reports that 81.7% of firm-years in his full sample have a line of credit. The average total credit lines account for 16% of total assets, which is similar to the proportion of cash. Corporate liquidity decisions are one of the most important decisions for many CFOs. To a large extent, they view their job as securing funding for investments proposed by CEOs (Graham & Harvey 2001). If bank liquidity supply shocks affect corporate investment, given the prevalence and importance of LC in corporate liquidity management, I would expect that firms which have LC maturing right in the crisis face more severe liquidity pressures due to the illiquidity in the banking sector than firms whose credit lines do not mature in the crisis. As a result, firms' inability to obtain liquidity on demand may lead to a fall of investment if other sources of financing are also costly. Almeida *et al.* (2011) show that firms with a significant portion of their long-term debt maturing in the crisis reduce investment by more than other similar companies with long-term debt due after crisis. However, their results do no point out whether the effect is due to bank liquidity supply shocks or not. My focus on the maturity of LC provides a more direct link between bank liquidity supply and firm investment. Furthermore, I also exploit the heterogeneous bank health within treated firms to exclude debt rollover risks story and more directly test the bank liquidity supply shocks story.

3.1 Abadie-Imbens matching method

To investigate whether the maturity of LC affects corporate investment, I compare the change in investment of firms whose credit lines are predetermined to mature in the crisis to that of similar firms whose credit lines are scheduled to mature after crisis. During the crisis, the latter group still enjoys the small loan margins of LC liquidity arranged before crisis, and they can potentially draw down from the cheap LC to fund daily operations and

investment. If bank liquidity supply affects investment, then I would expect firms that have LC maturing after crisis to be less adversely affected than the firms whose credit lines are predetermined to mature right in the crisis when bank liquidity is scarce. To implement this comparison, following Almeida *et al.* (2011) and Kahle and Stulz (2013), I employ the Abadie and Imbens matching method (2004). This matching approach minimizes the distance between a vector of covariates across treated and non-treated companies and chooses the controls with a minimum distance. The Abadie-Imbens matching can produce the exact matches over categorical variables, and it implicitly account for all possible interactions of matching covariates.

The treated group is defined to be a set of firms whose last credit lines originated before Lehman bankruptcy (September 15, 2008) are predetermined to mature in the crisis October 2008 to June 2009. The baseline non-treated group contains firms whose last pre-crisis credit lines do not mature in the crisis. I also require that non-treated firms to have LC available right before crisis so that both treated and non-treated firms rely on bank liquidity LC to some extent. With this restriction, the non-treated firms are essentially firms that have LC due after crisis. As shown later, my results are unchanged without this restriction. I also require firms' last pre-crisis facilities to be credit lines to better capture the accuracy of the LC availability. The control firms are selected from the non-treated group based on the Abadie-Imbens matching approach using a selection of matching variables. Following Almeida *et al.* (2011) and Kahle and Stulz (2013), I match on cash flow, cash, size, market-to-book ratio (or "*Q*"), leverage, and categorical variables including industry and ratings (unrated, junk rated, and investment rated).

In the baseline matching, for each treated firm, I choose only one firm from the non-treated group as a control. Since matching is done with replacement, so there may be a fewer number of unique controls. In the robustness tests, I further choose 2 to 4 firms as controls for each treated firm. The results are similar in terms of economic magnitude and statistical significance.

Based on the Abadie-Imbens matching estimate of the average effect of the treatment on treated (ATT), I can infer whether the predetermined maturity of LC has an impact on

corporate investment. As a comparison, the traditional difference-in-differences estimator is also sometimes reported.

3.2 Results

3.2.1 Baseline matching and Placebo test

To implement Abadie-Imbens matching and determine if the predetermined maturity of last pre-crisis LC affects firm investment, I first compare the financial characteristics of treated and non-treated firms and test if the two groups differ significantly across financial variables. In the baseline matching, there are 94 treated firms and 835 non-treated firms.

Table 1 provides a comparison of the means of financials measured at the end of 2006 for treated, non-treated, and matched control firms. Panel A shows that on average treated firms are smaller, less profitable and more cash-rich than non-treated firms. After implementing the Abadie-Imbens matching, Panel B reports that these differences disappear across treated and control firms. The means of the other financial variables Q, leverage, and investment are also indistinguishable across treated and control groups.

Table 2 compares the distribution of the financials measured at the end of 2006 across treated, non-treated, and matched control firms. Panel A shows that before matching, treated and non-treated firms differ significantly in the distribution of size, cash, and leverage. Panel B demonstrates that after the matching, treated and control firms are similar in the distribution across all financial controls.

Table 3 provides the main results of the Abadie-Imbens matching method. In Panel A and Panel B, I compare the change in investment from 2006:Q4-2007:Q2 (column 1) to 2008:Q4-2009:Q2 (column 3). Panel A reports that treated firms decrease investment from 2.25 to 1.21 percentage points in the crisis, a drop of 1.04 percentage points (or 1.04/2.25=46% lower investment rate), while non-treated companies reduce investment from 1.89 to 1.34 percentage points in the crisis, a fall of 0.55 percentage point (or 0.55/1.89=29% lower investment rate). Investment drops by 0.49 percentage point more for treated firms (on a quarterly basis). The difference-in-differences (DiD) estimate is statistically significant.

Panel B presents the main matching results. Matched control firms are selected from the non-treated group based on the firm characteristics at the end of 2006. After the matching, the investment of treated firms still experiences a drop of 1.04 percentage points, while the investment of control firms is reduced by 0.40 percentage point. As a result, the DiD estimate is −0.64 percentage point. The matching estimate of ATT is −0.70 percentage point (or 0.70/2.25=31% lower investment rate). That is, treated firms that have last LC maturing in the crisis drop investment by 0.70 percentage point more than otherwise similar control firms whose last credit lines mature after crisis.

To examine whether treated firms and control firms follow parallel trends before crisis, I present the evolution of investment of treated and controls in Figure 1. Parallel assumption seems satisfied as treated and controls exhibit similar investment trend from 2004:Q4 to 2007:Q2. I also test the change in investment across treated and controls from the period 2005:Q4-06:Q2 to the normal period 2006:Q4-07:Q2, or from 2004:Q4-05:Q2 to the normal period 2006:Q4-07:Q2, the differences are small and statistically insignificant.

To strengthen the argument that bank liquidity supply shocks adversely affect firm investment, I choose a placebo period 2007:Q1-Q3 when bank liquidity supply shocks were absent, and I test if the maturity of LC in this placebo period also affects investment. In this placebo test, the pre-placebo period is defined as 2006:Q1-Q3. The treated firms are those whose last LC is due in the placebo period 2007Q1-Q3 measured at the end of 2006, and non-treated firms are those whose last pre-crisis LC is due after 2007Q3. I match on the same set of control variables measured at the end of 2006. Panel C reports the matching results. Treated firms and control firms exhibit similar investment trends in the crisis. Both DiD and the matching estimates are economically small and statistically insignificant, which suggests that the maturity of LC does not have an impact on firm investment in a non-crisis period when there are no bank liquidity supply shocks. This falsification test eliminates the possibility that some unobservable characteristics predict the maturity of LC and a drop in investment in general.

3.2.2 Value implications

One may wonder if treated firms were overinvesting before the crisis.[12] In such case, the reduction in investment would increase firm value. To evaluate this possibility, I now turn to the value implications of maturing LC in the crisis.

To this end, I compare the percentage change in *Q* from the normal period 2006Q4-2007Q2 to the crisis period 2008Q4-2009Q2 between the treated and control firms. In untabulated results, treated firms' Q decreases by –47.5%, whereas control firms' Q declines by –37.3%, leading to a DiD estimate of –10.2%. The matching estimate of the ATT (–9.1%) tells the same story. Both traditional DiD and matching estimate are statistically significant. Therefore, firms with maturing LC also lose more values in the crisis.

In short, I do not find evidence that the abandoned projects of treated firms are value-maximizing. Rather, the results are consistent with the argument that firms that are more affected by bank credit supply shocks lose more value, which may be partially attributed to the investment cut of these firms.

3.2.3 Predetermined LC maturity tests

The key identification assumption in the matching strategy is that the assignment to the treated and non-treated group is exogenous to firm outcome variables, conditional on observable firm characteristics. In the baseline matching, I measure the predetermined variation in whether firms have last pre-crisis LC due in the crisis based on information right before Lehman bankruptcy (September 15, 2008). In the data, the median treated firms originate their last pre-crisis LC in August 2006, and the median control firms receive their last pre-crisis LC in March 2007, both in a normal period.[13] Considering that it takes about three months between the time a bank approves a term sheet and the time syndication loans start (Murfin, 2012), the decisions of both typical treated firms and control firms to obtain

[12] In the baseline matching, although I do not match on the pre-crisis investment levels, the resulted control firms and treated firms not only share similar investment trend in the pre-crisis period but also have similar pre-crisis investment levels. Therefore, it is unlikely treated firms overinvest relative to control firms in the first place. In addition, when I match on the pre-crisis investment levels, treated firms still cut investment by more (the matching estimate of ATT is –0.45 percentage point).

[13] Matched control firms originate their last LC later than treated firms, because I impose the restriction in the baseline matching that non-treated firms have pre-crisis LC maturing after crisis. Such restriction naturally pushes facility start date for non-treated firms to a later time. Without this restriction, the matching results are similar.

their last pre-crisis LC are made in 2006, a normal period in which household debt default rate is still low and similar to historical levels (Mian and Sufi, 2016). In other words, it is unlikely that typical firms anticipate the collapse of subprime mortgage market and adjust their bank credit lines beforehand. Therefore, whether firms have last pre-crisis LC maturing in the crisis can be arguably viewed as predetermined.

Nonetheless, I implement the following two tests to address the concern that treated dummy is not perfectly predetermined. First, it might be possible that some smart CEOs (Almeida *et al.*, 2011) could potentially predict the 2008 financial crash, which was the worst in global history stated by Bernanke, the former Federal Reserve Chairman. Such smart CEOs adjusted their old LC originally due in the crisis by renewing the bank liquidity beforehand so that new credit lines mature after crisis. If that is the case, such firms that should have been assigned to treated group choose to self-select into non-treated group, leaving only "dumb" CEOs in the treated group. As a result, the treated dummy is less predetermined. To exclude this possibility, I exclude from the non-treated group those firms that originate their last pre-crisis LC after the end of June 2007. In other words, I exclude the non-treated firms whose CEOs could potentially foresee the 2008 financial crisis based on the information at the end of June 2007. As a reference, an early sign of banks' weak performance points to August 2007 when BNP Paribas froze three investment funds with a high stake in subprime markets. Hence, all the firms with smart CEOs are likely to be removed from non-treated firms. After this exclusion, treated firms still cut investment by more than new control firms, with the similar economic magnitude and statistically significance. Therefore, the smart CEOs story that could potentially make treated dummy less predetermined cannot explain the baseline matching results.

Second, I measure the treated dummy, whether firms have last pre-2006 LC due in the crisis, based on the information available at the end of 2006. That is, I find firms' last LC before the end of 2006, if such credit lines mature in the crisis period October 2008 to June 2009, then the corresponding firms are assigned to the treated group, regardless of whether firms amend or refinance such LC during the period January 2007 to September 2008. Accordingly, if firms' last pre-2006 credit lines do not expire in the crisis, such firms

are assigned to the non-treated group, regardless of whether firms obtain new credit lines afterwards that are due in the crisis.

The treated dummy measured at 2006 year end is more predetermined than the one used in baseline matching. However, some treated firms might amend old LC or originate new LC in the period from January 2007 to September 2008. As a result, their actual last pre-Lehman collapse (September 15, 2008) LC might mature after crisis. If the majority of treated firms amend LC in that period, then the matching estimate might change materially. By this definition of treated dummy using the 2006 year end information, I end up with 98 treated firms. About one third of these treated firms amend old LC or originate new ones between January 2007 and September 2008, so that new credit lines do not mature in the crisis. The rest two thirds still have last pre-crisis LC due in the crisis.

Table 4 column 1 presents the matching results based on the more predetermined treated dummy. Treated firms still cut investment by more. The matching estimate (−0.48 percentage point) is smaller than that (−0.70) in baseline matching based on the information before Lehman failure, which is reasonable since about one third of treated firms based on 2006 information do not actually have LC due in the crisis. However, the matching estimate is still statistically significant. I then split the 98 treated firms in column 1 to two groups, the 61 firms in column 2 that do not adjust their LC and actually have last pre-crisis LC due in the crisis, and 37 firms in column 3 that do not have last pre-crisis LC due in the crisis. Column 2 show that firms in former group do reduce investment by more. The economic magnitude of matching estimate is rather large (−1.23) and statistically significant, whereas firms in the latter group increase investment by more (0.84). Overall, based on the more predetermined treated dummy measured at 2006 year end, the treated firms that have last pre-2006 LC due in the crisis period 2008Q4-2009Q2 still cut investment by more. This effect is driven solely by the treated firms that do not adjust their last pre-crisis LC and actually have last pre-crisis LC maturing in the crisis. The results are consistent with the interpretation that when firms' pre-crisis credit lines mature in a period with limited bank liquidity supply, firms reduce investment due to insufficient liquidity provision.

3.2.4 The heterogeneous effect by financial constraints

I next examine whether the effect of predetermined maturity of LC in the crisis varies in the firms with different levels of financial constraints. If bank lending supply shocks story explains the investment decline in the crisis, then firms that are *ex ante* more financially constrained or more reliant on external financing should be more adversely affected by the maturity of LC in the crisis. Put differently, within the treated firms that have LC due in the crisis, the investment behavior of financially constrained firms should drive the main matching result to a larger degree than that of unconstrained firms.

To implement the tests, I split the 94 treated firms into two groups based on the medians of *ex ante* financial constraint measures or external financing dependence measures in the treated sample. Then I separately match each group to the full sample of 835 non-treated firms. For example, when splitting based on Kaplan-Zingale index (K-Z index), I first find the median of K-Z index of 94 treated firms. Then all the treated firms below the median K-Z will be matched to the full sample of 835 non-treated firms, the matching estimate of this ATT for this matching is 0.12 percentage point, reported in Table 5 column 4 row 7; all the treated firms above the K-Z index median will also be matched to the same 835 non-treated firms, the corresponding matching estimate is −1.66 percentage points, displayed in column 4 row 8.

The variables I initially choose to measure the financial constraint include leverage, non-dividend payer, payout ratio, Kaplan-Zingale index, and bank dependence (Kahle and Stulz, 2013), all measured at the end of 2006. Non-dividend payer is the group of firms that do not pay dividend in the past three years prior to 2006. Bank dependent firms are defined as those that have two or more loans with the same U.S. lead lender in the five years before 2006 (Kahle and Stulz, 2013). The rest firms form the non-bank dependent group. The variables to measure the extent to which firms rely on external financing are firm level and industry level external finance dependence. Firm level external finance dependence is defined as the proportion of investment not financed by cash flow from operations. Industry level external finance dependence is defined as the industry (SIC2) median of firm level external finance dependence (Duchin *et al.*, 2010). This industry level variable is less influenced by firm choices, thus are more exogenous.

Table 5 reports the matching results by different definitions of financial constraint and external finance dependence. I consistently find that treated firms in the financially constrained group (high leverage, non-dividend payer, low payout ratio, high Kaplan-Zingales index, bank dependent firms) or in the high level of external financing dependence group (both firm level and industry level firms) are more adversely affected by the maturity of LC in the crisis than treated firms in the financially unconstrained group (low leverage, dividend payer, high payout ratio, low Kaplan-Zingales index, non-bank dependent) or in the low level of external financing dependence group. For example, in column 7, 94 treated firms are split into 50 low and 44 high industry level external finance dependent treated firms. After matching each subgroup with all the 835 non-treated firms, column 7 reports that the investment for high industry level external dependent treated firms experiences a fall of 1.34 percentage points relative to control firms, but the investment for low external dependent treated firms drops by only statistically insignificant 0.12 percentage point relative to their corresponding controls. Therefore, high external dependent treated firms are more adversely affected by the expiration of LC in the crisis. In sum, the results are consistent with the prediction of bank liquidity supply shocks story, i.e., treated firms that are *ex ante* financially constrained are more severely affected.

3.2.5 The heterogeneous effect by bank health

To more directly examine if bank liquidity shocks affect the corporate investment, I exploit the variation of bank health within treated firms. If bank liquidity supply story explains the differential response of treated and control firms to the maturity of bank liquidity in the crisis, I would expect those treated firms whose pre-crisis banks are unhealthy to be more adversely affected by the maturity of LC, because such treated firms may be less likely to obtain new bank liquidity in the crisis.

Similar to Chodorow-Reich (2014), I measure the bank health in two ways. First, I use percentage change in loans to all other borrowers $\Delta L_{-i,b}$ (see equation (1) as shown later). Specifically, $\Delta L_{-i,b}$ equals the change in the number of loans made by firm i's lead bank b to all other firms between the periods 2005:10-2006:6 & 2006:10-2007:6 and the crisis periods 2008:10-2009:6. Lead bank refers to that in the firm's last pre-crisis LC. The second measure of bank health is ABX exposure, which is defined as the lead bank's exposure to

ABX AAA 2006-H1 index. This index tracks the price of residential mortgage-backed securities issued in later 2005 and it has an AAA rating at issuance. The ABX exposure is defined as the loading of a bank's stock price to this index over the period October 2007 to December 2007. I obtain ABX exposure data from Chodorow-Reich's website. Firm level measures of ΔL_i (see equation (2)) and ABX exposure are the weighted average by bank allocation over the lead banks in the last pre-crisis LC.

The matching procedure is the same as the one in analyzing the heterogeneous effects by financial constraints. I split the 94 treated firms into two subgroups based on the medians of bank health measures, and then match each subgroup to all the 835 non-treated firms. Table 6 presents the results. Column 1 reports that treated firms with unhealthy lead banks (low ΔL_i) in the last pre-crisis LC are severely affected by LC expiration cut investment by 0.84 percentage point, but firms with healthy lead banks (high ΔL_i) cut investment by 0.56 percentage point. In particular, column 2 shows that treated firms attached to the last pre-crisis banks with a large ABX exposure reduce investment significantly by 1.08 percentage points, whereas treated firms whose last pre-crisis banks with a small ABX exposure share the same investment trend as control firms. This result directly traces the investment behavior of the treated firms to the bank losses from "toxic" assets.

A related concern in interpreting the baseline matching results in Table 3 is that the heightened debt rollover risk in the crisis may also explain the effect of LC maturity on corporate investment. One may argue that consumptions fell significantly in late 2008 and firms' debt repayment risks increased accordingly. However, out of 94 treated firms, only 28 (34) treated firms draw down funds from LC in 2006 (2007). The majority of treated firms have zero debt under LC. When I exclude the treated firms that have drawdown activities in either 2006 or 2007, and match the majority of treated firms without drawdown to the full non-treated firms, the matching results are slightly larger in economic magnitude and still statistically significant. Abadie-Imbens ATT estimate is −0.83 percentage point (−0.91) when removing 28 (34) treated firms with drawdown activities in 2006 (2007), compared to −0.70 percentage point in the baseline matching in Table 3. Therefore, since treated firms that have no drawdown funds from LC do not have debt repayment risks, debt rollover risk cannot explain the drop in investment associated with the expiry of LC in

baseline matching result. In addition, even if there is debt rollover risk associated with the maturity of LC for typical treated firms, it cannot explain the results that treated firms with lenders that are unhealthy or have large exposures to "toxic" assets are more adversely affected.

As shown later in the second approach, I directly test if the bank health measure ΔL_i is endogenous and find evidence against the endogeneity of this measure ΔL_i. The exogeneity of bank health measure and the finding that treated firms whose pre-crisis banks are unhealthy are more adversely affected further support that bank liquidity supply shocks affect corporate investment.

However, the above results are subject to criticism of imprecise matching. If bank health does affect corporate investment for these treated firms, then the channel through which bank health imposes its influence should be through relieving the financial constraints of treated firms potentially by providing new liquidity in the crisis. Indeed, out of the 47 treated firms whose pre-crisis banks have large ABX exposures, only 5 (11%) firms obtain new LC in the crisis, whereas out of the 47 treated firms whose pre-crisis banks have small ABX exposures, 25 (53%) firms originate LC in the crisis. In Table 7, formal regression tests within all the 94 treated firms consistently find that treated firms with healthy banks in pre-crisis are more likely to obtain new LC in the crisis. Therefore, bank health affect corporate investment through relieving the financial constraints of treated firms by providing new liquidity in the crisis.

3.2.6 Other time periods

The results in the previous section show that treated firms reduce investment by more than matched control firms when they have LC due in three quarters after Lehman bankruptcy, a severe crisis period when the TED spread soared to a record high level (see Figure 2). However, the TED spread started to increase in August 2007 and recession began in December 2007.[14] It is interesting to know whether firms adjust their behaviors when they have external liquidity LC maturing in that early financial distress period. To this end, I define the early crisis period as the first nine months of the recession, December 2007 to

[14] NBER recession began in December 2007 and ended in June 2009.

August 2008, following Chodorow-Reich (2014). Treated firms include those that have last LC originated before December 2007 maturing in the early crisis period. Non-treated firms are those that have last LC due after August 2008. Considering the heightened the TED levels after Lehman collapse relative to that in early crisis period, one may expect that treated firms cut investment to a lesser extent if they do. That is what I find. Treated firms appear to reduce their investment based on the matching result, but the economic magnitude is smaller, statistical significance is weaker, and the matching results seem to be less robust to the matching variables.[15] Given that the treated firms are public firms that have more options of financing and that the TED spread levels are lower in early crisis period than that after Lehman bankruptcy, the results are not surprising. Therefore, I conclude that the maturity of LC in early crisis period has a lesser impact on corporate investment.

3.3 Robustness tests

In section 3.2, I already show that 1) parallel assumption seems satisfied, 2) my matching results are unchanged when I use the more predetermined treated dummy measured at 2006 year end, 3) smart CEOs story is ruled out, and 4) debt rollover risk cannot explain the drop in investment for treated firms because of the differential response between the treated firms with unhealthy banks and those with healthy banks.

In this section, I further examine whether the baseline matching results are robust. The findings are as follows. First, one may wonder if maturing LC is just a proxy for maturing long-term debt that affects investment as documented in Almeida *et al.* (2011). I already show that the majority of treated firms do not have drawdown funds from LC, and that when dropping treated firms that have drawdown activities, the matching results are unchanged. Therefore, it is the expiry of external bank liquidity, not coming due long-term debt, that forces companies to adjust investment behaviors. Moreover, when I match additionally on long-term debt due defined as in Almeida *et al.* (2011)[16], the matching result

[15] Abadie-Imbens ATT estimate is –0.25 percentage point (p-value 0.265) when I match on the baseline matching variables, –0.39 (p-value 0.043) when matching additionally on investment in 2006, and –0.31 (p-value 0.176) when matching on cash, cash flow, and size. Therefore, although economic magnitude is about half of that in baseline matching for the crisis after Lehman collapse, the results are not robust in terms of statistical significance.

[16] I adjust the long-term debt due measure to represent the portion that is due in 2008 and 2009. Specifically, it is defined as long-term debt due in year 2 (*dd2*) plus long-term debt due in year 3 (*dd3*) divided by long-term debt due more than 1 year (*dltt*), all measured at 2006 fiscal year end.

is still similar. Thus, bank liquidity shocks are transmitted to firms through a new channel, the credit line channel.

Second, firms may match the maturity of LC to that of their investment opportunities, so when credit lines are maturing, corporate investment declines accordingly. If that explains the investment cut of treated firms with LC due in the crisis, then treated firms that have LC due in the placebo period 2007Q1 to Q3 should also experience a drop in investment. But that is not what I find in Panel C of Table 3. Moreover, I match additionally on the LC's maturity at issuance, i.e., I require both treated and non-treated firms have similar maturity at issuance when they originate LC. The two groups differ only in when they originate LC. The treated firms are the unlucky ones to have LC due in the crisis. The matching result remain unchanged.

Third, the matching results are consistently economically large and statistically significant when different selections of control variables are used as reported in Table 8. When gradually adding financial control variables from cash to the full set of control variables, both the DiD and the ATT estimates are similar in terms of economic magnitude and statistical significance. Besides, on may wonder if the pre-crisis investment level affects the results. I find that when matching additionally on the pre-crisis investment, the matching result is still similar.

Fourth, I also confirm that matching on the number of matched controls from 1 to 4 produces similar results. The results are also unchanged when matching on two-digit SIC.

Fifth, in the baseline matching, I impose the restriction that non-treated firms need to have LC available right before crisis. This restriction ensures that both treated and non-treated firms rely on bank lines of credit to some extent. When I release this restriction and only require that non-treated firms have some LC before the crisis, irrespective of whether these credit lines mature before or after crisis, the results are also similar.

Last, I use regressions to test if the baseline matching results still hold. I regress change in investment on the same set of matching control variables measured at 2006. Treated firms still cut investment by more.

3.4 Adjustment of cash and other policies

This section examines how treated firms adjust cash and other policies in response to their maturing LC. Previous research documents that firms substitute between cash and LC (Lins *et al.*, 2010; Campello *et al.*, 2011).[17] When the best all-around substitute for cash holdings matures in the bad times, treated firms may be forced to hoard cash to pay for additional expenses that were previously covered by LC if they find it hard to reduce these expenses.

As shown in column 1 of Table 9, treated firms increase the cash-to-assets ratio by more. The matching estimate of the ATT is 1.92 percentage points and statistical significant. In terms of the economic magnitude, the saved cash is slightly less than the annual investment cut (4×0.70=2.8 percentage points, see Panel B of Table 3). Column 2 to 4 document that treated firms barely adjust other policies. Treated and control firms experience similar changes in inventory, dividend, and research and development (R&D). In the untabulated results, I find that they also share similar growth in cost of goods sold (COGS), selling, general and administrative expense (SG&A), sales, and employment. Together, the results suggest that firms facing maturing LC in a period with disruptions in the banking system choose to cut investment and save cash, possibly due to their inability to adjust other policies.

To sum up, I interpret the results based on the predetermined maturity structure of LC as follows. When firms' pre-crisis bank liquidity matures in the crisis, firms suffer insufficient bank liquidity supply and consequently are forced to cut investment. However, those treated firms whose pre-crisis banks are healthy or have small exposures to mortgage-backed securities are more likely to obtain bank liquidity in the crisis, and thus are less adversely affected by the maturity of credit lines.

4 Bank health, corporate liquidity, and investment

Previous analysis demonstrates that 94 firms with last pre-crisis LC due in the crisis experience a large decline of investment relative to control firms, and within these treated firms, bank health affects the severity of investment cut and new LC availability in the crisis.

[17] Campello *et al.*, 2011 find that firms with abundant cash voluntarily choose to have smaller credit lines and fewer drawdowns. I show in this section that firms with maturing LC in the bad times choose to hoard cash.

However, it is silent on whether bank health has an impact on corporate liquidity and investment for more general firms which do not have LC due in the crisis. If bank health matters, then what are the aggregate effects of bank liquidity supply shocks on investment in the crisis?

To answer these questions, I need to isolate the change in credit supply from the change in credit demand. The fact that the recent financial crisis is originated outside of banks' corporate loan portfolio makes it suitable to disentangle the credit supply effect. The identification strategy closely follows Chodorow-Reich (2014) who study the effect of credit supply effect on employment in the crisis. First, I show that bank health measure is uncorrelated with unobserved credit demand, conditional on firm observable characteristics, within the set of firms that have LC in both pre-crisis and crisis. Thus, bank health measure is plausibly exogenous. Second, I examine the effect of bank health on lines of credit and investment. Third, I show how the effect of bank health varies by firm types. Fourth, I evaluate the aggregate effects of bank liquidity supply on investment. Last, I examine whether the bank liquidity supply shocks affect the composition of lines of credit and cash.

4.1 Bank health measure

Following Chodorow-Reich (2014), I measure bank health using the percentage change in the number of loans to all other firms between the normal and crisis periods. Specifically, suppose firm *i* receives a loan from bank *b* at time *t*, then I define $L_{i,b,t}$=1. The bank health measure is defined as

equation (1)

$$\Delta L_{-i,b} = \frac{\sum_{j \neq i} \alpha_{j,b,crisis} \times L_{j,b,crisis}}{0.5 \sum_{j \neq i} \alpha_{j,b,normal} \times L_{j,b,normal}} - 1$$

where α is the bank allocation to denote the importance of that bank to the syndicate. Crisis definition is the same as previous analysis, i.e., from October 2008 to June 2009. Normal period includes October 2005 to June 2006 and October 2006 to June 2007.

The firm level bank health measure is the weighted average of $\Delta L_{-i,b}$ over the lead lenders of the last pre-crisis syndicate. More specifically, firm's bank health is

equation (2)

$$\Delta L_i = \sum_b \alpha_{i,b,last} \times \Delta L_{-i,b}$$

where b is a lead lender in the last pre-crisis syndicate; α is the bank allocation of that lead lender in the last pre-crisis syndicate.

4.2 Identification

To investigate whether bank health matters for corporate liquidity and investment, I regress the outcome variable (LC growth or investment growth) on the firm level bank health ΔL_i and a set of financial controls measured at the end of 2006. That is, I run the following regression:

equation (3)

$$g_i = \beta \Delta L_i + firm\ controls_i + \varepsilon_i$$

where g_i is $\Delta\log(investment)_i$ or $\Delta\log(line\ of\ credit)_i$, i.e., change in the log of outcome variable from period October 2006 to June 2007 to October 2008 to June 2009. Investment is defined as a firm's total capital expenditures in corresponding quarters. Firm controls include size, cash, cash flow, leverage and Q. Industry (SIC 2), state, and rating fixed effects are also included. The identification assumption is that firm level bank health ΔL_i is orthogonal to the unobserved characteristics that affect credit or investment outcomes.

Like Chodorow-Reich (2014), I also use ABX exposure to instrument firm level bank health ΔL_i. Similar to the construction of ΔL_i, the firm level ABX exposure is defined as the weighted average of bank level ABX exposure over the lead lenders of the last pre-crisis syndicate.

4.3 Exogeneity of bank health

I use firm-bank level data to examine whether bank health measure is plausibly exogenous. To this end, I select only firms that have a LC in their last pre-crisis syndicate and obtain a LC in the crisis. In addition, I also require that firms' last pre-crisis LC have at least two lenders so that firm fixed effects can be included in regression. I then investigate for the

same firm receiving LC liquidity from two different banks in the last pre-crisis syndicate, whether it receives more LC liquidity in the crisis from the healthy bank than from unhealthy bank. To fully control for change in the credit demand, I add the firm fixed effect when regressing *change* in bank-firm level LC liquidity on bank health measure $\Delta L_{-i,b}$. Since the dependent variable is the *change*, not the level of firm-bank level LC liquidity, the firm fixed effect fully absorbs both observed and unobserved change in credit demand. As a result, this bank-firm level regression provides an unbiased estimation of bank credit supply effect. More specifically, I run the following bank-firm regression:

equation (4)

$$\log\left(1 + \alpha_{i,b,crisis} \times V_{i,crisis}\right) - \log\left(\alpha_{i,b,last} \times V_{i,last}\right) = \beta \Delta L_{-i,b} + firm\ FE_i + \varepsilon_{i,b}$$

where $V_{i,last}$ is the last LC amount; $\alpha_{i,b,last}$ is the bank b's allocation in the last pre-crisis LC to firm i; $\alpha_{i,b,last} \times V_{i,last}$ represents firm's LC liquidity from bank b in the last LC; $\alpha_{i,b,crisis} \times V_{i,crisis}$ is firm's LC liquidity form bank b in the crisis LC. Since a pre-crisis bank can withdraw offering LC in the crisis LC, I add 1 to the bank's LC liquidity in the crisis $\alpha_{i,b,crisis} \times V_{i,crisis}$ so that log form is meaningful.

Table 10 reports the results of this firm-bank level regressions using 94 firms that have LC originations in both pre-crisis and crisis period. Column 1 shows the result of regression without firm FE. Column 2 adds firm FE. Again, since dependent variable is the change, not the level of liquidity, this firm FE fully absorbs any observed and unobserved credit demand change from normal period to the crisis period. Therefore, the coefficient in column 2 can be viewed as an unbiased estimate of bank health. Column 3 exclude firm FE and add firm financial controls measured at the end of 2006 that potentially affect credit demand. Any unobserved factors that could potentially affect credit demand from normal period to crisis period are in the error terms. If unobserved credit demand correlates with bank health $\Delta L_{-i,b}$, then one would expect the coefficient of bank health to change substantially compared to the coefficient estimate with firm FE in column 2. The results in column 1-3 demonstrate that there is little variation in the coefficient estimates. Therefore, I conclude that bank health is uncorrelated with unobserved firm characteristics that affect credit demand. The positive coefficient of bank health means that for the same firm receiving

LC liquidity from two banks in the pre-crisis LC, it receives more LC liquidity in the crisis from healthy banks than from unhealthy banks. In other words, unhealthy banks reduce liquidity by more than healthy banks to the same firm. Therefore, bank liquidity shocks can be transmitted to firms through less liquidity provisions by unhealthy banks.

4.4 Bank health, Liquidity growth, and investment growth

The next question is whether bank health affects corporate liquidity and investment growth in the full sample. Building on the results of exogeneity of bank health in Table 10, I regress outcome variables (corporate liquidity growth and investment growth) on firm level bank health ΔL_i. The regressions are at the firm level, so I cannot include firm FE. Table 11 reports that bank health consistently has a large and statistically significant effect on firms LC liquidity growth. I normalize bank health to have unit variance. Column 2 shows that a one standard deviation increase of bank health increases LC liquidity by 90%. Note that LC amount is not extracted from 10-K or 10-Q, but it is constructed by aggregating all the outstanding LC facilities from Dealscan at a given point in time (Acharya *et al.*, 2013).

Table 12 presents the main results of the effect of bank liquidity supply on corporate investment for the sample of firms that have ever had at least a LC before crisis. Formal regressions consistently show that firms that borrow from healthy lenders before the crisis experience a higher investment growth than firms that borrow from unhealthy banks. Using the result of column 2, a one standard deviation (19%) increase of bank health ΔL_i makes investment grow by 8.2%. Borrowing from 75th percentile (–16.8%) rather than 25th percentile of bank health (–42.9%) results in an investment growth of 11.2% ((–16.8% + 42.9%) /19% * 8.2%=11.2%).

Since firm-level bank health measure is based on the health of last pre-crisis syndicate, to alleviate the concern that some firms might foresee the financial crash and adjust banking relationships beforehand, I use only firms that obtain their last pre-crisis syndicate before 2006 year end and find similar effects of bank health on liquidity and investment growth.

I then examine whether bank health has a heterogenous effect on LC and investment across firm rating. Table 13 reports that bank health has an economically large and

statistically significant effect on LC liquidity and investment growth for unrated firms, but the effect is economically small and statistically insignificant for rated firms, especially the effect on investment. The results are consistent with Chodorow-Reich (2014) who shows that bank health has a large impact on employment growth for unrated firms, but no such impact for rated firms.

In addition, following Chodorow-Reich (2014), I gauge the aggregate effect of bank liquidity supply on investment in the full unrated sample because Table 13 demonstrates that bank health has a small and insignificant effect on rated firms. To do so, for each unrated firm, I increase the bank health from the existing real firm level bank health to the 95th percentile (-9.14%) of bank health in the sample, which is deemed as the hypothetical bank health without bank liquidity shocks.[18] Then I estimate the new investment growth using the new bank health and firm controls measured at the end of 2006, and the regression coefficients in Table 13 column 2. Taking the exponential of this new investment growth, and then multiplying this exponential by that firm's total investment in the period October 2006 to June 2007 will result in that firm's hypothetical total investment in the crisis period October 2008 to June 2009. I then aggregate the total investment change across firms that experience an actual positive investment growth and firms with a negative investment growth. I find that for unrated firms with negative investment growth, i.e., firms cut investment in the crisis relative to normal period October 2006 to June 2007, the bank liquidity supply shocks can explain 22.4% of aggregate investment drop. For unrated firms with positive investment growth, without the bank liquidity supply shocks, their investment would be boosted by another 21.8% relative to the actual dollar amount of investment increase.

4.5 Bank liquidity shocks and corporate liquidity composition

Last, I analyze whether bank liquidity shocks affect the composition of lines of credit and cash. Existing literatures that study the corporate liquidity management almost exclusively focus on whether and how certain firm characteristics affect the composition of lines of credit and cash. Table 14 column 1-2 demonstrate that firms with healthy banks before the

[18] If a firm's existing bank health measure is greater than 95th percentile, then I do not make the change.

crisis increase the proportion of LC in their total liquidity (LC plus cash) relative to those firms attached to unhealthy banks. A one standard deviation of increase in ΔL_i (19%) increases the LC to total liquidity ratio by 3%. Column 3-4 show that it is the increase of LC that drives the results. Unreported results show that bank health has no impact on cash over net assets.

Overall, the results from the second empirical strategy are consistent with the bank liquidity shocks story. For the firms that borrow LC in both the pre-crisis and the crisis periods, unhealthy banks reduce liquidity provision by more than healthy banks to the same firms. For more general firms that have ever had LC before crisis, firms that borrow from healthy banks in pre-crisis have a higher bank liquidity growth and investment growth in the crisis.

5 Conclusion

Through the role of an important source of external liquidity—bank lines of credit—I use two empirical strategies to study whether bank liquidity supply shocks affect corporate investment during the 2008-2009 financial crisis. In the first approach, I exploit the predetermined variation in the maturity structure of LC and find that unlucky firms that have LC maturing at the time of the crisis reduce investment by more than otherwise similar firms that have LC maturing after the crisis. In addition, the effect of maturing LC is more pronounced for financially constrained firms and bank-dependent firms. Notably, treated firms that borrow from unhealthy banks in the pre-crisis period are more adversely affected because they are less likely to obtain LC in the crisis. I rule out the smart CEOs story and the debt rollover risk story. A battery of robustness tests produce similar results. Importantly, I also find that treated firms save more cash but hardly adjust other expenses, suggesting that firms with maturing LC in the crisis may be forced to cut investment and hoard cash to service their obligations that were partly covered by LC.

The second approach directly links bank health to corporate liquidity and investment. For the firms that obtain credit lines in both the pre-crisis and crisis periods, unhealthy banks reduce the liquidity provision by more than healthy banks to the same firms. For more general firms that have LC in the pre-crisis period, firms that borrow from unhealthy banks

in the pre-crisis period experience lower growth in LC and investment during the crisis. Overall, these findings highlight a line of credit channel through which bank credit supply shocks are transmitted to firms, and the results are consistent with the causal effect of bank credit supply shocks on firm outcomes.

However, my results do not invalidate alternative channels that could also affect investment in the crisis (Mian *et al*., 2013). Rather, the findings that treated and control firms respond differently to maturing LC in the crisis, and that firms attached to healthy banks in the pre-crisis period are less adversely affected, are more closely aligned with a bank credit supply shock story rather than a demand shock story.

References

Abadie, A., Drukker, D., Herr, J., Imbens, G., 2004. Implementing matching estimators for average treatment effects in Stata. The STATA Journal 4 (3), 290-311.

Abadie, A., Imbens, G., 2011. Bias-corrected matching estimators for average treatment effects. Journal of Business & Economic Statistics 29, 1-11.

Acharya, V., Almeida, H., Campello, M., 2013. Aggregate risk and the choice between cash and lines of credit. Journal of Finance 68, 2059–2116.

Almeida, H., Campello, M., Laranjeira, B., Weisbenner, S., 2012. Corporate debt maturity and the real effects of the 2007 financial crisis. Critical Finance Review 1, 3–58.

Brunnermeier, M., 2009. Deciphering the Liquidity and Credit Crunch 2007-2008. Journal of Economic Perspectives 23, 77-100.

Campello, M., Giambona, E., Graham, J., Harvey, C., 2011. Liquidity management and corporate investment during a financial crisis. Review of Financial Studies 26, 1944–1979.

Campello, M., Graham, J., Harvey, C., 2010. The real effects of financial constraints: Evidence from a financial crisis. Journal of Financial Economics 97, 470–487.

Chava, S., Purnanandam, A., 2011. The effect of banking crisis on bank-dependent borrowers. Journal of Financial Economics 99, 116–135.

Chava, S., Roberts, M., 2008. How does financing impact investment? the role of debt covenants. The Journal of Finance 63, 2085-2121.

Chodorow-Reich, G., 2014. The employment effects of credit market disruptions: firm-level evidence from the 2008–09 financial crisis. Quarterly Journal of Economics 129 (1), 1–59.

Chodorow-Reich, G., Falato, A., 2018. The loan covenant channel: how bank health transmits to the real economy. Working Paper.

Cingano, F., Manaresi, F., and Sette E., 2013 Does credit crunch investments down? new evidence on the real effects of the bank-lending channel. Review of Financial Studies 29, 2737–2773.

Duchin, R., Ozbas, O., Sensoy, B., 2010. Costly external finance, corporate investment, and the subprime mortgage financial crisis. Journal of Financial Economics 97, 418–435.

Gan, J., 2007. The real effects of asset market bubbles: Loan- and firm-level evidence of a lending channel. Review of Financial Studies 20, 1941–1973.

Ivashina, V., Scharfstein, D., 2010. Bank lending during the financial crisis of 2008. Journal of Financial Economics 97, 319–338.

Iyer, R., Lopes, S., Peydró, J., Schoar, A., 2010. Interbank liquidity crunch and the firm credit crunch: evidence from the 2007–2009 crisis. Review of Financial Studies 27, 347-372.

Kahle, K., Stulz, R., 2013. Access to capital, investment, and the financial crisis. Journal of Financial Economics 110, 280–299.

Khwaja, A., Mian, A., 2008. Tracing the impact of bank liquidity shocks: Evidence from an emerging market. American Economic Review 98, 1413-1442.

Lins, K., Servaes, H., Tufano, P., 2010. What drives corporate liquidity? An international survey of cash holdings and lines of credit. Journal of Financial Economics 98, 160–176.

Mian, A., Rao, K., Sufi, A., 2013. Household balance sheets, consumption and the economic slump. Quarterly Journal of Economics 128, 1687–1726.

Mian, A., Sufi, A., 2016. Household debt and defaults from 2000 to 2010: The credit supply view. Working Paper.

Murfin, J., 2012. The supply-side determinants of loan contract strictness. Journal of Finance 67, 1565-1601.

Schnabl, P., 2012. The International transmission of bank liquidity shocks: evidence from an emerging market. The Journal of Finance 67, 897–932.

Sufi, A., 2009. Bank lines of credit in corporate finance: an empirical analysis. Review of Financial Studies 22, 1057–1088.

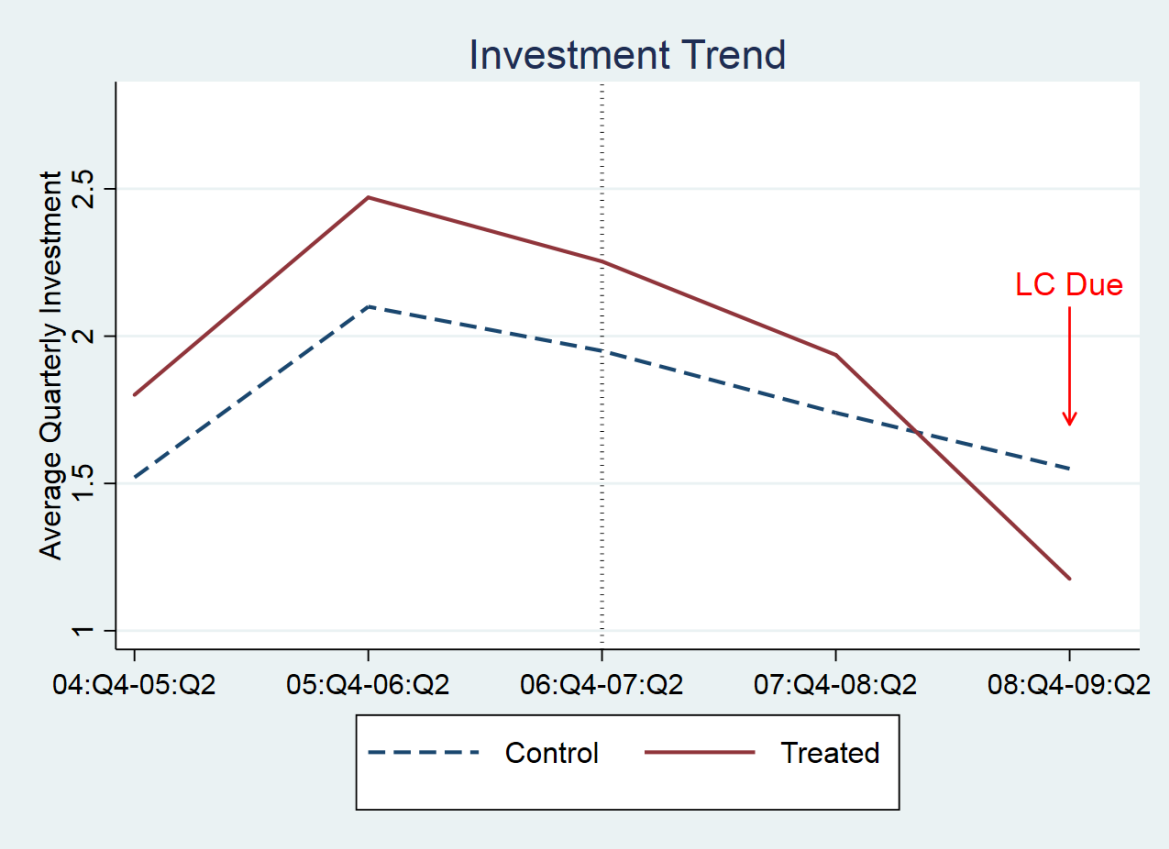

Figure 1. Investment trend for treated and control firms. This figure shows the evolution of investment (unit: percentage point) for treated and control firms resulted from the baseline matching. Each point is the average of investment across all treated firms (red real line), or control firms (blue dashed line). Investment is defined as the average of quarterly capital expenditures over lagged assets in a 3-quarter period. The treated firms (94 firms) are defined as those whose last pre-crisis LC expires in the crisis October 2008 to June 2009. The non-treated firms are defined as those for which the last pre-crisis LC expires after June 2009. Control firms are selected from the non-treated group based on Abadie-Imbens estimator using matching variables including size, cash flow, cash, Q, leverage, investment, 1-digit SIC, and credit ratings, all measured at the end of 2006.

Figure 2. TED spread. This figure shows the TED spread from January 2007 to December 2009. TED spread is defined as the difference between the 3-month interest rates on interbank loans (LIBOR) and 3-month Treasury bills. It is an indicator of perceived credit risk in the economy. Shaded area indicates the recession period from December 2007 to June 2009. Source: Federal Reserve Bank of St. Louis.

Table 1

Pre-crisis financial characteristics of treated, non-treated, and control firms

	Size	Cash Flow	Cash	Q	Leverage	Investment
Panel A. Means for treated and non-treated firms in 2006						
Treated	6.693	0.138	0.112	2.016	0.221	0.022
Non-Treated	7.145	0.153	0.088	1.926	0.235	0.019
Difference	–0.452	–0.015	0.024	0.090	–0.014	0.003
p-value	0.009	0.135	0.014	0.476	0.540	0.201
Panel B. Means for treated and matched control firms in 2006						
Treated	6.693	0.138	0.112	2.016	0.221	0.022
Control	6.807	0.145	0.104	1.941	0.216	0.019
Difference	–0.114	–0.007	0.008	0.075	0.005	0.003
p-value	0.680	0.596	0.577	0.638	0.881	0.521

Notes. This table provides a comparison of the means of financial variables for treated, non-treated, and matched control firms. The sample consists of 929 firms whose last pre-crisis facility is a line of credit (LC). The treated firms (94 firms) are defined as those for which the last pre-crisis LC expires in the crisis October 2008 to June 2009. The non-treated firms (835 firms) are defined as those for which the last pre-crisis LC expires after June 2009. Matched control firms are selected from the non-treated group based on Abadie-Imbens estimator using matching variables including size, cash flow, cash, Q, leverage, 1-digit SIC, and credit ratings, all measured at the end of 2006. See the main text for variable definitions. P-values of two sample t test are reported.

Interpretation. Treated and non-treated differ significantly in terms of the means of size, cash. After employing Abadie-Imbens matching method, treated and matched control firms are similar across all dimensions.

Table 2

Pre-crisis financial distributions of treated, non-treated, and control firms

		25%	Median	75%	Kolmogorov-Smirnov Test p-value
		Panel A. Treated vs. Non-Treated firms in 2006			
Size	Treated	5.258	6.402	8.019	0.004
	Non-Treated	6.116	7.117	8.020	
Cash Flow	Treated	0.086	0.127	0.186	0.205
	Non-Treated	0.102	0.140	0.196	
Cash	Treated	0.026	0.084	0.188	0.035
	Non-Treated	0.020	0.053	0.133	
Q	Treated	1.295	1.679	2.280	0.893
	Non-Treated	1.276	1.630	2.220	
Leverage	Treated	0.008	0.164	0.352	0.051
	Non-Treated	0.093	0.207	0.329	
Investment	Treated	0.006	0.010	0.022	0.825
	Non-Treated	0.006	0.011	0.021	
		Panel B. Treated vs. Matched control firms in 2006			
Size	Treated	5.258	6.402	8.019	0.330
	Control	5.455	6.544	7.953	
Cash Flow	Treated	0.086	0.127	0.186	0.248
	Control	0.096	0.135	0.184	
Cash	Treated	0.026	0.084	0.188	0.782
	Control	0.023	0.073	0.147	
Q	Treated	1.295	1.679	2.280	0.662
	Control	1.318	1.654	2.240	
Leverage	Treated	0.008	0.164	0.352	0.782
	Control	0.047	0.189	0.330	
Investment	Treated	0.006	0.010	0.022	0.540
	Control	0.006	0.009	0.018	

Notes. This table compares the 25 percentiles, medians, and 75 percentiles of financials for treated, non-treated, and control firms. The sample consists of 929 firms whose last pre-crisis facility is a line of credit (LC). The treated firms (94 firms) are defined as those for which the last pre-crisis LC expires in the crisis October 2008 to June 2009. The non-treated firms are defined as those for which the last pre-crisis LC expires after June 2009. Matched control firms are selected from the non-treated group based on Abadie-Imbens estimator using matching variables including size, cash flow, cash, Q, leverage, 1-digit SIC, and credit ratings, all measured at the end of 2006. See the main text for variable definitions. P-values of two sample Kolmogorov-Smirnov test for equality of distribution functions are reported.

Interpretation. Treated and non-treated differ significantly in the distribution of size, cash, and leverage. After employing Abadie-Imbens matching method, treated and matched control firms are similar in the distribution across all variables.

Table 3

Investment comparison in the crisis and placebo periods (unit: percentage point)

Panel A: Crisis investment comparison (Treated vs Non-Treated)

	2006Q4-2007Q2	2007Q4-2008Q2	2008Q4-2009Q2	
	(1)	(2)	(3)	(3)-(1)
Treated firms	2.25***	1.93***	1.21***	–1.04***
	(0.33)	(0.28)	(0.12)	(0.26)
Non-Treated firms	1.89***	1.83***	1.34***	–0.55***
	(0.08)	(0.09)	(0.05)	(0.06)
Treated - Non-Treated	0.36	0.10	–0.13	–0.49*
	(0.34)	(0.30)	(0.13)	(0.27)

Panel B: Crisis investment comparison (Treated vs Matched Control)

	2006Q4-2007Q2	2007Q4-2008Q2	2008Q4-2009Q2	
	(1)	(2)	(3)	(3)-(1)
Treated firms	2.25***	1.93***	1.21***	–1.04***
	(0.33)	(0.28)	(0.12)	(0.26)
Control firms	1.95***	1.74***	1.55***	–0.40**
	(0.33)	(0.25)	(0.21)	(0.19)
Treated - Control	0.30	0.19	–0.34	–0.64**
	(0.47)	(0.37)	(0.24)	(0.30)
Matching estimator				–**0.70****
(Abadie-Imbens)				(0.21)

Panel C: Placebo period investment comparison (Treated vs Matched Control)

	2006Q1-Q3	2007Q1-Q3	
	(1)	(2)	(2)-(1)
Treated firms	1.47***	1.50***	0.03
	(0.19)	(0.18)	(0.11)
Control firms	1.89***	1.80***	–0.09*
	(0.08)	(0.07)	(0.05)
Treated - Control	–0.42	–0.30	0.12
	(0.21)	(0.20)	(0.12)
Matching estimator			0.04
(Abadie-Imbens)			(0.17)

Notes. Panel A and B compare the average quarterly investment from 2006Q4-2007Q2 (column 1) with that from 2008Q4-2009Q2 (column 3). Panel C compares the average quarterly investment from 2006Q1-Q3 with that from placebo period 2007Q1-Q3. Investment is defined as quarterly capital expenditure over lagged assets and is displayed in percentage points. In Panel A, treated firms and non-treated firms are compared. In Panel B, treated and matched control firms are compared. In Panel A and Panel B, treated firms are defined as those for which the last pre-crisis line of credit (LC) expires in the crisis October 2008 to June 2009; the non-treated firms are defined as those for which the last pre-crisis LC expires after June 2009; matched control firms are selected from the non-treated group based on Abadie-Imbens estimator using matching variables including size, cash flow, cash, Q, leverage, 1-digit SIC, and credit ratings, all measured at the end of 2006. In Panel C, treated firms are defined as those for which the last pre-2006 year end LC expires in placebo period 2007Q1-Q3; non-treated firms are defined as those for which the last pre-2006 year end LC expires after September 2007. Matching is also based on the same set of financial variables measured at the end of 2006. There are 94 treated firms and

88 unique control firms in Panel B, and 63 treated and 61 unique control firms in Panel C. Heteroskedasticity consistent robust standard errors are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. This table presents the central results of Abadie-Imbens matching method. Treated firms whose last pre-crisis LC expires in the crisis October 2008 - June 2009 cut investment by 0.7 percentage points more than matched control firms whose LC expires after June 2009. In the placebo period January to September 2007, the change in investment of treated and control firms are similar and the difference is economically small and statistically insignificant.

Table 4

Investment comparison based on predetermined LC maturity measured at 2006 year end (unit: percentage point)

	(1) LC maturity measured on Dec 31, 2006	(2) Firms that actually have LC due in the crisis	(3) Firms that do not have LC due in the crisis
Difference in differences (DiD)	–0.40*	–1.06***	0.82
	(0.22)	(0.32)	(0.59)
Matching estimator (Abadie-Imbens)	–0.48*	–1.23***	0.84**
	(0.29)	(0.38)	(0.41)
Number of firms in treated	98	61	37

Notes. This table compares change in average quarterly investment from 2006Q4-2007Q2 to 2008Q4-2009Q2 across treated firms and matched control firms based on the LC's maturity information at the end of 2006. In column 1, treated firms are those for which the last pre-2006 LC is due in the crisis 2008Q4-2009Q2, irrespective of whether they amend or refinance the last pre-2006 LC in the period between January 2007 and September 2008. In column 2, treated firms are a subset of firms in column 1 whose last LCs originated before crisis do mature in the crisis (*e.g.,* no amendment or refinancing in the period between January 2007 and September 2008). The rest treated firms are in column 3 (*e.g.,* their actual last pre-crisis LC do not mature in the crisis due to LC amendment or refinancing). In all the three columns, non-treated firms are the ones whose last pre-2006 credit lines do not mature in the crisis based on the 2006 information set, irrespective of whether they refinance or amend LCs afterwards. Control firms are selected from the non-treated group based on Abadie-Imbens estimator using matching variables including size, cash flow, cash, Q, leverage, 1-digit SIC, and credit ratings, all measured at the end of 2006. In DiD specification, I regress change in average quarterly investment from 2006Q4-2007Q2 to 2008Q4-2009Q2 on the same set of matching variables measured at the end of 2006. Heteroskedasticity consistent robust standard errors are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. This table shows that based on the predetermined maturity measure at the end of 2006, treated firms still cut investment by more. This effect is solely driven by firms whose last pre-2006 credit lines mature in the crisis.

Table 5
Investment comparison by financial constraint (unit: percentage point)

	Matching estimator (Abadie-Imbens)							#
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	treated
Low leverage	–0.52							47
	(0.33)							
High leverage	–1.16***							47
	(0.40)							
Dividend Payer		0.03						43
		(0.24)						
Non-dividend Payer		–1.26***						51
		(0.34)						
Payout Ratio High			–0.40					47
			(0.34)					
Payout Ratio Low			–1.20***					47
			(0.30)					
Kaplan-Zingales index Low				0.12				47
				(0.25)				
Kaplan-Zingales index High				–1.66***				47
				(0.40)				
Non-bank dependent					–0.26			38
					(0.32)			
Bank Dependent					–1.09***			56
					(0.30)			
Firm level external finance dependence Low						–0.04		43
						(0.24)		
Firm level external finance dependence High						–1.59***		42
						(0.42)		
Industry level external finance dependence Low							–0.12	50
							(0.19)	
Industry level external finance dependence High							–1.34***	44
							(0.42)	

Notes. This table reports the Abadie-Imbens ATT estimates of investment comparison (2006Q4-2007Q2 vs 2008Q4-2009Q2) by splitting the 94 treated firms into two groups based on the median *ex ante* financial constraint measures of treated firms. For example, when splitting based on leverage, all the treated firms below the median leverage of 94 treated sample firms will be matched to all the non-treated firms, the matching estimate of ATT for this matching is reported in column 1 row 1; all the treated firms above the median leverage will also be matched to the same non-treated firms, the corresponding ATT estimate is reported in column 1 row 2. Non-dividend payer is the group of firms that do not pay dividend in the past three years prior to 2006; the rest firms form the dividend payer group. Payout ratio=(cash dividends (dvp+dvc)+repurchases(prstkc))/income before extraordinary items (ib). Kaplan-Zingales index= –1.002*cash flow+0.283*Q + 3.319*debt–39.368*Dividends–1.315*cash. Bank dependent firms are defined as those that have two or more loans with the same US lead lender in the five years before 2006 (Khale and Stulz, 2010); the rest firms form the non-bank dependent firms. Firm level external finance dependence is the proportion of investment not financed by cash flow from operations, which is (capital expenditures (capx) –funds from operations (fopt))/capital expenditures (capx). Industry level external finance dependence is the SIC2-median of firm level external finance dependence. The low and high subsamples consist of firms with each measure above and below the median. Heteroskedasticity consistent robust standard errors are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. All matching results show that more financially constrained firms are more adversely affected by the maturity of LC than financially unconstrained firms.

Table 6

Investment comparison by bank health (unit: percentage point)

	Matching estimator		number of treated firms by type
	(1)	(2)	
%Δ loans to other borrowers (ΔL_i) High	–0.56***		47
	(0.22)		
%Δ loans to other borrowers (ΔL_i) Low	–0.84***		47
	(0.27)		
Small ABX exposure		–0.28	47
		(0.19)	
Large ABX exposure		–1.08***	47
		(0.40)	

Notes. This table reports the Abadie-Imbens ATT estimates of investment comparison (2006Q4-2007Q2 vs 2008Q4-2009Q2) by splitting the 94 treated firms into two groups based on the median of bank health measures. For example, when splitting based on ABX exposure, all the treated firms below the median will be matched to all the non-treated firms, the ATT estimate for this matching is reported in column 2 row 3; all the treated firms above the median will also be matched to the same non-treated firms, the corresponding ATT estimate is reported in column 2 row 4. %Δ loans to other borrowers (ΔL_i) equals the change in the number of loans made by firms' lead bank to all other firms between the periods October 2005-June 2006 & October 2006-June 2007 and the crisis period October 2008-June 2009. Lead bank refers to that in the borrower's last pre-crisis lines of credit syndicate. Firms whose lead bank experiences a severe drop of bank lending will be categorized into ΔL_i Low group, while firms whose lead bank has a mild drop will be in ΔL_i High group. ABX exposure is lead bank's exposure to ABX AAA 2006-H1 index (ABX exposure data is from Chodorow-Reich's website). Firm level measures of ΔL_i and ABX exposure are the weighted average by bank allocation over the lead banks in the last pre-crisis LC syndicate. Heteroskedasticity consistent robust standard errors are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. All matching results show firms whose pre-crisis banks are unhealthy (low ΔL_i or high ABX exposure) are more adversely affected by LC expiry than firms whose pre-crisis banks are healthier. For example, in column 2, treated firms in low ABX group do not cut investment by more than control group even though they have LC due in the crisis, but treated firms in high ABX exposure group do reduce their investment by more than their corresponding control group.

Table 7

Lines of credit availability in the crisis and bank health for treated firms

	Dependent: firms obtaining a new LC in the crisis			
	Probit	Probit	OLS	IV
				ABX exposure
	(1)	(2)	(3)	(4)
%Δ loans to other borrowers (ΔL_i)	0.401***	0.266**	0.076**	0.172**
	(0.148)	(0.133)	(0.037)	(0.073)
Financial controls	NO	YES	YES	YES
Industry	NO	YES	YES	YES
Rating	NO	YES	YES	YES
First stage F statistics				30.11
Lead lender 1 cluster	23	23	23	23
Lead lender 2 cluster	24	24	24	24
Observations	94	94	94	94

Notes. This table reports the firm level regression of whether 94 treated firms obtains a new LC in the crisis October 2008-June 2009 on their bank health measure ΔL_i. %Δ loans to other borrowers (ΔL_i) equals the change in the number of loans made by firms' lead bank to all other firms between the periods October 2005-June 2006 & October 2006-June 2007 and the crisis period October 2008-June 2009. ABX exposure is lead bank's exposure to ABX AAA 2006-H1 index (ABX exposure data is from Chodorow-Reich's website). Firm level measures of ΔL_i and ABX exposure are the weighted average by bank allocation over the lead banks in the last pre-crisis LC syndicate. Financial controls include Q, cash flow, cash, size (log of assets) and leverage. Industry is 1-digit SIC dummy, Rating are categorized into unrated, below-investment grade, and investment grade. Standard errors are two-way clustered on the lead lenders in the borrower's last pre-crisis lines of credit syndicate, and are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. For 94 treated firms whose LC is due in the crisis, the health of lead banks in the last pre-crisis lines of credit syndicate positively predicts their new LC availability in the crisis.

Table 8

Investment comparisons with different matching variables (unit: percentage point)

	(1)	(2)	(3)	(4)	(5)
Difference in differences	–0.57**	–0.71**	–0.50*	–0.67**	–0.64**
	(0.29)	(0.29)	(0.30)	(0.30)	(0.30)
Matching estimator	–0.56**	–0.72***	–0.51**	–0.69**	–0.70***
(Abadie-Imbens)	(0.26)	(0.27)	(0.24)	(0.28)	(0.21)
Cash	×	×	×	×	×
Cash flow		×	×	×	×
Size			×	×	×
Leverage				×	×
Q					×
Ratings	×	×	×	×	×
Industry	×	×	×	×	×

Notes. This table compares the average quarterly investment (quarterly capital expenditures divided by lagged assets) from 2006Q4-2007Q2 to 2008Q4-2009Q2 by gradually adding matching variables. For example, column 1 matches on cash, ratings and industry, and column 5 uses all the matching variables. The treated firms (94 firms) are defined as those for which the last pre-crisis LC expires in the crisis October 2008 to June 2009. Control firms are selected from the non-treated group which are defined as those for which the last pre-crisis LC expires after June 2009. In DiD specification, I regress change in average quarterly investment from 2006Q4-2007Q2 to 2008Q4-2009Q2 on the same set of matching variables measured at the end of 2006. Heteroskedasticity consistent robust standard errors are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. All matching results show that treated firms cut investment by more than control firms.

Table 9
Comparison of cash and other policies
(unit: percentage point)

	(1) Cash	(2) Inventory	(3) Dividend	(4) R&D
Difference in differences	1.78**	–0.58	0.22	–0.07
	(0.63)	(0.51)	(0.18)	(0.09)
Matching estimator	1.92*	–0.64	0.23	–0.13
	(1.07)	(0.52)	(0.15)	(0.14)

Notes. This table compares change in cash and other policies from 2006Q4-2007Q2 to 2008Q4-2009Q2 across treated and matched control firms. Cash, inventory, and dividend are defined as quarterly cash, inventory, and dividend, all divided by assets. R&D is defined as quarterly R&D expense over lagged assets to make it comparable with the definition of investment. Treated firms are defined as those for which the last pre-crisis line of credit (LC) matures in the crisis October 2008 to June 2009; the non-treated firms are defined as those for which the last pre-crisis LC expires after June 2009; matched control firms are selected from the non-treated group based on Abadie-Imbens estimator using matching variables including size, cash flow, cash, Q, leverage, 1-digit SIC, and credit ratings, all measured at the end of 2006. There are 94 treated firms and 88 unique control firms. Heteroskedasticity consistent robust standard errors are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. Treated firms save more cash than control firms, but they experience similar changes in inventory, dividend, and research and development (R&D).

Table 10

Test for endogeneity of bank health (firm-bank level regression)

	Δ Log(lines of credit in firm-bank pair)		
	No firm FE effect	firm FE effect	No firm FE effect
	(1)	(2)	(3)
% Δ loans to other borrowers ($\Delta L_{-i,b}$)	1.16**	1.11***	1.16***
	(0.48)	(0.41)	(0.43)
Size			1.71***
			(0.48)
Cash flow			33.44***
			(10.76)
Leverage			–4.84
			(3.25)
Cash			–5.83
			(3.55)
Q			–1.09
			(0.79)
Borrower FE	NO	**Yes**	NO
Rating FE	Yes	NO	Yes
Industry FE	Yes	NO	Yes
Adjusted R^2	0.060	0.309	0.154
Borrowers	94	94	94
Banks	42	42	42
Observations	695	695	695

Notes. This sample includes firms that obtain a new LC in the crisis October 2008-June 2009. I also require such firms' last pre-crisis facility is LC and has at least two lenders. The restrictions lead to 94 firms. The regression is at the loan level, so each bank-firm pair in a firm's last pre-crisis LC syndicate is an observation. The dependent variable is the log change in the dollar amount of LC lending from that bank to the borrower. %Δ loans to other borrowers ($\Delta L_{-i,b}$) equals the change in the number of loans made by firms' bank *b* to all other firms between the periods October 2005-June 2006 & October 2006-June 2007 and the crisis period October 2008-June 2009. $\Delta L_{-i,b}$ has been normalized so it has unit variance. Industry is 1-digit SIC dummy. Rating are categorized into unrated, below-investment grade, and investment grade. All regressions in the table are estimated by OLS. Standard errors are clustered on the last pre-crisis lender in column 2, and on the last pre-crisis lender and borrower in column 1 and 3. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. The firm fixed effects in column 2 fully absorb any change in credit demand because the dependent variable is the change in LC lending, not the level of lending. Column 3 drops firm fixed effects but add firm financial controls to proxy for credit demand. The similarity of coefficients of $\Delta L_{-i,b}$ in the three columns supports the assumption that conditional on observables, $\Delta L_{-i,b}$ is orthogonal to the firms' unobserved characteristics that affect credit demand.

Table 11

The effect of bank liquidity supply on LC liquidity growth (firm-level regression)

	Lines of credit growth rate		
	OLS	OLS	IV (ABX exposure)
	(1)	(2)	(3)
%Δ loans to other borrowers (ΔL_i)	1.152***	0.897***	0.916**
	(0.349)	(0.306)	(0.341)
Financial variables	No	Yes	Yes
Industry FE	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
First stage F-statistics			43.53
Lead bank cluster 1	40	40	40
Lead bank cluster 2	42	42	42
Observations	1257	1257	1257

Notes. This sample includes firms that have at least one facility before crisis October 2008-June 2009. The restriction leads to 1257 firms. The regression is at the firm level. The dependent variable is the LC liquidity growth rate defined as the change in log (average lines of credit) from October 2006-June 2007 to the crisis period October 2008-June 2009. LC amount is not extracted from 10-K or 10-Q, but it is constructed by aggregating all the outstanding LC facilities from Dealscan at a given point in time (Acharya et al., 2013). %Δ loans to other borrowers (ΔL_i) equals the change in the number of loans made by firms' lead bank to all other firms between the periods October 2005-June 2006 & October 2006-June 2007 and the crisis period October 2008-June 2009. ΔL_i has been normalized, so it has unit variance. ABX exposure is the lead bank's exposure to ABX AAA 2006-H1 index (ABX exposure data is from Chodorow-Reich's website). Firm level measures of ΔL_i and ABX exposure are the weighted average by bank allocation over the lead banks in the last pre-crisis syndicate. Financial variables include size, cash flow, cash, Q, and leverage. Industry is 2-digit SIC. Ratings are categorized into unrated, below-investment grade, and investment grade. Standard errors are two-way clustered on the lead lenders in the borrower's last pre-crisis syndicate and are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. This table reports the effect of bank liquidity supply on firms' LC growth for the large sample of 1257 firms. Firms that borrowe before the crisis from relatively healthy banks experience a higher LC growth than those that borrow before the crisis from unhealthy banks.

Table 12

The effect of bank liquidity supply on investment (firm-level regression)

	Investment growth rate		
	OLS	OLS	IV (ABX exposure)
	(1)	(2)	(3)
%Δ loans to other borrowers (ΔL_i)	0.083**	0.082**	0.137***
	(0.036)	(0.035)	(0.028)
Financial variables	No	Yes	Yes
Industry FE	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes
State FE	Yes	Yes	Yes
First stage F-statistics			46.6
Lead bank cluster 1	40	40	40
Lead bank cluster 2	42	42	42
Observations	1257	1257	1257

Notes. This sample includes firms that have at least one facility before crisis October 2008-June 2009. The restriction leads to 1257 firms. The regression is at the firm level. The dependent variable is the investment growth rate defined as the change in log(total quarterly capital expenditures) from October 2006-June 2007 to the crisis period October 2008-June 2009. %Δ loans to other borrowers (ΔL_i) equals the change in the number of loans made by firms' lead bank to all other firms between the periods October 2005-June 2006 & October 2006-June 2007 and the crisis period October 2008-June 2009. ΔL_i has been normalized, so it has unit variance. ABX exposure is the lead bank's exposure to ABX AAA 2006-H1 index (ABX exposure data is from Chodorow-Reich's website). Firm level measures of ΔL_i and ABX exposure are the weighted average by bank allocation over the lead banks in the last pre-crisis syndicate. Financial variables include size, cash flow, cash, Q, and leverage. Industry is 2-digit SIC. Ratings are categorized into unrated, below-investment grade, and investment grade. Standard errors are two-way clustered on the lead lenders in the borrower's last pre-crisis syndicate and are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. This table reports the main results of the effect of bank liquidity supply on investment for the large sample of 1257 firms. Firms that borrow before the crisis from relatively healthy lenders experience a higher investment growth than firms attached to unhealthy banks before the crisis.

Table 13

The effect of bank liquidity supply on LC and investment by ratings

	Lines of credit growth rate	Investment growth rate
	(1)	(2)
%Δ loans to other borrowers (ΔL_i) * Unrated	1.068***	0.117**
	(0.383)	(0.050)
%Δ loans to other borrowers (ΔL_i) * Rated	0.496	0.015
	(0.309)	(0.035)
Financial controls	Yes	Yes
Industry FE	Yes	Yes
Rating FE	Yes	Yes
State FE	Yes	Yes
Lead bank cluster 1	40	40
Lead bank cluster 2	42	42
Observations	1257	1257

Notes. This sample includes firms that have at least one facility before crisis October 2008-June 2009. The restrictions lead to 1257 firms. The regression is at the firm level. The dependent variable in column 1 is the bank liquidity growth rate defined as the change in log (average lines of credit) from 2006:10-2007:6 to 2008:10-2009:6. The dependent variable in column 2 is the investment growth rate defined as the change in log (total capital expenditures) from October 2006-June 2007 to 2008-June 2009. %Δ loans to other borrowers (ΔL_i) equals the change in the number of loans made by firms' lead bank to all other firms between the periods October 2005-June 2006 & October 2006-June 2007 and the crisis period October 2008-June 2009. ΔL_i has been normalized, so it has unit variance. Firm level measures of ΔL_i are the weighted average by bank allocation over the lead banks in the last pre-crisis syndicate. Financial variables include size, cash flow, cash, Q, and leverage. Industry is 2-digit SIC. Rating are categorized into unrated, below-investment grade, and investment grade. Standard errors are two-way clustered on the lead lenders in the borrower's last pre-crisis syndicate and are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. This table reports the heterogeneous effects of bank liquidity supply on bank liquidity and investment growth for the large sample of 1257 firms. The health of last pre-crisis syndicate lenders has an economically large and statistically significant effect on the bank liquidity growth and investment growth for unrated firms but only mild effects on rated firms.

Table 14

The effect of bank liquidity supply on choice of cash and LC

	LC/(LC+cash)		LC/net assets	
	OLS	IV (ABX exposure)	OLS	IV (ABX exposure)
	(1)	(2)	(3)	(4)
%Δ loans to other borrowers (ΔL_i)	0.030***	0.039***	0.021**	0.026***
	(0.011)	(0.014)	(0.009)	(0.009)
Financial controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
First stage F-statistics		47.1		47.1
Lead bank cluster 1	40	39	40	39
Lead bank cluster 2	42	42	42	42
Observations	1257	1257	1257	1257

Notes. This sample includes firms that have at least one facility before crisis October 2008-June 2009. The restriction leads to 1257 firms. The regression is at the firm level. The dependent variable in column 1 – 2 is change in average LC/(LC+cash) from October 2006-June 2007 to the crisis period October 2008-June 2009. The dependent variable in column 3 – 4 is change in average LC/net assets from October 2006-June 2007 to the crisis period October 2008-June 2009. %Δ loans to other borrowers (ΔL_i) equals the change in the number of loans made by firms' lead bank to all other firms between the periods October 2005-June 2006 & October 2006-June 2007 and the crisis period October 2008-June 2009. ΔL_i has been normalized, so it has unit variance. ABX exposure is lead bank's exposure to ABX AAA 2006-H1 index (ABX exposure data is from Chodorow-Reich's website). Financial variables include size, cash flow, Q, leverage, net worth ((assets – liabilities)/assets), and tangibility (tangible assets/total assets). Firm level measures of ΔL_i and ABX exposure are the weighted average by bank allocation over the lead banks in the last pre-crisis syndicate. Industry is 2-digit SIC. Ratings are categorized into unrated, below-investment grade, and investment grade. Standard errors are two-way clustered on the lead lenders in the borrower's last pre-crisis syndicate and are displayed in parenthesis. ***, **, * represents significance levels are the 1%, 5%, and 10%, respectively.

Interpretation. This table reports the effect of bank liquidity supply on firm's choice of LC and cash for the large sample of 1257 firms. Firms whose pre-crisis lenders are relatively healthy use more bank liquidity in their liquidity management than those attached to unhealthy pre-crisis banks.