

ABSTRACT

Title of Dissertation: ESSAYS ON FINANCIAL INTERMEDIATION

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This dissertation explores the relationship between financial intermediaries and the macroeconomy, both internationally and domestically. The dissertation is composed of two chapters, which study the role of financial sectors in international finance and the US economy, respectively.

In the first chapter, I build a two-country two-goods open economy model with asymmetric financial development levels to jointly match two puzzling observations during the 2008 global financial crisis (GFC): (1) the real consumption growth declined more in foreign countries than in the US although the crisis broke out in the US; (2) the US dollar appreciated against foreign currencies despite the sharp net foreign asset position (NFA) deterioration in the US. The key innovation is to introduce a milder financial constraint in the US within an international context. In tranquil times, the US holds more risky assets due to its more advanced financial market and consequently is more exposed to risks. When a crisis unfolds, the US

financial intermediaries suffer heavier capital losses and are forced to liquidate risky asset holdings to deleverage. This deleveraging process leads to a capital retrenchment in the US, which will smooth the US consumption, raise the relative demand of US goods, push up the domestic price index, and lead to a US dollar appreciation. Meanwhile, the NFA deterioration in the US is mainly due to the valuation effect rather than the transaction effect. I show that the valuation effect does not affect the contemporaneous relative consumption between countries, a fact that has been overlooked in the literature. I then verify the model predictions in the data covering major countries from 2003 to 2018. The empirical evidence echoes the theoretical predictions: (1) The US financial sector net worth plunged more than its foreign counterparts and there was a large capital retrenchment in the US during the GFC. (2) The US capital retrenchment had a significant negative impact on foreign countries' consumption and currency value.

In the second chapter, I identify a series of credit supply shocks in the US since the 1970s using sign restriction VAR and apply the identified shock to firm-level data using the panel local projection method. I document two main findings. First, the identified credit supply shock has a significant and persistent impact on firm investment. One unit of a credit supply shock (0.39% movement of credit volume) induces over 1% movement of firm investment on average at the peak. Different from monetary policy shocks, the credit supply shock has medium- and long-term effects on real variables. Second, the heterogeneous responses of firm investment to the credit supply shock conditional on firm default risk are state-dependent. Firms with lower default risk will increase investment more relative to average firms dur-

ing credit expansions, and contract investment less during credit contractions. Low default risk firms have consistently lower borrowing costs and better access to external financing over credit cycles. This state-dependence of heterogeneous effects also holds for firms that are large, mature, and less volatile. The second finding has important implications for both empirical and theoretical studies in the future. On the empirical side, it suggests a possibility of misspecification when assuming the effects of firm characteristics on firm activity to exogenous shocks are invariant in expansionary and contractionary phases. This paper highlights that the effects of firm characteristics on firm investment to credit supply shocks have flipped signs and commensurate magnitudes during credit expansions and contractions. On the theoretical side, the evidence is consistent with the insights of financial friction literature arguing that financially constrained firms will be more negatively impacted during credit contractions. Nevertheless, it also suggests that this effect is nonlinear and state-dependent, i.e., financial frictions will amplify the effects of negative shocks, but dampen the effects of positive shocks. A future model featuring credit cycles and heterogeneous financial frictions should take this observation into account.

ESSAYS ON FINANCIAL INTERMEDIATION

by

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Dedication

*To Jiuzhi Huang, my mother,
and Weiqin Yang, my girlfriend*

Acknowledgments

It has been a long journey to finally get here. When it is finally time, I do not know what to say except thanks.

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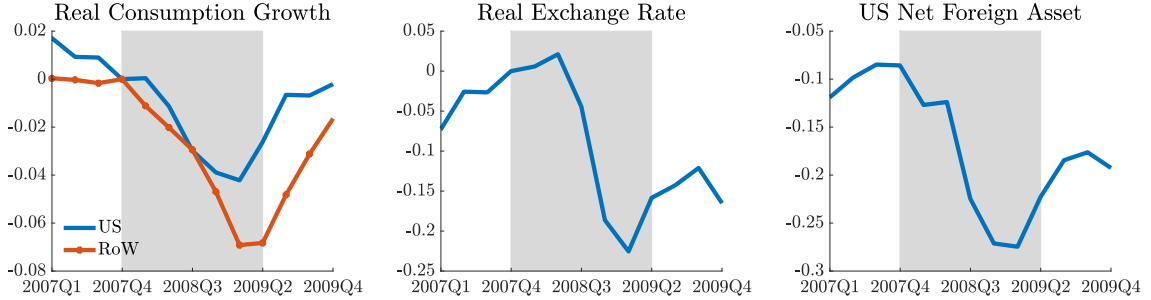
Chapter 1: Consumption, Exchange Rate, and External Adjustment in a Crisis

1.1 Introduction

A domestic housing slump that originated in the US turned into a global financial crisis (GFC) in 2008. During this global economic meltdown, we observe two puzzling facts: first, the real consumption growth declined more in foreign countries than in the US, even though the crisis broke out in the US; second, the US dollar appreciated against foreign currencies despite the sharp net foreign asset position (NFA) deterioration in the US. This paper builds a two-country open economy model with asymmetric financial development levels, studies the interactions between financial intermediaries across countries during the GFC, and generates global risk-sharing, exchange rate, and external account dynamics that are consistent with the two observations.

Figure 1.1 shows the global real consumption growth, real exchange rate, and the US NFA during the GFC.¹ The country sample is divided into two groups: the

¹The data sample includes 10 advanced economies (Australia, Belgium, Canada, France, Germany, Italy, Japan, Netherlands, United Kingdom, United States) and 6 emerging economies (Argentina, Brazil, China, India, Korea, Mexico). These are the countries that have bilateral international investment position and transaction data vis-à-vis the US available from BEA.



Note: This figure displays the global real consumption growth, real exchange rate, and the US NFA during the GFC. Real consumption growth is the year-on-year log-difference of real consumption and averaged for the RoW. The real exchange rate is logged and averaged for the RoW weighted by bilateral trade volume with the US. Both series are normalized to zero in 2007Q4. The US NFA is scaled by nominal GDP. This figure shows that the US real consumption growth declined less than the RoW during the GFC although the crisis originated in the US, and the US dollar appreciated against foreign currencies despite the sharp NFA deterioration in the US.

Figure 1.1: Puzzling Facts During the Global Financial Crisis

US and the rest of the world (RoW).² The RoW real consumption growth is the average across countries other than the US, and the real exchange rate is weighted by bilateral trade volume with the US.³ The real exchange rate is denoted as the US dollar price of foreign currency, and a fall in the exchange rate indicates a US dollar appreciation against other currencies. Both series are normalized to zero in 2007Q4. The US NFA is scaled by the US nominal GDP. In the left column, the real consumption growth in the RoW plunged deeper than in the US, both reaching the lowest point in 2009Q1. The RoW real consumption growth dropped over 3% more than the US. The middle column shows a sharp real exchange rate decline around the same time. The weighted real exchange rate appreciation of the US

²The RoW in the data sample accounts for around 65% of the world output excluding the US and is a fairly reasonable representation of the world economy.

³Using the trade-volume-weighted exchange rate is a common method to aggregate bilateral exchange rates, such as BIS effective exchange rates. Using alternative weights would not change the main results.

dollar was substantial, around 22.5% in 2009Q1 since 2007Q4.⁴ The sharp US dollar appreciation was unexpected considering the large US NFA deterioration during the GFC as shown in the right column. The US NFA, scaled by GDP, declined around 19% in 2009Q1 since 2007Q4.

The two observations are puzzling since the financial turmoil originated in the US financial sector and then spread to other countries. Why would the peripheral countries suffer more consumption growth drop than the epicenter country during a global financial earthquake? How should we relate the external account adjustments to the consumption and exchange rate dynamics during the GFC?

These questions are challenging to answer in existing macro models. First, [Gourinchas et al. \(2010\)](#) and [Maggiore \(2017\)](#) argue that there is a large wealth transfer from the US to the RoW during the GFC, and thus there should be a relative increase in the RoW consumption, the opposite of what we see in the data. Their models could generate consistent predictions on the US external account dynamics during a crisis yet fail to match the consumption and exchange rate dynamics.

Second, conventional macro models predict that a country with a deteriorated external balance sheet tends to have a depreciated currency value. [Maggiore \(2017\)](#) characterizes the tension between the US dollar appreciation and the US NFA deterioration during the GFC as “the reserve currency paradox.” A related strand of literature connects the dollar appreciation and the role of the US dollar as a reserve currency ([Farhi and Gabaix \(2015\)](#); [Jiang et al. \(2018\)](#)) and argues that the US dol-

⁴Figure [A.1](#) in Appendix [A.2](#) presents the country-level evidence of global consumption and exchange rate dynamics during the GFC. 12 out of 15 countries suffer a deeper consumption growth drop and currency depreciation against the US dollar during the GFC.

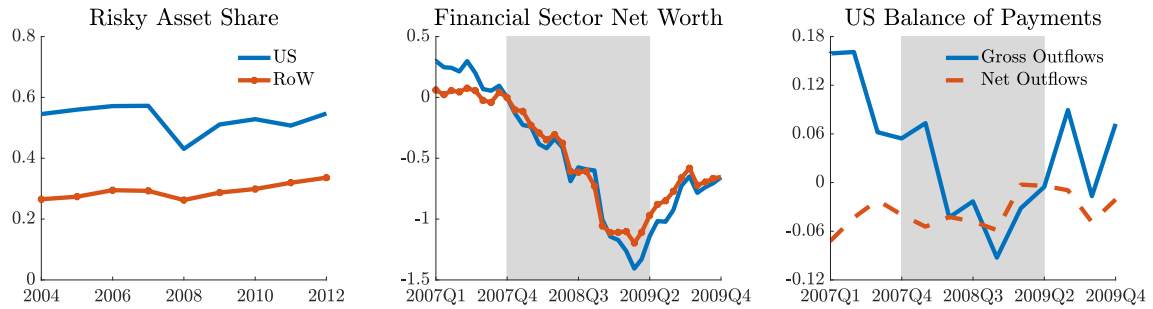
lar appreciation during the GFC resulted from a demand for safe assets. However, the consumption and external account dynamics are absent in their theory.

The goal of this paper is to provide a theoretical framework that could rationalize the two puzzling observations during the GFC and verify the model predictions in the data. Despite extensive debates on the factors behind the global impacts of the GFC, there are very few formal structures to analyze these phenomena jointly. This paper fills this gap in the literature. The key assumption is that both the US and foreign countries are financially constrained, though the constraint is milder in the US. The mechanism is intuitive. The US financial intermediaries hold more risky assets in tranquil times, both domestically and internationally, due to their higher financial development level. Therefore, they are more exposed to financial risks and suffer heavier capital losses when a crisis unfolds. In turn, they have a stronger incentive to liquidate their risky asset holdings to deleverage and meet the financial constraint, compared to their foreign counterparts. The US fire sales will bring capital flows back to the US and smooth the domestic consumption during the crisis. The relative increase in the US consumption will raise the relative demand for domestic goods due to the domestic consumption bias, push up the domestic price index, improve the terms of trade, and in the end, lead to a US dollar appreciation. The NFA deterioration in the US is dominated by asset price fluctuations – the valuation effect. However, I will show that the valuation effect does not play a role in the contemporaneous relative consumption and exchange rate dynamics during the crisis, a fact that has been overlooked in the literature.

Introducing asymmetric financial frictions in both countries generates inter-

esting interactions between financial sectors. The conventional wisdom considers the US more financially developed and it has a better financial risk capacity than other countries. Though economists realize the financial frictions in the US in a closed economy such as [Gertler and Karadi \(2011\)](#); [Gertler and Kiyotaki \(2010\)](#), in an international context, the US often serves as a frictionless benchmark country and the deleveraging process is usually considered more urgent in foreign countries. However, a higher financial development level is not equivalent to no financial frictions in an open economy. In the presence of financial frictions, the US financial intermediaries would face a tighter binding constraint and a stronger incentive to deleverage during a crisis, since they bear more losses and higher financial risks thanks to their aggressive risky asset holdings in normal times. This paper studies the fire sales of the US financial intermediaries during a crisis in an open economy and highlights its nontrivial global impacts.

The model predicts that the US financial sector will bear more capital losses and thus fire sell during a financial crisis since they hold more risky assets in normal times. The model predictions are consistent with the data. [Figure 1.2](#) shows the risky asset share on the external balance sheet, the financial sector net worth in the US and RoW, and the US balance of payments during the GFC. The risky asset share is defined as the annual equity asset holdings over the total asset net of derivatives. The financial sector net worth is the monthly market value of financial firms, normalized by output, and averaged for the RoW. The financial sector market value is normalized to zero in 2007M10. The quarterly gross and net US capital outflows are scaled by the US GDP. In the left column, over 55% of the US external



Note: This figure displays the external portfolio and financial sector market value in the US and RoW, and the US balance of payment. The risky asset share is calculated as the equity asset holdings (FDI, portfolio, and other equity investments) over the total asset net of derivatives. The derivatives are excluded to avoid possible issues associated with the netting of contracts. The financial sector market value is normalized by output and averaged for the RoW, normalized to zero in 2007M10. The financial sector includes banks, life and non-life insurance, real estate investment & services, real estate investment trusts, financial services, and equity investment instruments following Industry Classification Benchmark jointly created by FTSE and Dow Jones. I only include the financial firms that already exist before 2007 to exclude the extensive margin of the market value changes. The gross and net outflows in the US are scaled by the US GDP. This figure shows the US financial sector bore more capital losses and liquidated their risky asset holdings during the GFC.

Figure 1.2: External Account and Financial Sector Net Worth

portfolio is composed of risky assets while the ratio in the RoW is around 30% since 2004. The US is more exposed to risky asset price fluctuations than the RoW, and there is a sharp 14% decline in risky asset holdings in the US during the GFC. The decline is less obvious in the RoW. Financial sectors suffered substantial capital losses during the GFC as shown in the middle column, reaching the lowest point in both the US and RoW in February 2009. The RoW financial sector market value, scaled by output, recorded a 58.4% plunge while the US financial sector suffered a 61.8% dive since October 2007, around 3.4% more than their RoW counterparts.⁵ The right column shows a sharp gross outflow decline and negative net outflows in the US, indicating a large capital retrenchment during the GFC.

⁵Figure A.2 in Appendix A.2 presents the country-level evidence of risky asset share and the financial sector net worth during the GFC. The US suffered the largest risky asset share drop, and bore more capital losses in the financial sector than two-thirds of the countries in the sample during the GFC.

I then verify the model predictions in the data. Based on a data sample covering major economies from 2003 to 2018, I run a panel regression and a recursive VAR estimation to study how the gross capital inflows from the US in foreign countries would respond when the global economic uncertainty rises, and how the US investors' decision on their overseas investment would impact foreign countries' consumption and currency value. The panel regression finds that foreign countries' gross capital inflows from the US will decline during a crisis. The capital stop in foreign countries has significant negative effects on their real consumption growth and currency value. The recursive VAR estimation finds similar results. To a one standard deviation increase of VIX, the capital inflows from the US in foreign countries would incur a sharp decline; consumption declines more in foreign countries than in the US; and the US dollar appreciates against foreign currencies.

The contribution of this paper is twofold. First, I find that the recession severity variation across countries, measured by real consumption growth, can be explained by a dominant overseas factor – the US capital retrenchment. There is a long literature studying the cross-country variations on the macroeconomic impacts of the GFC. They attribute the recession severity in foreign countries to their own domestic factors such as household leverage increase, credit growth, asset price appreciation, and so on.⁶ In contrast, I find that the deeper consumption decline in foreign countries is associated with the US capital retrenchment, a channel less studied in the literature.

⁶See [Berkmen et al. \(2012\)](#); [Claessens et al. \(2010\)](#); [Glick and Lansing \(2010\)](#); [Kamin and DeMarco \(2012\)](#); [Lane and Milesi-Ferretti \(2011\)](#); [Musso et al. \(2011\)](#); [Rose and Spiegel \(2010, 2011, 2012\)](#).

The GFC also inspires a discussion of the role of the US in the international financial system. [Gourinchas et al. \(2010\)](#) and [Maggiori \(2017\)](#) argue that the US took on an exorbitant duty as a global insurance provider during the GFC. They document the US NFA deterioration during the GFC and argue that the NFA deterioration implies a wealth transfer from the US to the RoW, which would smooth the RoW consumption. Assuming the US is either less risk-averse or financially frictionless, their models are successful in matching the NFA dynamics but fail to explain the risk-sharing patterns in the data. Following the NFA decomposition in [Gourinchas et al. \(2012\)](#), I will show that the valuation effect does not play a role in the contemporaneous relative consumption dynamics, even though it is the dominant force in driving the NFA dynamics.

Second, I propose a new channel of the US dollar appreciation during the GFC that could potentially solve the reserve currency paradox and the consumption–real exchange rate anomaly. Several recent works provide theories to explain this puzzling fact.⁷ They typically take the stand that the US assets are safe, and the US dollar appreciation is a safety compensation. This paper proposes an alternative channel: the US real exchange rate appreciates because the US capital retrenchment from overseas increases the US consumption relative to foreign countries, which raises the relative demand of domestic goods and pushes up the domestic price index. The capital retrenchment stems from the US financial intermediaries’ deleveraging process, not the flight-to-safety behavior by foreign agents. My model prediction is consistent with the empirical findings in [Fratzscher \(2009\)](#). He documents that the

⁷See [Colacito et al. \(2018\)](#); [Farhi and Gabaix \(2015\)](#); [Jiang et al. \(2018\)](#).

currencies in countries with larger than average financial liabilities vis-à-vis the US depreciated by 25% in the period July 2008 – February 2009, whereas those with a lower-than-average financial exposure fell only by 14%.

The new channel also speaks to the consumption–real exchange rate anomaly. [Backus and Smith \(1993\)](#) and [Chari et al. \(2002\)](#) discovered that the correlation between relative consumption and real exchange rate is unity in the model while it is negative in the data. The traditional international business cycle model predicts that a country with a higher relative consumption will have a currency depreciation, at odds with the US dollar appreciation during the GFC. The existing literature could reconcile this discrepancy by introducing incompleteness in the financial market and non-tradable goods, or low trade elasticity.⁸ I find that the introduction of financial frictions in an open economy model could also account for this anomaly by breaking the tight link between relative consumption and real exchange rate.

Relation to the literature. This paper is related to several strands of literature. First, this paper is an open economy model with financial frictions in the spirit of [Dedola and Lombardo \(2012\)](#); [Dedola et al. \(2013\)](#); [Devereux and Yetman \(2010\)](#). These papers investigate the international transmission of shocks via financial markets, extending the seminal work of [Bernanke et al. \(1999\)](#); [Gertler and Karadi \(2011\)](#); [Gertler and Kiyotaki \(2010\)](#); [Kiyotaki and Moore \(1997\)](#) into open economies.⁹ Unlike their focus on international financial contagion, I investigate the consumption and exchange rate dynamics during a global crisis. The international

⁸See [Benigno and Thoenissen \(2008\)](#); [Corsetti et al. \(2008\)](#).

⁹Other related papers include [Bai and Zhang \(2012\)](#); [Bruno and Shin \(2015\)](#); [Kalemli-Ozcan et al. \(2013\)](#); [Kollmann et al. \(2011\)](#); [Mendoza and Quadrini \(2010\)](#); [Perri and Quadrini \(2018\)](#).

transmission mechanism in this paper is in line with [Devereux and Yetman \(2010\)](#). The model in this paper is similar to [Dedola et al. \(2013\)](#) who also develop a two-country open economy model based on [Gertler and Karadi \(2011\)](#); [Gertler and Kiyotaki \(2010\)](#). There are two key differences from their work: first, financial frictions in this paper are asymmetric between two countries; second, I introduce exchange rate dynamics. The asymmetric financial frictions across countries are in line with [Caballero et al. \(2008\)](#); [Maggiore \(2017\)](#); [Mendoza et al. \(2009\)](#). The most relevant work is [Maggiore \(2017\)](#). The key novelty in this paper is to introduce a milder financial constraint in the US. This assumption reverses the risk-sharing pattern and exchange rate dynamics predicted in [Maggiore \(2017\)](#) and generates predictions that are consistent with the data.

Second, this paper relates to the conventional international risk-sharing literature.¹⁰ [Backus et al. \(1992\)](#) is the first work documenting the puzzling fact that the cross-country correlation of consumption is higher than the output in the theory while the data reveals the opposite. Taking one step further, [Gourinchas et al. \(2010, 2012\)](#); [Maggiore \(2017\)](#) argue that international risk-sharing is not only insufficient in the data but also works in one direction, the US insuring other countries during a crisis due to its higher financial development level. Their risk-sharing conclusion comes from model predictions while their models are built to match the NFA dynamics. However, their model predictions on global risk-sharing are at odds with empirical evidence. The data reveals that foreign countries are providing insurance to the US during a crisis. This paper provides a theory that could match both the

¹⁰See [Cole and Obstfeld \(1991\)](#); [Kehoe and Perri \(2002\)](#); [Lewis \(1996\)](#).

consumption and NFA dynamics observed during the GFC.

Third, this paper also speaks to the transfer problem. The transfer problem about the relationship between international payments and exchange rate dynamics dates back to 1920s between [Ohlin \(1929a,b\)](#) and [Keynes \(1929a,b,c\)](#). [Lane and Milesi-Ferretti \(2004\)](#) find that on average a country with net liabilities tends to have a depreciated currency. The conventional macro model fails to predict the US dollar appreciation during the GFC. [Maggiore \(2017\)](#) proposes that the asymmetric international trade cost could be the potential solution. [Farhi and Gabaix \(2015\)](#) argue that safe countries will have a currency appreciation during a disaster since they can recover faster, which replicates the US dollar appreciation during the GFC. The underlying assumption in both [Farhi and Gabaix \(2015\)](#); [Maggiore \(2017\)](#) is that capital flows into the US since the US is safe heaven during the GFC. I propose an alternative channel: capital flows into the US due to the US financial intermediaries' fire sales of international assets during their deleveraging process, which leads to a US dollar appreciation. The model predictions are consistent with the empirical evidence documented in [Broner et al. \(2013\)](#); [Fratzcher \(2009\)](#); [Milesi-Ferretti and Tille \(2011\)](#); [Tressel \(2010\)](#).

Fourth, this paper is related to the strand of literature investigating the consumption–real exchange rate anomaly. [Backus and Smith \(1993\)](#); [Chari et al. \(2002\)](#) are among the first that find the discrepancy between the model and the data on the correlations between relative consumption and real exchange rate. [Benigno and Thoenissen \(2008\)](#); [Corsetti et al. \(2008\)](#) find that introducing incompleteness in the financial market and nontradable goods, or low trade elasticity could miti-

gate this discrepancy. This paper is complementary to their work and shows that introducing financial frictions could also break the tight link between relative consumption and real exchange rate in the model. Moreover, the relative rise in home country consumption and home currency value is caused by a positive shock in their work. Yet the similar consumption and exchange rate dynamics in this paper are generated by a negative shock.

Structure of the paper. The structure of the paper is as follows. In the second section, I describe the model setup and provide an analysis of relative consumption and exchange rate dynamics in the presence of asymmetric financial frictions. In the third section, I report and discuss the quantitative results. The fourth section provides empirical evidence in support of the model predictions. And the last section concludes.

1.2 Open Economy with Asymmetric Financial Frictions

This section presents a two-country two-goods open economy model with asymmetric financial frictions. Each country is endowed with a differentiated good and goods can flow freely between countries without a trading cost. In each country, savers make deposits in their domestic financial intermediaries (banks), who will invest in the claims against Home and Foreign endowments. Since the endowments fluctuate over time, I refer to the claims against them as risky assets. Financial frictions in this model arise in an agency problem that constrains the banks' ability to obtain funds from domestic savers. Other than that, there are no frictions in

enforcing the financial contracts while banks claim their shares of the endowments.

The key assumption in this paper is to introduce asymmetric financial development levels in the two countries. Home banks are assumed to be more financially developed such that they are larger and run at a higher leverage ratio. We can think of the Home country as the US, and the Foreign country as the RoW. I will mainly describe the settings for the Home country and specify Foreign country equations when necessary. Consistent with the convention in the international finance literature, the Foreign variables are denoted by the superscript $*$. Throughout the paper, uppercase letters denote aggregate variables, while lowercase letters denote individual agents' variables.

1.2.1 Model Setup

1.2.1.1 Households

Each country is populated by a continuum of measure one of households. Within each household, there are $1 - f$ fraction of the households that are “savers” and the remaining fraction f “bankers”. Savers make decisions on consumption and savings. Each banker manages a financial intermediary which raises funds from domestic savers and invests in both domestic and foreign risky assets. The deposits in banks are riskless one-period securities. To make the existence of financial intermediaries valid, I assume that only bankers have the technology to hold risky assets. The financial intermediary can be best thought of as a bank. Both savers and bankers transfer their earnings back to their households and hence there is per-

fect risk-sharing within each household. Households are homogeneous and I can describe the behavior of the representative household for simplicity.

Consumption Maximization. Each household in the Home country has a utility function over a basket of both Home and Foreign goods,

$$C_t = C_t^H C_t^{F1-\alpha}$$

where C_t^H and C_t^F are the consumption of Home and Foreign goods. I further assume $\alpha \in (0.5, 1)$ to reflect the consumption bias towards domestic goods.

Solving the static consumption maximization problem yields Home households' demand for Home and Foreign goods

$$C_t^H = \alpha \left(\frac{p_t}{P_t}\right)^{-1} C_t, \quad C_t^F = (1 - \alpha) \left(\frac{p_t^*}{P_t}\right)^{-1} C_t$$

where p_t and p_t^* are the prices of Home and Foreign goods and P_t the price index of the Home consumption basket.

The Home price index is a function of Home and Foreign good prices

$$P_t = \left(\frac{p_t^*}{1 - \alpha}\right)^{1-\alpha} \left(\frac{p_t}{\alpha}\right)^\alpha$$

The terms of trade (ToT) are defined as the ratio of Foreign good to Home good prices

$$\text{ToT}_t = \frac{p_t^*}{p_t}$$

where an increase in ToT represents a deterioration of the Home ToT.

The real exchange rate is defined as the Home price of Foreign currency

$$\mathcal{E}_t = \frac{P_t^*}{P_t}$$

where a fall in \mathcal{E} is a Home currency appreciation.

Utility Maximization. The representative household in the Home country maximizes its lifetime utility given by

$$\max_{\{C_t, D_t\}} E_t \sum_{t=0}^{\infty} \Theta_t \ln(C_t)$$

where

$$\Theta_t = \beta_{t-1}(\bar{C}_{t-1})\Theta_{t-1} = \zeta(1 + \bar{C}_{t-1})^{-\kappa}\Theta_{t-1}, \quad \Theta_0 = 1$$

is the external endogenous discount factor borrowing from [Schmitt-Grohe and Uribe \(2003\)](#) to induce stationarity. This assumption pins down the steady state without changing the dynamic results of the model.

The budget constraint for the representative household is

$$C_t + D_t = \Pi_t + R_{t-1}D_{t-1}$$

where C_t is the consumption at time t , D_t the quantity of the one-period deposits from t to $t + 1$, and R_{t-1} the real interest rate from $t - 1$ to t . The profit Π_t is generated from domestic banks.

The Euler equation is:

$$E_t \beta_t \Lambda_{t,t+1} R_t = 1$$

where $\beta_t \Lambda_{t,t+1} = \beta_t \frac{u_c(t+1)}{u_c(t)}$ is the stochastic discount factor and $u_c(t)$ the marginal utility with respect to consumption at time t .

1.2.1.2 Banks

Banks operate in two markets: the domestic retail market, where they obtain deposits from savers, and the global asset markets, where they can invest in risky assets issued by either the Home or Foreign country. In addition to obtaining funds from domestic savers, banks can also raise funds internally by their own net worth.

For an individual Home bank, the balance sheet constraint implies:

$$Q_t s_t^H + \mathcal{E}_t Q_t^* s_t^F = n_t + d_t$$

where s_t^H is the holdings of risky assets issued by the Home country and s_t^F the holdings of risky assets issued by the Foreign country. Q_t is the price of Home risky assets and Q_t^* the price of Foreign risky assets. Overall, the value of risky assets must equal the sum of its net worth n_t and the domestic deposits d_t .

For convenience, I denote the value of total assets held by a Home bank u_t as

$$u_t = Q_t s_t^H + \mathcal{E}_t Q_t^* s_t^F$$

and define the portfolio share of Foreign risky assets χ_t as

$$\mathcal{E}_t Q_t^* s_t^F = \chi_t u_t$$

Bankers have an incentive to over-accumulate capitals instead of paying dividends to their households and fund the investments internally if they would stay in business forever. To avoid potential capital over-accumulation, I assume an exogenous role switch rate between savers and bankers so that each banker can stay as a banker only for a finite horizon. Each period, with an i.i.d probability $1 - \sigma$, a banker exits in the next period and becomes a saver. Upon exit, a banker transfers retained earnings to its household. Meanwhile, $(1 - \sigma)f$ savers will randomly become bankers, keeping the overall population of savers and bankers constant over time. Since new bankers need start-up funds to operate, I assume that the households transfer the fraction $\frac{\xi}{1 - \sigma}$ of the total assets of exiting bankers to new bankers.

An individual Home bank's net worth from time $t - 1$ to time t evolves as

$$n_t = R_{kt}(1 - \chi_{t-1})u_{t-1} + \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} R_{kt}^* \chi_{t-1} u_{t-1} - R_{t-1} d_{t-1}$$

with R_{kt} and R_{kt}^* defined as

$$R_{kt} = \frac{\frac{p_t}{P_t} Y_t + Q_t}{Q_{t-1}}, \quad R_{kt}^* = \frac{\frac{p_t^*}{P_t^*} Y_t^* + Q_t^*}{Q_{t-1}^*}$$

where R_{kt} and R_{kt}^* are the gross rate of return on Home and Foreign risky assets respectively, and Y_t and Y_t^* are Home and Foreign endowments.

Given that bankers pay dividends to their households only when they exit, bankers will maximize their expected present value of future dividends upon possible exit:

$$V_t = \max_{\{u_t, \chi_t\}} E_t \sum_{\tau=1}^{\infty} (1 - \sigma) \sigma^{\tau-1} \Theta_{t+\tau} \Lambda_{t,t+\tau} n_{t+\tau}$$

To motivate an endogenous constraint on banks' ability to raise external funds, I introduce the following agency problem. Suppose after obtaining funds and making investment decisions, bankers may divert a fraction θ of their total assets for individual purposes. If a banker diverts the assets, the bank will be forced into bankruptcy and shut down. Depositors will only be able to reclaim the remaining fraction $(1 - \theta)$ of the assets but would not be able to recover the diverted part. With the recognition of the bankers' incentive to divert the funds, depositors will restrict the amount they lend. In this way, an endogenous credit constraint on banks arises. To validate the bankers' incentive of diverting funds to their own households and still keep the model tractable, it is better to think that savers save their deposits in banks that are managed by bankers belonging to other households.

The incentive compatibility constraint for depositors to be willing to deposit in banks must be satisfied by each Home bank:

$$V_t(u_t, \chi_t, d_t) \geq \theta u_t$$

In general, the Home banks' problem satisfies the Bellman equation, subject

to the endogenous credit constraint:

$$V_{t-1}(u_{t-1}, \chi_{t-1}, d_{t-1}) = \max_{\{u_t, \chi_t\}} E_{t-1} \beta_{t-1} \Lambda_{t-1,t} \left[(1 - \sigma)n_t + \sigma V_t(u_t, \chi_t, d_t) \right]$$

$$V_t(u_t, \chi_t, d_t) \geq \theta u_t$$

I conjecture that the value function of the Home banks is linear in $\{U_t, d_t\}$:

$$V_t = \eta_{st}^H (1 - \chi_t) U_t + \eta_{st}^F \chi_t U_t - \eta_{dt} d_t$$

where η_{st}^H is the marginal value of investing in Home risky assets, η_{st}^F the marginal value of Foreign risky asset investment, and η_{dt} the marginal cost of domestic deposits. These are time-varying parameters that will be determined endogenously.

The first order conditions are:

$$\eta_{st}^H - \eta_{dt} = \frac{\theta \lambda_t}{1 + \lambda_t} \tag{1.1}$$

$$\eta_{st}^H = \eta_{st}^F \tag{1.2}$$

$$\phi_t = \frac{u_t}{n_t} = \frac{\eta_{dt}(1 + \lambda_t)}{\theta} \tag{1.3}$$

where λ_t is the Lagrangian multiplier for the credit constraint, and ϕ_t is defined as Home banks' leverage ratio. Combining the first order conditions and the conje-

tured value function, the value function is linear if $\{\eta_{st}^H, \eta_{st}^F, \eta_{dt}\}$ satisfy:

$$\eta_{st}^H = E_t \beta_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1} \quad (1.4)$$

$$\eta_{st}^F = E_t \beta_t \Lambda_{t,t+1} \Omega_{t+1} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} R_{kt+1}^* \quad (1.5)$$

$$\eta_{dt} = E_t \beta_t \Lambda_{t,t+1} \Omega_{t+1} R_t \quad (1.6)$$

where

$$\Omega_t = 1 - \sigma + \sigma(1 + \lambda_t)\eta_{dt}$$

is defined as the marginal value of banks' net worth at time t , which is a weighted average of marginal values of exiting and continuing banks.

The key assumption in this paper is that both the Home and Foreign countries are financially constrained, while the constraint is milder in the Home country. The financial development level in each country is measured by θ . A smaller value of θ indicates a higher financial development level. Intuitively, if banks in one country could divert a smaller fraction of the total assets they are managing, depositors in that country will be more willing to save in their financial intermediaries. In the end, banks can run at a higher leverage ratio, hold more risky assets, and earn more profits. When $\theta = 0$, banks can raise an arbitrary amount of funds from domestic savers and invest in risky assets, driving the risk premium between the asset return and borrowing cost to zero, as shown in Equation (1.1). As a result, the leverage ratio constraint imposed by Equation (1.3) will not be binding.

The financial development level in one country can be measured in multiple

dimensions as documented in the influential work [Beck et al. \(1999, 2010\)](#), presumably the size and efficiency of the financial system. In the highly-stylized model in this paper, the financial development level in each country is simplified into the value of θ . In the steady state, a smaller θ indicates a higher bank leverage ratio and larger risky asset holdings at the same time, where the former captures the efficiency and the latter the size of the financial sector in the model. This alleviates the concern that some European countries were as highly levered as the US in their financial sectors before the GFC, yet we still count them as the RoW in this paper. Considering the size of these European countries' financial sectors, none of them is larger than 30% of the financial sector market value in the US or 40% of the overall external equity asset holdings. The US is the more financially developed country measured in almost every dimension, even though some other countries might be comparable in some categories. Without any doubt, measuring a country's financial development level by a single parameter is an over-simplification, but it is a reasonable assumption to serve the main purpose of this paper.

The term $\beta_t \Lambda_{t,t+1} \Omega_{t+1}$ in Equation (1.4) to (1.6) is the “augmented stochastic discount factor”, which differs from the representative households' stochastic discount factor $\beta_t \Lambda_{t,t+1}$. From a perspective of asset pricing, banks are concerned about two risks: consumption risk and financial risk. Banks dislike the assets with low returns when the aggregate consumption or their net worth is low. The former is captured by the term $\Lambda_{t,t+1}$. The latter, due to the credit constraint, is captured by Ω_{t+1} . If banks face no credit constraints, the Lagrangian multiplier $\lambda_t = 0$ and the marginal value of banks' net worth $\Omega_{t+1} = 1$. The individual bank's value will

be determined only by its net worth $V_t = n_t$, and it will price the assets as the representative household. However, if banks are binding by the credit constraint, the consumption risk and the financial risk will be positively correlated in equilibrium, and banks will discount assets more than the representative households. In the steady state, a smaller θ indicates a smaller financial risk Ω_{t+1} .

Therefore, I assume that

$$0 < \theta < \theta^* < 1$$

to reflect the higher financial development level in the Home country. This is the key assumption in this model to generate the consumption and exchange rate dynamics that match the empirical observations. Other than that, the two countries are symmetric. In equilibrium, I assume the credit constraint always binds within a local region of the steady state.

The aggregate evolution of the net wealth of Home banks includes two parts: the continuing banks and the newly-entering banks.

$$N_t = \sigma [R_{kt} Q_{t-1} S_{t-1}^H + \mathcal{E}_t R_{kt}^* Q_{t-1}^* S_{t-1}^F - R_{t-1} D_{t-1}] + \xi U_{t-1}$$

Portfolio Choice. Besides the no-arbitrage condition between the retail market and the global asset market as in a closed economy, there is an additional no-arbitrage condition between Home and Foreign risky assets from Equation (1.2). Otherwise, banks will invest more in the asset with a higher return, push the asset

price up, and eventually drive the return discrepancy between the two assets to zero.

In equilibrium, one of the two no-arbitrage conditions from the Home and Foreign banks' problem is redundant up to the first order approximation. Here I make a further assumption: $\chi_t = \chi_t^* = \chi$, i.e., portfolio choice is symmetric between countries and constant over time following [Dedola et al. \(2013\)](#). The portfolio choice is determined by the domestic consumption bias in the steady state $\chi = 1 - \alpha$, that is, the bias towards domestic assets equals the consumption bias towards domestic goods.¹¹ Households will hold the share of claims that is consistent with their preference towards that good.

1.2.1.3 Equilibrium

To close the model, I will specify the remaining variables and the aggregate market clearing conditions.

The Home and Foreign endowments Y_t and Y_t^* are exogenously given as

$$Y_t = \exp(A_t)Y, \quad Y_t^* = \exp(A_t^*)Y^*$$

where Y and Y^* are normalized to one. A_t and A_t^* are the endowment shocks following $AR(1)$ processes

$$A_t = \rho_A A_{t-1} + \varepsilon_{A_t} + \varepsilon_t, \quad A_t^* = \rho_A^* A_{t-1}^* + \varepsilon_{A_t^*} + \varepsilon_t$$

¹¹The proof is provided in [Appendix A.3](#).

where ε_{A_t} and $\varepsilon_{A_t^*}$ are country-specific endowment innovations and ε_t is a global common innovation. The endowment shocks are the only sources of exogenous disturbances in the model.

Without loss of generality, the total supply of each risky asset is also normalized to one

$$S^F + S^{*F} = 1, \quad S^H + S^{*H} = 1$$

The capital clearing market conditions are

$$Q_t = (1 - \chi_t)U_t + \varepsilon_t \chi_t^* U_t^*, \quad Q_t^* = (1 - \chi_t^*)U_t^* + \frac{\chi_t U_t}{\varepsilon_t}$$

The goods markets clearing conditions are

$$Y_t = C_t^H + C_t^{*H}, \quad Y_t^* = C_t^F + C_t^{*F}$$

The trade balance (NX) is defined as the difference between the endowment and the aggregate consumption in terms of domestic price

$$NX_t = \frac{p_t}{P_t} Y_t - C_t, \quad NX_t^* = \frac{p_t^*}{P_t^*} Y_t^* - C_t^*$$

The net foreign asset (NFA) is the difference between foreign assets owned by domestic banks and domestic assets owned by foreign banks denominated in

domestic price

$$NFA_t = \mathcal{E}_t Q_t^* S_t^F - Q_t S_t^{*H}, \quad NFA_t^* = \frac{Q_t}{\mathcal{E}_t} S_t^{*H} - Q_t^* S_t^F$$

1.2.2 Analysis

In this section, I will report some analytical analysis of the model and highlight the key mechanisms in consumption and exchange rate dynamics.

1.2.2.1 Global Consumption Dynamics

Home risky asset pricing equations in the Home and Foreign country are

$$\eta_{st}^H = E_t \beta_t \Lambda_{t,t+1} \Omega_{t+1} R_{kt+1}, \quad \eta_{st}^{*H} = E_t \beta_t^* \Lambda_{t,t+1}^* \Omega_{t+1}^* \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} R_{kt+1}$$

The two equations imply that Home and Foreign banks are pricing the same risky asset with different stochastic discount factors due to asymmetric financial development levels. The terms Ω_{t+1} and Ω_{t+1}^* measure their financial risks, receptively.

Equate these two asset pricing equations above and recall that

$$\Lambda_{t,t+1} = \frac{u_c(t+1)}{u_c(t)} = \frac{C_t}{C_{t+1}}, \quad \Lambda_{t,t+1}^* = \frac{u_c^*(t+1)}{u_c^*(t)} = \frac{C_t^*}{C_{t+1}^*}$$

I get

$$\frac{\mathcal{E}_{t+1} C_{t+1}^*}{C_{t+1}} = \frac{\Omega_{t+1}^*}{\Omega_{t+1} \Gamma_t} \quad (1.7)$$

where $\Gamma_t = \frac{\beta_t C_t \eta_{st}^{*H}}{\beta_t^* C_t^* \eta_{st}^{*H}}$ is a pre-determined condition.¹²

The dynamics of relative consumption, measured in Home currency, between the Home and Foreign countries are determined by two components: the relative financial risk and the initial condition. The initial condition is pinned down by the calibration. For a large range of reasonable parameter values, the main results do not change. For the rest of the analysis, I will focus on the relative financial risk term. The Home country is less financially constrained and its financial risk is lower in tranquil times. Thus, Home banks run at a higher leverage ratio and hold more risky assets. When a crisis unfolds, Home banks suffer heavier capital losses, deviate more from their credit constraints, and their financial risk surge higher than Foreign banks. As a result, the relative financial risk term $\frac{\Omega_{t+1}^*}{\Omega_{t+1}}$ on the right hand side (RHS) of Equation (1.7) will decline. So does the relative consumption in the Foreign country. This is the key consumption dynamics condition in the model. Home banks have a stronger incentive to fire sell their risky assets holdings to deleverage, which will smooth the consumption in the Home country.

My model prediction is contrary to [Maggiore \(2017\)](#) where the term Ω_{t+1} is missing in his risk-sharing equation when the US financial sector is assumed to be financially frictionless. In this case, the consumption dynamics condition is only determined by the foreign country's financial risk. During a downturn, the US financial intermediaries can run at an arbitrary high leverage ratio and have no

¹²I report the consumption share dynamics instead of the consumption growth for the rest of the analysis following [Maggiore \(2017\)](#). The consumption quantity dynamics and the exchange rate dynamics move in the same direction to a Home and Global endowment shock, and opposite directions to a Foreign endowment shock. Since the first two scenarios are of particular interest, the main results are invariant to this change.

incentives to deleverage. Rising financial risks in foreign countries will improve their relative consumption. Introducing financial frictions in both countries yields interesting interactions between financial sectors across countries. In the steady state, a higher financial development level means a higher leverage ratio and a lower financial risk in the Home country. However, when a crisis breaks out, Home banks are hit harder and their financial risks increase more than Foreign banks.

Consumption–real exchange rate anomaly. The consumption dynamics condition also provides a new approach to address the consumption–real exchange rate anomaly. Suppose there are no credit constraints in both countries, i.e., $\Omega_t = \Omega_t^* = 1$. Equation (1.7) becomes

$$\mathcal{E}_{t+1} = \frac{C_{t+1}}{C_{t+1}^* \Gamma_t}$$

which is the exchange rate determination equation in a standard international business cycle model. In equilibrium, when relative consumption rises in the Home country, the Home exchange rate will depreciate. The correlation between relative consumption and real exchange rate will be unity according to the model, yet we find no supporting evidence in the data. Introducing financial frictions in both countries could break the tight link between relative consumption and exchange rate. When the relative financial risk increases in the Home country during a crisis, so is the relative consumption. As will be shown next, the relative demand for Home goods will rise due to the domestic consumption bias, push up the domestic price index, and result in a Home currency appreciation. The relative consumption and real

exchange rate move in the opposite directions as documented in the data.

1.2.2.2 Exchange Rate Dynamics

From the consumption dynamics condition and the goods markets clearing conditions, the demand for Home and Foreign goods in the Home and Foreign country is

$$C_{t+1}^H = \frac{\alpha\Gamma_t}{\alpha\Gamma_t + (1-\alpha)\frac{\Omega_{t+1}^*}{\Omega_{t+1}}} Y_{t+1}, \quad C_{t+1}^F = \frac{(1-\alpha)\Gamma_t}{(1-\alpha)\Gamma_t + \alpha\frac{\Omega_{t+1}^*}{\Omega_{t+1}}} Y_{t+1}^*$$

$$C_{t+1}^{*H} = \frac{(1-\alpha)\frac{\Omega_{t+1}^*}{\Omega_{t+1}}}{\alpha\Gamma_t + (1-\alpha)\frac{\Omega_{t+1}^*}{\Omega_{t+1}}} Y_{t+1}, \quad C_{t+1}^{*F} = \frac{\alpha\frac{\Omega_{t+1}^*}{\Omega_{t+1}}}{(1-\alpha)\Gamma_t + \alpha\frac{\Omega_{t+1}^*}{\Omega_{t+1}}} Y_{t+1}^*$$

Plug these demand functions back to the consumption dynamics condition, I get the ToT and real exchange rate as functions of the relative financial risk

$$ToT_{t+1} = \frac{(1-\alpha)\Gamma_t + \alpha\frac{\Omega_{t+1}^*}{\Omega_{t+1}}}{\alpha\Gamma_t + (1-\alpha)\frac{\Omega_{t+1}^*}{\Omega_{t+1}}} \cdot \frac{Y_{t+1}}{Y_{t+1}^*} \quad (1.8)$$

$$\mathcal{E}_{t+1} = ToT_{t+1}^{2\alpha-1} \quad (1.9)$$

The ToT is determined by two components: the endowment ratio and the relative financial risk. First, the endowment fluctuations will alter the relative supply of the two goods. If the Home good becomes relatively more scarce, the relative price of the Home good will rise and improve the Home ToT. This effect is present irrespective of domestic consumption bias. Second, if there is domestic consumption bias ($\alpha > 0.5$), the ToT will comove positively with the relative financial risk term. As discussed in the previous part, the relative consumption will increase along with

the relative financial risk in the Home country during a crisis. It will raise the relative demand for the Home good, push up the Home good price index, and improve the Home ToT. Overall, the endowment ratio effect turns out to be the dominant force. Besides the endowment ratio effect and the relative financial risk effect, the exchange rate is also determined by the domestic consumption bias. If $\alpha > 0.5$, the ToT and the exchange rate will be positively related. A Home crisis will lead to a Home ToT improvement and a Home currency appreciation. And a Foreign crisis will lead to a Home ToT deterioration and a Foreign currency appreciation. Suppose there is a global innovation that will affect the Home and Foreign endowment equally, the endowment ratio will remain constant during a crisis. In this case, the financial risk term will lead to a Home currency appreciation.

Reserve currency paradox. In the absence of financial frictions in the US, [Maggiore \(2017\)](#) predicts that the US dollar will depreciate during a global crisis, which makes US dollar-denominated assets riskier ex-ante. This prediction contradicts the US dollar appreciation during the GFC, and [Maggiore \(2017\)](#) refers to this contradiction as “the reserve currency paradox”. Complementary to the strand of literature arguing that the US dollar appreciation during GFC comes from its safety compensation as a global reserve currency, I propose an alternative channel: the fire sales by US financial sector due to its surging financial risk. During a crisis, the deleveraging process by the US financial intermediaries will lead to a capital inflow into the US and thus a US dollar appreciation. The two views are not necessarily in contradiction but rather complementary to each other. First, the flight-to-safety argument typically focuses on the US safe assets such as the US

treasuries, which are absent in this model, since this model only has risky assets. Second, the former captures the capital inflows into the US due to the demand of the US safe assets from foreign agents, while the latter captures those from the fire sales by the US agents.

1.3 Quantitative Results

In this section, I will report the quantitative results of the model and verify the conjecture in the analysis.

First, I report the steady state under the benchmark calibration. In the steady state, the Home country will hold more risky assets, enjoy more consumption, and run a current account deficit, as long as it has a higher financial development level. Also, I conduct steady state comparative statics by varying Home and Foreign countries' financial development level parameters θ and θ^* . As predicted in the previous section, in the steady state, the more financially developed the Home country is, the lower the financial risk it will bear, the higher leverage ratio it could run at, and the more risky assets it will hold.

Second, I report the impulse responses of the key variables. During a global financial crisis, the Home country consumption will increase relative to the Foreign country and the Home currency will appreciate, along with a NFA deterioration and a capital retrenchment, consistent with the empirical observations during the GFC. I will focus on the impacts of a global shock in the analysis so that I can isolate the effects of the relative financial risk on the exchange rate from that of

the endowment supply ratio. The impulse responses to country-specific shocks are reported in Appendix [A.2](#).

Third, I decompose the NFA dynamics into the valuation effect and transaction effect following [Gourinchas and Rey \(2007a,b\)](#). I will show that the NFA deterioration in the Home country is mainly due to the valuation effect. However, a country-level balance sheet transformation will show that the valuation effect does not play a role in the contemporaneous relative consumption. Instead, the transaction effect has an active but minor role in affecting the consumption and exchange rate dynamics.

1.3.1 Calibration

There are 12 parameters in the model and [Table 1.1](#) presents their values in the benchmark calibration. I set $\alpha = 0.75$ to reflect the domestic consumption bias following [Engel \(2011\)](#). The endogenous discount factor parameters are set as $\zeta = 0.995$ and $\kappa = 0.009$ to target the Home Discount Factor at 0.99 and the Home to Foreign consumption ratio at 2 in the steady state.¹³

I follow the calibration in the banks' problem closely with [Gertler and Karadi \(2011\)](#) considering my model is an open economy extension based on their work. I first set $\sigma = 0.972$ to match an average horizon of banks of a decade. The start-up funds transfer parameter is calibrated $\xi = 0.001$ to target Home banks' annualized risk premium at $100bp$. The Home and Foreign financial development levels are $\theta = 0.349$ and $\theta^* = 0.692$. The corresponding Home and Foreign banks' leverage

¹³I follow [Choi et al. \(2008\)](#) to calibrate κ targeting relative consumption in a two-country model.

Description	Parameter	Value	Note
Domestic consumption bias	α	0.75	Engel (2011)
Endogenous discount factor	ζ	0.995	Home Discount Factor: 0.99
Endogenous discount factor	κ	0.009	Consumption Ratio: 2
Start-up funds transfer	ξ	0.001	Home Risk Premium: 100bp
Bank survival rate	σ	0.972	Gertler and Karadi (2011)
Home financial development level	θ	0.349	Home Leverage Ratio: 6
Foreign financial development level	θ^*	0.692	Foreign Leverage Ratio: 4
Autocorrelation	ρ_A	0.95	
Innovation Variance	$\varepsilon_A/\varepsilon_A^*/\varepsilon$	0.1	

Note: This table reports the parameter values in the benchmark calibration. The parameters in the bank problem are calibrated at the same targets with Gertler and Karadi (2011) except for the bank leverage ratio. The Home country is calibrated to be more financially developed with a bank leverage ratio at 6 in the steady state, while the Foreign bank leverage ratio at 4. The two countries are symmetric except for the θ s.

Table 1.1: Parameters

ratios in the steady state are 6 and 4, respectively, which are close to the calibration targets in Gertler and Karadi (2011). They calibrate the US financial intermediaries' leverage ratio at 4. It is a tricky task to calibrate the banks' leverage ratio given its wide range among various sectors and different types of banks. The goal is to reflect the asymmetric financial development levels in the two countries and keep the parameters away from the boundaries. I assume the endowment shocks follow AR(1) processes. The variance of all innovations is set to be a 10% deviation, and the autocorrelations of endowment shocks are 0.95. The global shock will hit both Home and Foreign endowments at the same time.

1.3.2 Steady States

The benchmark steady state results are reported in Table 1.2. In the steady state, Home banks run at a higher leverage ratio and hold more risky assets due to

their more advanced development level. As a result, the Home country earns more profits, enjoys more consumption, and runs current account deficits. This is in line with the global imbalance literature (Caballero et al. (2008); Mendoza et al. (2009)) and the exorbitant privilege hypothesis (Gourinchas et al. (2010)), which argue that the US holds more risky assets and earns excess returns of external assets. The higher aggregate consumption in the Home country implies a higher demand for Home goods due to the domestic consumption bias. As a result, it leads to a higher Home good price relative to the Foreign good, and both the ToT and exchange rate are smaller than one in the steady state. Since the two goods are not perfect substitutes, domestic consumption bias will also generate a domestic asset portfolio bias. Banks will hold a larger share of the claims against the good their domestic savers prefer.

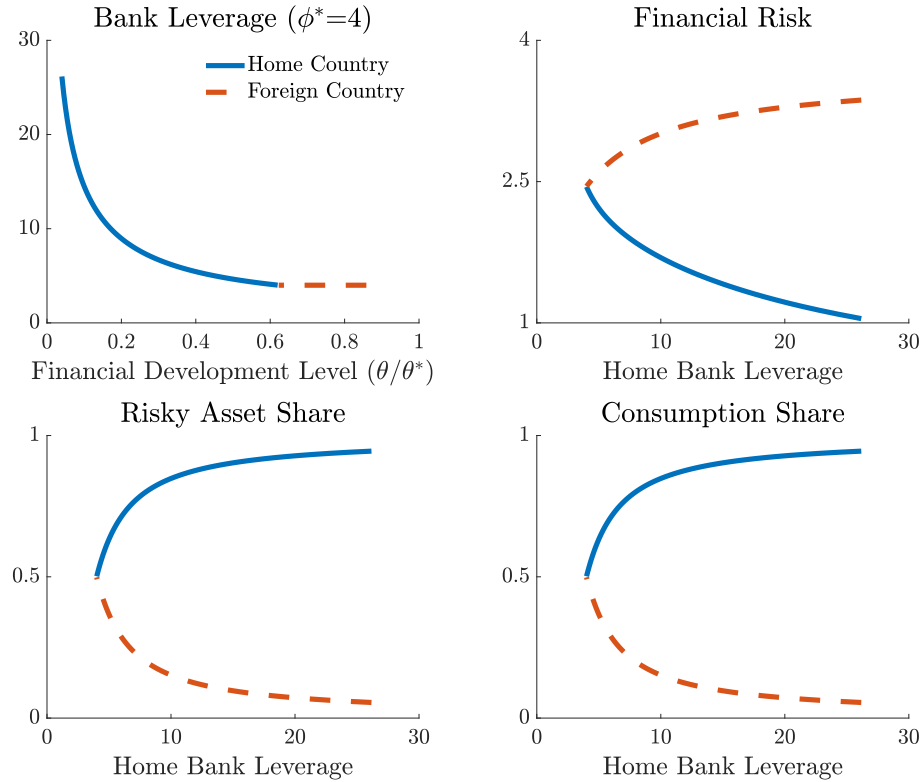
Variables	Home Country	Foreign Country
Consumption	0.746	0.373
Profits	0.249	0.196
Bank Total Asset	59.708	29.854
Bank Net Worth	9.951	7.463
Bank Leverage Ratio	6	4
Risk Premium	100bp	184bp
Net Export	-0.111	0.138
NFA	8.914	-11.066
ToT	0.649	
Real Exchange Rate	0.806	
Overseas Asset Portfolio	0.25	

Note: This table reports the value of key variables in the steady state in the benchmark calibration. The Home and Foreign countries' bank leverage ratio and the Home country's risk premium are calibration targets. The top panel displays the household's variables, the middle panel for the bank's variables, and the bottom panel for the international account variables. Net export and NFA are measured in domestic currency. In the steady state, the Home country holds more risky assets, earns more revenues, and enjoys more consumption.

Table 1.2: Benchmark Steady State

The NFA in the Home country is positive while the US has a negative international investment position in reality. This is because I only model risky assets in the international asset market. A potential solution to this issue is to introduce an inter-bank market for safe assets. Foreign banks have a higher precautionary saving incentive since they are more likely to hit the binding credit constraint relative to Home banks. Therefore, they will borrow from Home banks in the inter-bank safe asset market. Overall, Home banks could have a negative NFA position. However, introducing an inter-bank market will not alter the main results of this paper. Recall that the consumption and exchange rate dynamics are determined by the relative financial risk as discussed in the previous part. As long as the Home country holds more risky assets in the steady state, they will bear more capital losses in a crisis and their financial risk will surge higher relative to Foreign banks.

To verify the analysis in the previous part, I conduct steady state comparative statics and show that θ and θ^* are good measures of the Home and Foreign countries' financial development levels, shown in Figure 1.3. I fix Foreign banks' leverage ratio at 4 and search from the smallest valid θ (the steady state exists) to the upper limit θ^* ($\theta \leq \theta^*$). I end up with a series of (θ, θ^*) pairs such that Foreign banks' leverage ratio is fixed at 4 and Home banks' leverage ratio ranges from slightly above 4 to around 25, as shown in the top-left panel. In the top-right panel, Home banks bear lower financial risk in the steady state as they are more developed, and the Home financial risk will be even lower if Home banks run at a higher leverage ratio. As we can see, when Home banks' leverage ratio approaches 25, their financial risk almost degenerates to unity, which indicates Home banks are barely constrained by



Note: This figure displays the corresponding bank leverage, financial risk, risky asset share, and consumption share by varying financial development levels. Home banks' leverage ratio varies with the feasible (θ, θ^*) pairs, while Foreign banks' leverage ratio is fixed at 4. This figure shows that as the financial constraint in the Home country gets less binding, it will run at a higher leverage ratio, hold more risky assets, and consume more.

Figure 1.3: Steady State Comparative Statics

the credit constraint. In the bottom row, the Home country holds a larger share of risky assets, earns more profits and consumes more due to its higher financial development level. As the financial constraint becomes less tightening in the Home country, it could hold even more risky assets and be able to consume more.

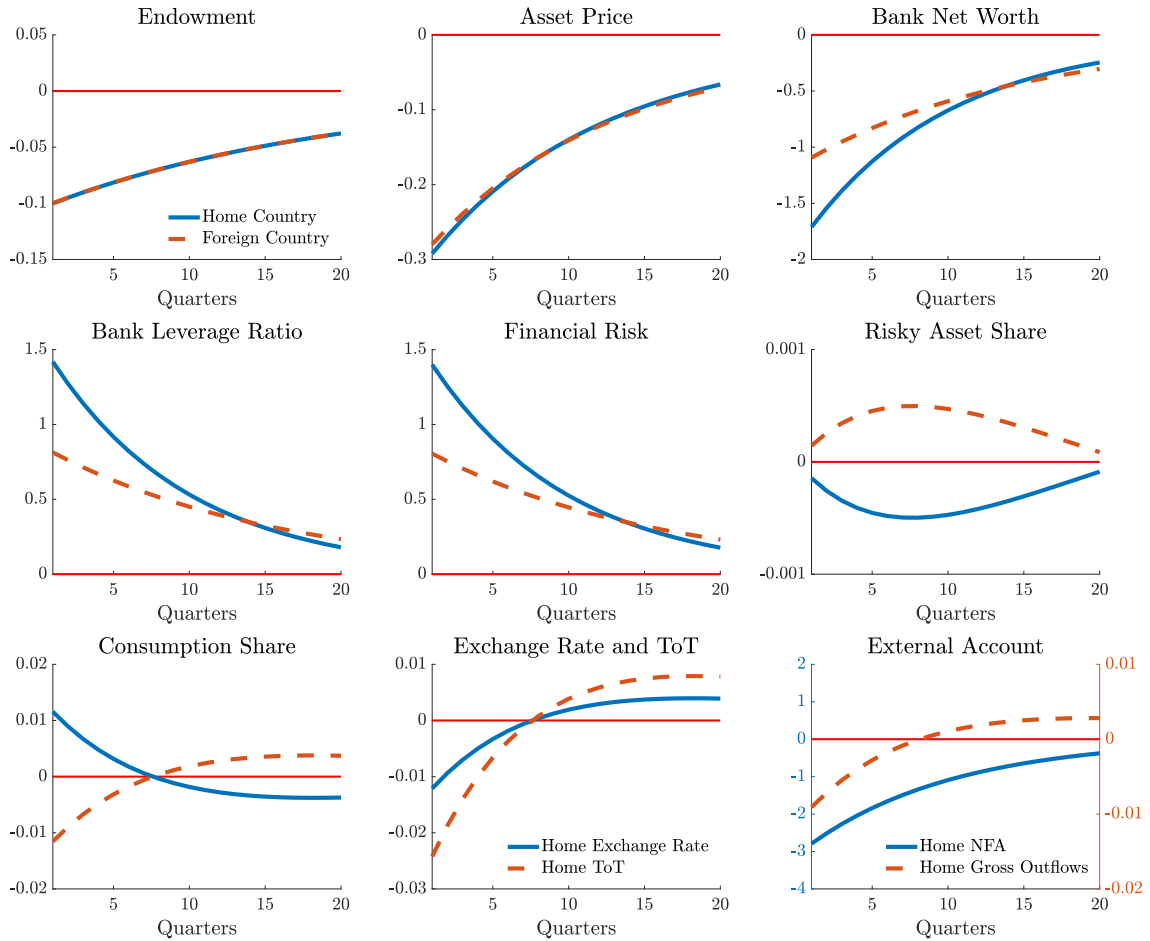
1.3.3 Impulse Responses

There are three exogenous innovations in the model: two country-specific endowment innovations and one global endowment innovation. I will only report the

impulses responses to a global shock in the main text to highlight the role of the relative financial risk during a crisis. The impulse responses to country-specific shocks are reported in Appendix A.2. The global innovation will affect both Home and Foreign endowments equally at the same time. Figure 1.4 presents the key variables' impulse responses in the model.

When a crisis unfolds, endowments and asset prices decline in both countries. Since both Home and Foreign banks hold risky assets on their balance sheet, bank net worth declines in both countries. However, Home banks bear heavier capital losses during the crisis as they hold a larger share of risky assets in steady state. They deviate more from the leverage ratio constraint and their financial risk rises higher than foreign banks. Therefore, Home banks have a stronger incentive to liquidate their risky assets holdings to deleverage and their risky asset share declines. The fire sales will smooth the domestic consumption, leading to an increase in the consumption share in the Home country.¹⁴ The increase in the relative consumption in the Home country raises the relative demand of Home good due to the domestic consumption bias, pushes up the relative price of the Home good, improves the Home ToT, and lead to a Home currency appreciation. The Home NFA deterioration is driven by multiple factors that will be discussed shortly. The main driving force is the asset price plunges as Home banks hold a larger amount of risky assets. The financial sector fire sales will lead to a capital retrenchment in the Home country, and the gross outflows decline. The model generates consistent global consump-

¹⁴Figure A.5 in Appendix A.2 shows the impulse responses of real consumption growth to exogenous innovations. The real consumption growth in the Foreign country declines more than in the Home country to each endowment shock.



Note: This figure displays the key variables' impulse responses to a 10% endowment decline globally. The figure highlights the heavier capital losses in the Home country during a global crisis and its stronger incentive to fire sell and deleverage. The fire sales by the Home country will smooth its domestic consumption, improve its currency value, and lead to a capital retrenchment despite an NFA deterioration.

Figure 1.4: Impulse Responses to a Global Endowment Shock

tion, exchange rate, and external account dynamics with the empirical observations during the GFC as shown in Figure 1.1 and 1.2.

This is the key risk-sharing mechanism in this model. As predicted by this model, a higher financial development level is a double-edged sword. It enables the US banks to run at a higher leverage ratio, bear lower risks, hold more risky assets, and earn more profits in tranquil times. Meanwhile, the US is also more exposed

to risks, and aggressive risky asset holdings will backfire when the crisis breaks out. During a crisis, the US banks will bear heavier losses and witness rocketing financial risks. In the end, the US banks will have to fire sell their risky assets holdings to deleverage, which will smooth the Home country consumption and result in a Home currency appreciation.

One last note is that the relative consumption in the Home country increases in the first two years and then starts declining. This is because Foreign banks hold more risky assets and earn more profits after they take over Home banks' fire sales. Therefore, the relative consumption in the Foreign country will gradually increase over time.

1.3.4 The Role of Valuation Effect

The impulse responses in the model bring a puzzling phenomenon: on one hand, the Home NFA deterioration implies a capital gain in the Foreign country's balance sheet and it predicts a relative increase in Foreign country's consumption as argued by [Gourinchas et al. \(2010\)](#) and [Maggiore \(2017\)](#); on the other hand, the fire sales by Home banks will bring capital flows back to the Home country and smooth the Home consumption as predicted in my model. In this part, I will decompose the NFA into the valuation effect and the transaction effect to explain this seemingly puzzling phenomenon. The Home NFA deterioration during a crisis is mainly due to the valuation effect yet it does not affect the contemporaneous global consumption and exchange rate dynamics.

Sum up the budget constraints of the Home households and banks, we get the Home country budget constraint

$$C_t + U_t = R_{kt}(1 - \chi_{t-1})U_{t-1} + \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}R_{kt}^*\chi_{t-1}U_{t-1}$$

where the RHS is the Home country's income from returns of holding both Home and Foreign risky assets, and the LHS is the Home country consumption C_t and wealth U_t . The Home country's income is either consumed or saved for the next period. Analogously, the Foreign country budget constraint denoted in Home currency is

$$\mathcal{E}_t C_t^* + \mathcal{E}_t U_t^* = \mathcal{E}_t R_{kt}^*(1 - \chi_{t-1}^*)U_{t-1}^* + R_{kt}\mathcal{E}_{t-1}\chi_{t-1}^*U_{t-1}^*$$

Subtract the two countries' budget constraints, we get the relative consumption equation between the two countries¹⁵

$$\begin{aligned} C_t - \mathcal{E}_t C_t^* &= -\Delta \text{NFA}_t + \text{VA}_t + \underbrace{(R_{kt}\mathcal{W}_{t-1} - \mathcal{W}_t)}_{\tilde{C}_t} - \mathcal{E}_t \underbrace{(R_{kt}^*\mathcal{W}_{t-1}^* - \mathcal{W}_t^*)}_{\tilde{C}_t^*} \\ &= -\text{NX}_t + \tilde{C}_t - \mathcal{E}_t \tilde{C}_t^* \end{aligned} \quad (1.10)$$

where $\mathcal{W}_t = (1 - \chi_t)U_t$ and $\mathcal{W}_t^* = (1 - \chi_t^*)U_t^*$ are the value of Home and Foreign countries' domestic asset holdings from t to $t + 1$, and \tilde{C} and \tilde{C}_t^* are consumption that could be supported from domestic markets, which reflects each country's saving decisions in their domestic asset market. The intuition of Equation (1.10) is

¹⁵The detailed proof can be found in Appendix A.4.

straightforward. To consume more than the Foreign country at period t , the Home country can either save less for the next period in their domestic market or borrow from the Foreign country, i.e., a negative net export or equivalently, a positive net import. The last step comes from [Gourinchas et al. \(2012\)](#)

$$\Delta\text{NFA}_t = \text{NX}_t + \text{VA}_t \tag{1.11}$$

where ΔNFA_t is the changes of NFA from $t - 1$ to t in the Home country, NX_t the net export, and VA_t the valuation effect. A negative VA_t implies a wealth transfer from the Home country to Foreign country, as argued by [Gourinchas et al. \(2012\)](#) and [Maggiori \(2017\)](#).

In an autarky economy where $\chi_t = \chi_t^* = 0$,

$$C_t = \tilde{C}_t = R_{kt}\mathcal{W}_{t-1} - \mathcal{W}_t, \quad C_t^* = \tilde{C}_t^* = R_{kt}^*\mathcal{W}_{t-1}^* - \mathcal{W}_t^*$$

and

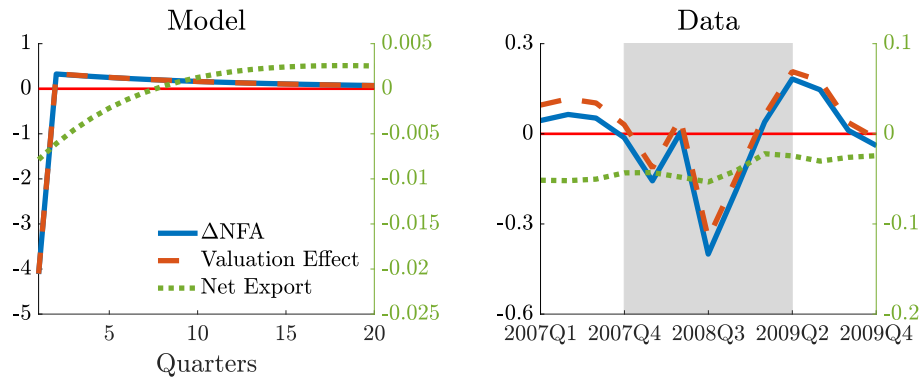
$$\text{NX}_t = 0$$

There would be no risk-sharing between the two economies and thus no consumption reallocation between the two countries through the international trade. The overall consumption is only determined by the agents' saving decisions in their domestic asset markets.

From Equation (1.10), we can draw two important findings: 1, the valuation effect does not affect the contemporaneous relative consumption dynamics, though

it is the dominant force of the NFA fluctuations as will be shown shortly; 2, the relative consumption dynamics is mainly determined by the countries' saving decisions, either domestic or international.

Firstly, Figure 1.5 shows the decomposition of the NFA dynamics into the valuation effect and transaction effect, and demonstrates the dominant role of the valuation effect. The valuation effect measures the fluctuations of NFA that can be explained by asset price movements. During a global crisis, risky asset prices are depressed and both the NFA and valuation effect will deteriorate in the Home country, as shown in the left column. Most of the NFA deterioration is explained by the valuation effect, and the transaction effect plays a minor role. The right column verifies the model prediction using the US international investment position data from the BEA. We can see a close tie between the NFA and valuation effect fluctuations. The US NFA declined by around 40% in 2008Q3 since the breakout of the crisis while the net export dropped by 1%.



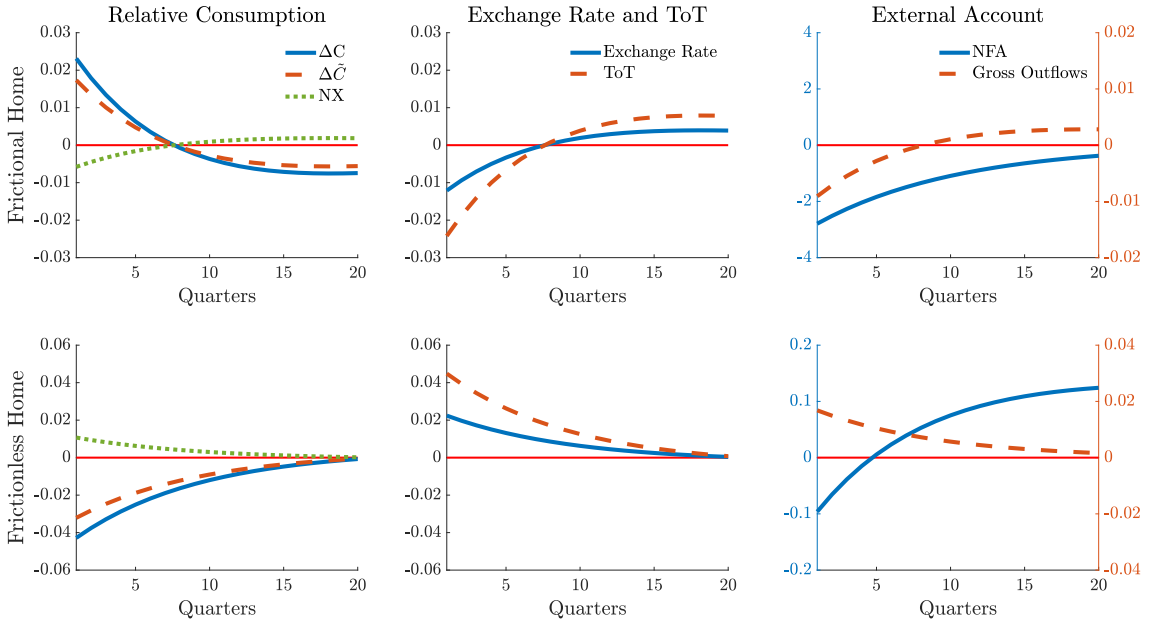
Note: This figure displays the decomposition of the US NFA dynamics in the model and the data following Equation (1.11). All variables are scaled by output in both the model and the data. The right y-axis is for the transaction effect, i.e., the net exports. The data is from BEA International Investment Position Tables. This figure highlights the dominant role of the valuation effect in the US NFA dynamics.

Figure 1.5: US NFA Dynamics Decomposition

Secondly, to show how the saving decisions and fire sales in the Home country determine the relative consumption, Figure 1.6 presents the impulse responses of key variables in two economies: one where both the Home and Foreign country are financially constrained as in this paper (the top row), and the other one where the Home country is financially frictionless as in Maggiori (2017) (the bottom row). The two economies are calibrated to be comparable.¹⁶ At first glance, the two economies predict contrary relative consumption and exchange rate in a crisis, though the NFA in the Home country declines in both economies. The left column shows the relative consumption decomposition as in Equation (1.10). When the global shock hits in my model, Home banks will fire sell their asset holdings to deleverage, and their savings for the next period decline. In addition, the Home country borrows from the Foreign country and the net exports decline. Overall, the relative consumption in the Home country increases during a global crisis, as shown in the top row. As a result, the Home ToT improves and the Home currency appreciates. In contrast, in an economy with a financially frictionless Home country, Home banks could keep running at a high leverage ratio without any incentives to deleverage during a crisis. Instead, Foreign banks will fire sell and deleverage. In this case, the Foreign country's consumption increases relative to the Home country, and the Home currency will depreciate, as shown in the bottom row. The Home NFA in both economies will deteriorate due to the valuation effect. However, the transaction effect works in opposite directions. In the frictional Home country economy, the fire sales by Home

¹⁶The two economies have the same Home country interest rate, Home and Foreign banks' leverage ratio, and relative consumption ratio in the steady state as in the benchmark calibration.

banks imply a capital retrenchment in the Home country. In contrast, there will be a capital flight in the Home country during a crisis if it faces no credit constraint. The fire sale behavior is the key factor that determines the global risk-sharing pattern since it reflects the agents' saving decisions for the next period, and in turn, affects relative consumption and exchange rate dynamics.



Note: This figure displays the consumption, exchange rate, and external account dynamics to a global shock in the Home country in the benchmark model and a model with a frictionless Home country (Maggiore (2017)). The two models are calibrated to match the same targets in the steady state. The first row displays the impulse responses of the benchmark model, and the second row the frictionless Home country model. In the right column, the right y-axis is for the gross capital outflow in the Home country. This figure shows that introducing financial frictions in the Home country will reverse the risk-sharing pattern and the exchange rate dynamics, though both models predict an NFA deterioration in the Home country.

Figure 1.6: Home Country Impulse Responses Comparison

1.4 Empirical Verification

This section empirically verifies the model predictions on global consumption and exchange rate dynamics. I collect the data on consumption, exchange rate, and

the bilateral balance of payment vis-à-vis the US for major countries. I will focus on the gross US capital outflows to foreign countries, i.e., gross inflows from the US in foreign countries, instead of the net outflows hereafter. The reason is that the fluctuations of gross US outflows reflect the behavior of US investors while the net outflow is a composite result of both US and foreign investors' decisions. I study the gross US capital outflows to investigate the impacts of US fire sales on the world economy during the GFC. The recent literature starts emphasizing the role of gross flows since the influential work by [Forbes and Warnock \(2012\)](#).

First, I run a panel regression to study how the gross capital inflows from the US in foreign countries will respond during the GFC and how they will affect the foreign countries' consumption growth and exchange rate. The result shows that a crisis is associated with a large capital retrenchment in the US, and the capital stop in foreign countries has significant negative impacts on their consumption and currency value.

Second, I study the dynamic responses of global consumption and exchange rate by estimating a VAR model. In response to an increase in economic uncertainty, the US will retrench its capital outflow from overseas, which leads to a deeper consumption decline and currency depreciation in foreign countries. The empirical results are consistent with the model predictions.

1.4.1 Data

The data sample runs from 2003Q1 to 2018Q4 and includes 10 advanced economies (Australia, Belgium, Canada, France, Germany, Italy, Japan, Netherlands, United Kingdom, United States) and 6 emerging economies (Argentina, Brazil, China, India, Korea, Mexico). The sample span and size are mainly constrained by the data availability of the bilateral international transaction tables vis-à-vis the US released by BEA. The quarterly nominal consumption, GDP, exchange rate, and CPI data are from the IMF IFS database. The consumption, exchange rate, and GDP are converted into real terms using CPI. The global economic uncertainty is measured by the VIX as standard in the literature. The details of data construction can be found in Appendix [A.1](#).

1.4.2 Panel Regression

To quantify the global impacts of the US fire sales during the GFC, I estimate the following specifications:

$$\text{Inflow}_{i,t} = \alpha_i + \beta \ln(\text{VIX}_t) + \varepsilon_{i,t} \quad (1.12)$$

$$\text{Consumption Growth}_{i,t} = \alpha_i + \beta_1 \ln(\text{VIX}_t) + \beta_2 \ln(\text{VIX}_t) \times \text{Inflow}_{i,t-2} + \varepsilon_{i,t} \quad (1.13)$$

$$\ln(\text{Real Exchange Rate}_{i,t}) = \alpha_i + \beta_1 \ln(\text{VIX}_t) + \beta_2 \ln(\text{VIX}_t) \times \text{Inflow}_{i,t-1} + \varepsilon_{i,t} \quad (1.14)$$

where α_i is the country fixed effects, and VIX_t a measure of global risk as standard in the literature. $\text{Inflow}_{i,t}$ is the gross capital inflows from the US in country

i , scaled by output. Consumption Growth $_{i,t}$ is year-on-year log-difference of real consumption, and Real Exchange Rate $_{i,t}$ is the real exchange rate denoted as the US dollar price of foreign currency in country i . Equation (1.12) estimates how the gross inflows from the US in foreign countries comove with the VIX $_t$. Equation (1.13) and (1.14) estimate the impacts of capital inflows from the US on foreign countries' consumption growth and exchange rate in responses to VIX $_t$ fluctuations. The inflows are lagged to ensure exogeneity.¹⁷ The model is estimated in two sample periods: the whole sample period from 2003Q1 to 2018Q4 and the GFC period from 2007Q4 to 2009Q2. I use Driscoll and Kraay (1998) standard errors to control for heteroskedasticity, serial, and cross-sectional correlation.

Table 1.3 reports the coefficients of interest β and β_2 in the specifications above. The first two columns show that the US will retrench its capital flows from overseas when the global economic uncertainty rises, both in the whole sample and in the GFC period. On average, a 10% increase in VIX is associated with a 0.21% decline of gross capital inflows from the US as a fraction of output in foreign countries. The capital retrenchment in the US is larger in the GFC period, around 0.32%. According to the model predictions, the capital retrenchment in the US will lead to a consumption growth decline and a currency depreciation in foreign countries, and the coefficients of the intersection term in Equation (1.13) and (1.14) are expected to be positive. As shown in columns (3) to (6), the sign of the coefficients on the intersection term is significantly positive in both specifications. The capital stop in

¹⁷The inflows are lagged two periods for the consumption growth to reflect the slow-moving feature of the consumption dynamics.

foreign countries will result in a real consumption growth decline and a currency depreciation, which echos the model predictions.

	Gross Inflows from US		Real Consumption Growth		Real Exchange Rate	
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{VIX}_t)$	-0.0321*	-0.0208***	-0.0466**	-0.0104	-0.146***	0.0645*
	(0.0145)	(0.0073)	(0.0142)	(0.0099)	(0.0143)	(0.0370)
$\ln(\text{VIX}_t) \times \text{Inflow}_{i,t-2}$			0.0212***	0.0211***		
			(0.0022)	(0.0069)		
$\ln(\text{VIX}_t) \times \text{Inflow}_{i,t-1}$					0.0425***	0.1025***
					(0.0111)	(0.0249)
Observations	105	956	105	920	105	941
GFC	Yes	No	Yes	No	Yes	No
Country FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: This table reports the panel regression results from estimating Equation (1.12), (1.13), and (1.14). I use Driscoll and Kraay (1998) standard errors for heteroskedasticity, serial, and cross-sectional correlation, shown in the parentheses. The data is from the IMF IFS and BEA. This table shows that a rise in VIX_t is accompanied by a capital stop in foreign countries, which has a significant negative impact on foreign countries' consumption growth and currency value.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.3: Panel Regression Results

1.4.3 VAR Estimation

In this part, I estimate the dynamic responses of foreign countries' capital inflows, consumption and exchange rate employing a VAR model. The structural VAR model is given by

$$\mathbf{A}\mathbf{Y}_{it} = \mathbf{a}_i + \sum_{j=1}^p \alpha_j \mathbf{Y}_{it-j} + \varepsilon_{i,t}$$

where \mathbf{a}_i is a vector of country fixed effects and $\varepsilon_{i,t}$ is an $n \times 1$ vector of structural residuals with $E[\varepsilon_{i,t}\varepsilon'_{i,t}] = I$ and $E[\varepsilon_t\varepsilon'_s] = 0$ for $s \neq t$, where I is the identity matrix.

The reduced form representation can then be written as

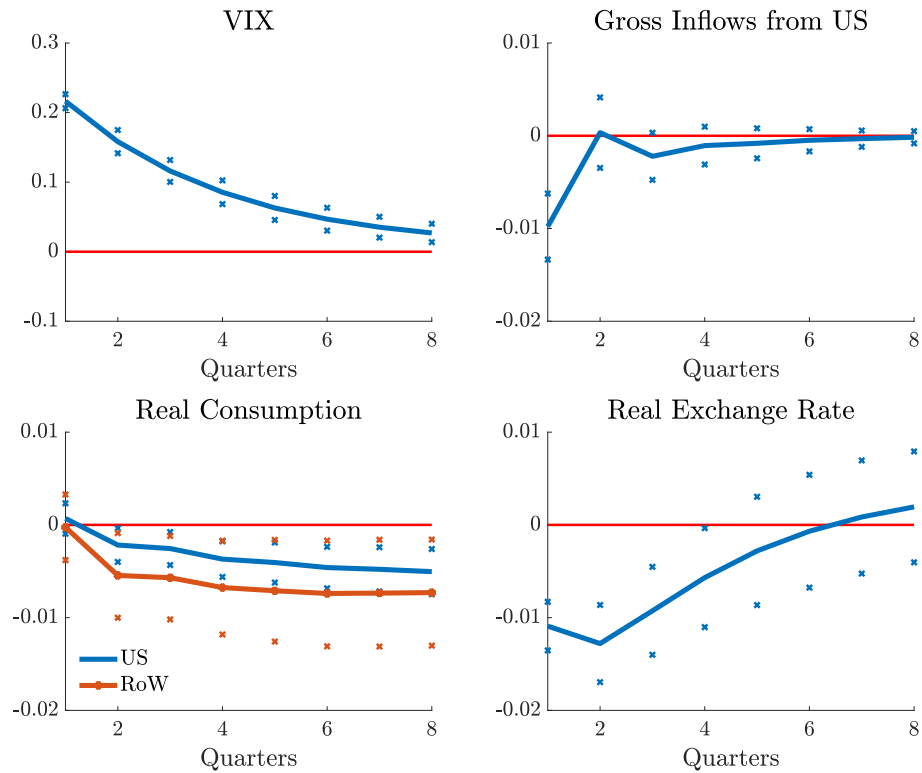
$$\mathbf{Y}_{it} = \mathbf{c}_i + \sum_{j=1}^p \beta_j \mathbf{Y}_{it-j} + \mathbf{u}_{i,t}$$

where $\mathbf{S} = \mathbf{A}^{-1}$, $\mathbf{c}_i = \mathbf{S}\mathbf{a}_i$, $\beta_j = \mathbf{S}\alpha_j$, and $\mathbf{u}_{it} = \mathbf{S}\varepsilon_{it}$ is the vector of reduced-form shocks with covariance matrix $E[\mathbf{u}_{it}\mathbf{u}'_{it}] = \mathbf{S}\mathbf{S}' = \Sigma_\mu$. The matrix \mathbf{S} maps the structural shocks into the reduced-form residuals.

In the baseline specification, I estimate a five-variable VAR including the VIX, the US and foreign countries' real consumption, real exchange rate, and the gross inflows from the US in foreign countries scaled by foreign output. All variables (except inflows) are in log-levels so that movements in the variables are in percentage points. I identify the structural shocks through a recursive identification strategy, and thus \mathbf{S} is the Cholesky decomposition of Σ_μ . I order VIX first and then the US consumption, gross inflows from the US in foreign countries, real exchange rate, and foreign consumption, shown in Equation (1.15). The ordering follows [Benigno et al. \(2012\)](#) and assumes that volatility shocks have contemporaneous effects on the endogenous variables. I set $p = 2$ based on the Schwarz information criterion.

$$\mathbf{Y}_{it} = \begin{bmatrix} \text{VIX}_t \\ \text{Real Consumption}_{us,t} \\ \text{Inflows}_{i,t} \\ \text{Real Exchange Rate}_{i,t} \\ \text{Real Consumption}_{i,t} \end{bmatrix} \quad (1.15)$$

Figure 1.7 presents the impulse responses of key variables for up to eight quarters to a one standard deviation increase in VIX. The starred lines are the two standard deviation bands using the delta method. The VIX gradually decays within the first two years after the shock as shown in the top-left panel. In the top-right panel, a rise in VIX results in a sharp short-lived capital stop in foreign countries as the US retrenches its overseas investment but it quickly vanishes. In the bottom-left panel, the real consumption in both the US and RoW declines in response to a VIX increase. However, the real consumption in the RoW declines more than in the US.



Note: This figure displays the impulse responses of VIX, the gross capital inflows in foreign countries from the US, the US and foreign countries' real consumption, and real exchange rate to a one standard increase in VIX. The starred lines are the two standard deviation bands calculated using the delta method. The optimal lag in the VAR is set to be 2 based on Schwarz information criterion. The structural shock is identified through a recursive identification. The figure implies a capital retrenchment in the US during a crisis, associated with a deeper consumption decline and a currency depreciation in foreign countries.

Figure 1.7: Impulse Responses to VIX

and the difference reaches over 0.3% within two years after a one std increase in VIX. The bottom-right panel shows the responses of real exchange rate in the RoW. After a positive VIX shock, the foreign currency depreciates in the subsequent six quarters. The results show that a one standard variation increase in VIX will lead to a capital retrenchment in the US, a deeper consumption decline in foreign countries relative to the US, and a foreign currency depreciation. The results are invariant to alternative VAR specifications reported in Figure [A.6](#) in Appendix [A.2](#).

1.5 Conclusion

In this paper, I develop a two-country two-goods open economy model with asymmetric financial development levels. The key innovation is to introduce a milder financial constraint in the US in an international context. The model investigates the interactions between financial sectors across countries when both of them are financially constrained and studies the role of financial frictions in intentional financial contagion, risk-sharing, and exchange rate dynamics during a crisis. The model predictions are consistent with the global consumption, exchange rate, and external account dynamics during the GFC.

The model is highly stylized. The US dollar appreciation responses in the model are far from matching the magnitude in the data although the direction is correct. Also, the government and the international risk-free asset market are absent in the model. The contribution of this paper is to shed light on the role of the US in the international financial system. The advanced financial development level in

the US is a double-edged sword. It means lower financial risk in tranquil times but a soaring risk during a crisis. However, it always works in favor of the US in the international economy. The US consistently enjoys higher relative consumption through the business cycles. A relevant question would be are there any costs for this exorbitant privilege? If yes, what are these costs? I leave these questions for future research.

Chapter 2: Credit Supply and Firm Investment

2.1 Introduction

The relationship between the credit market and the real economy has been one of the core topics in macroeconomics, especially after the Great Recession. This paper studies how firm investment responds to credit supply shocks conditional on firm characteristics in the US in the past three decades. How would firms respond to credit supply shocks? Would firm characteristics induce heterogeneous responses to the shocks? And more importantly, are the heterogeneous firm responses dependent on credit cycle phases? These questions are of great importance yet challenging to answer within the existing literature framework. The strand of literature based on event study or fixed effect approach can provide micro-level evidence on the effects of credit supply shocks. However, the event study approach can only focus on a specific period around an economically significant event such as a financial crisis, while the fixed effect approach identifies an idiosyncratic credit supply shock that is isomorphic to the common credit supply shock. There is another strand of literature identifying credit supply shocks within a VAR structure. Research along this line focuses on the aggregate implications of credit supply shocks and does not provide evidence on the firm-level responses.

This paper revisits these questions employing a joint approach based on the two strands of literature above. I identify a series of credit supply shocks from a sign restriction VAR and then apply the identified shock to firm-level data, to investigate the heterogeneity and state-dependence of firm investment responses. This paper inherits merits from both strands of literature and the advantage is twofold: first, I can extract a series of credit supply shocks that are common to the banking sector over a long horizon, and study the state-dependence of firm heterogeneous responses to the shocks, which is complementary to the first strand of literature; second, I provide micro evidence on the effects of credit supply shocks using firm-level data, which is absent in the second strand of literature.

My identification strategy builds on a growing strand of literature employing sign restriction VAR in identifying credit supply shocks and studying their real effects. This paper is different in three dimensions. First, I distinguish between household and corporate credit. The existing literature identifies credit supply shocks using aggregate credit volume including both household and corporate credit ([Hristov et al. \(2012\)](#) is an exception). However, as documented in [Beck et al. \(2012\)](#); [Mian et al. \(2017, 2020\)](#), credit granted to households and firms will have different impacts on the economy and operate via different mechanisms. More importantly, to document the firm-level responses to the identified credit supply shock, it would be problematic if I identify the shocks incorporating household credit. Second, I measure credit price using excess bond premium constructed in [Gilchrist and Zakrajsek \(2012a\)](#) rather than either the loan rate or credit spread typically used in the literature. There are several advantages in using excess bond premium: it has

a longer horizon and broader coverage of credit rating quality, addresses the maturity mismatch in measuring credit spread, and takes out the default risk from the firm side. Third, I investigate the effects of the identified credit supply shock using firm-level data. The exogeneity of the identified credit supply shock is guaranteed by construction in the structural model. And the credit supply shock extracted from the structural VAR is common to the whole banking sector and covers a long horizon since the 1970s including both expansions and contractions, which enables me to study the heterogeneity and state-dependence of firm investment responses.

One concern about the identification strategy is what on earth is the shock identified from this structural model and how to assure it is not contaminated by other factors. To be crystal-clear, the credit supply shock identified from the structural VAR is exogenous innovations that originate within the financial sector and are independent to either aggregate structural shocks or monetary policy shocks. I impose credit volume and credit price to move in opposite directions to isolate credit supply shocks from credit demand and other aggregate shocks. To distinguish between the credit supply shock and the credit channel of monetary policy shock, I assume monetary policy rate and credit volume move in the same direction in the identification, i.e., monetary policy tightens in response to a credit expansion and relaxes to a credit contraction. Thus, the identified credit supply shock is mutually exclusive to the credit channel of monetary policy shock and captures the fluctuations of the credit market that are not induced by monetary policy shocks. This identification strategy reflects two key distinctions between the credit supply shock and the monetary policy shock: first, the former is a real shock while the

latter is a nominal shock; second, the former is accompanied by a counter-cyclical monetary policy rate movement. For example, a credit expansion is accompanied by a monetary policy tightening and thus an increase of funding cost for the banking sector. The credit supply shock can originate from many sources, ranging from unexpected changes in banking sector regulation, technology, degree of competition, to risk aversion. From the perspective of structural models, one can think of the credit supply shock as innovations to banking sector financial constraints, net worth, or credit risk.

The firm-level data in this paper is from Compustat, a widely used data set with rich balance-sheet information for public firms in the US. And the main empirical results in this paper rely on the local projection method prominently advocated by [Jorda \(2005\)](#). The local projection method has been extended to large panel data recently as in [Drechsel \(2019\)](#); [Kalemli-Ozcan et al. \(2018\)](#); [Ottonello and Winberry \(2020\)](#). Methodology-wise, this paper follows this strand of emerging literature. Local projection is more robust to model misspecification, easy to implement, and conceptually identical to VAR estimation ([Mikkel and Wolf \(Forthcoming\)](#)). More importantly, it is computationally challenging to estimate a VAR model when it comes to a large panel data set as the one used in this paper. Therefore, the local projection method serves as a perfect alternative approach to estimate the dynamic responses of firm investment to exogenous shocks. The novel part in this paper is twofold: first, I estimate the firm investment responses to a different shock – credit supply shock; second, I document that the heterogeneous responses of firm investment are state-dependent on credit expansions and contractions, a fact that has

been overlooked in the literature.¹

This paper documents two main results. First, the identified credit supply shock has significant and persistent impacts on both macro variables and firm-level investment. On the aggregate side, one unit of a credit supply shock (0.39% movement in credit volume) leads to a 0.73% movement of output, 0.46% of consumption, 2.4% of investment, and -0.3% of the unemployment rate at the peak. On the firm-level side, one unit credit supply shock induces a 0.21% movement of firm investment on impact on average. The effect gradually grows over time and reaches above 1% five quarters after the shock and remains significant for around ten quarters. Although the impacts of credit supply shocks are quantitatively big and significant, one should take the specific numbers cautiously since the identification strategy is based on simulations.

Second, the heterogeneous firm investment responses to the credit supply shock are state-dependent. The investment of low default risk firms will increase more relative to average firms during a credit expansion and decline less during a credit contraction. Specifically, firms with one standard deviation higher distance-to-default will expand their investment 1% more than average firms to one unit of a positive credit supply shock, and contract 1.5% less to one unit of a negative shock. Overall, low default risk firms will always be better off through credit cycles, a larger increase in investment during credit expansions, and a smaller decline during credit contractions. In addition, I inspect the mechanism of the state-dependent heterogeneous

¹Kalemli-Ozcan et al. (2018) study the 2008 global financial crisis; Drechsel (2019) looks at the investment shock; and Cloyne et al. (2018); Jeenas (2018); Ottonello and Winberry (2020) investigate the monetary policy shock.

effects and find that low default risk firms have consistently low borrowing costs and better access to external financing over credit cycles. This state-dependence of heterogeneous effects also applies to larger, older, and less volatile firms. However, the heterogeneous effects will disappear when estimating using the entire data sample.

This finding has important implications on both the empirical and theoretical sides for future research. On the empirical side, it suggests that the insignificance of heterogeneous responses of firm investment to exogenous shocks conditional on firm characteristics during the entire sample period might be misleading. It conceals the fact that the state-dependent heterogeneous responses have flipped signs and commensurate magnitudes in credit expansions and contractions. On the theoretical side, it is consistent with the insights of financial friction literature, arguing that firms with higher default risk will be more negatively impacted during credit contractions. Nevertheless, it also suggests that this effect is nonlinear and state-dependent. Financial frictions do not systematically amplify or dampen exogenous shocks. Instead, they will amplify the effects of negative shocks, and dampen the effects of positive shocks.

The rest of the paper is structured as follows. Section 2.2 reviews the related literature. Section 2.3 elaborates the credit supply shock identification strategy, presents the identified shock series, and provides evidence on its implications on aggregate macro variables. Section 2.4 discusses the firm-level data and firm variable constructions in detail. Section 2.5 reports the main empirical results of this paper. And section 2.6 concludes.

2.2 Related Literature

This paper is related to three strands of literature. First, I contribute to the literature studying the real effects of credit supply shocks. There are four approaches in identifying credit supply shocks: event study, granular method, credit spread, and VAR estimation. First, the event study approach identifies a credit expansion via a bank deregulation period and a credit contraction via either bank liquidity tightening or a recession period.² Compared to this strand of literature, I can extract a series of credit supply shocks over a long horizon and investigate the state-dependence of the real effects of credit supply shocks. Second, the granular method isolates credit shocks on the supply side from the demand side by controlling for bank and firm fixed effects using detailed loan-level data and is widely used in countries where the data is available.³ [Greenstone et al. \(2020\)](#) uses county-level data in the US employing a similar approach. [Becker and Ivashina \(2014\)](#) use Compustat data and interpret firms' switching from loans to bonds as a contraction in bank credit supply. My paper is complementary to this strand of literature in two dimensions: first, I identify a common credit supply shock while they focus on a bank- or firm-specific idiosyncratic shock; second, I provide the firm-level evidence in response to credit supply shocks using the US data. Third, [Gilchrist and Zakrajsek \(2012a,b\)](#); [Gilchrist](#)

²See [Favara and Imbs \(2015\)](#); [Mian et al. \(2017\)](#) for credit expansions in the US during 2000s and 1980s; [Chodorow-Reich \(2013\)](#); [Cingano et al. \(2016\)](#); [Dell'Ariccia et al. \(2008\)](#); [Duchin et al. \(2010\)](#); [Ivashina and Scharfstein \(2010\)](#); [Iyer et al. \(2013\)](#); [Kalemli-Ozcan et al. \(2018\)](#); [Kashyap et al. \(1994\)](#); [Khwaja and Mian \(2008\)](#); [Lemmon and Roberts \(2010\)](#); [Rojas \(2018\)](#); [Schnabl \(2012\)](#) for credit contractions during bank liquidity crisis or recessions.

³For example, see [Khwaja and Mian \(2008\)](#) for Pakistan, [Amiti and Weinstein \(2018\)](#) for Japan, [Degryse et al. \(2019\)](#) for Belgium, [Alfaro et al. \(2020\)](#) for Spain, and [Doerr et al. \(2018\)](#) for Italy.

[et al. \(2009b\)](#) have a series of papers employing credit spread as an indicator of credit supply shocks. In contrast to their work, the credit supply shock in my paper is identified by combining information from both credit price and credit volume. Lastly, my paper is mostly related to the emerging strand of literature identifying credit supply shocks employing sign restriction VAR.⁴ I employ the sign restriction VAR identification approach for two reasons: first, it is hard to defend the recursive ordering of endogenous variables when the model contains both real and financial variables; second, [Mumtaz et al. \(2018\)](#) show that sign restriction identification can generate consistent impulse responses from the model-simulated data with those directly from the model, and deliver better performance than recursive identification in identifying credit supply shocks.⁵ The sign restriction choices are guided by theoretical models featuring financial intermediaries.⁶ I contribute to this strand of literature by applying the identified credit supply shock into firm-level data and investigate the heterogeneity and state-dependence of the real effects of credit supply shocks.

Second, this paper is related to the literature studying how firm activities respond to exogenous shocks or comove with business cycles conditional on firm characteristics. Most of the former literature focuses on the heterogeneous effects in response to monetary policy shocks and finds that firm responses depend on size,

⁴See [Barnett and Thomas \(2013\)](#); [Bijsterbosch and Falagiarda \(2014\)](#); [Eickmeier and Ng \(2015\)](#); [Furlanetto et al. \(2017\)](#); [Gambetti and Musso \(2017\)](#); [Helbling et al. \(2011\)](#); [Hristov et al. \(2012\)](#); [Moccerro et al. \(2014\)](#); [Peersman \(2012\)](#).

⁵See [Cesa-Bianchi et al. \(2018\)](#); [Musso et al. \(2011\)](#) for recursive identification.

⁶For example, [Atta-Mensah and Dib \(2008\)](#); [Christiano et al. \(2010\)](#); [Curdia and Woodford \(2010\)](#); [Gerali et al. \(2010\)](#); [Gertler and Karadi \(2011\)](#); [Gilchrist et al. \(2009a\)](#).

age, leverage, liquidity, or default risk.⁷ Moscarini and Postel-Vinay (2012) document that large firms have a disproportionate response, relative to small firms, to deviations of unemployment rate. Crouzet and Mehrotra (2020) find that sales of small firms are more cyclically sensitive over business cycles. Complementary to these works, I study the heterogeneous responses of firm activities to a different structural shock – credit supply shock. Also, I find that the heterogeneous responses are state-dependent. Gertler and Gilchrist (1994) also noticed that small firms contract more to a monetary tightening during recessions but the effect is not significant during booms. Ottonello and Winberry (2020) argue that low default risk firms are more responsive to monetary policy shocks independent of monetary expansions or contractions. On the theoretical side, existing models rely on combining heterogeneous agents and financial frictions to match the heterogeneity of firm responses documented in the data.⁸ My work provides empirical evidence in support of their theories yet also proposes new challenges in generating state-dependent heterogeneous responses.

Third, the state-dependent heterogeneous responses documented in this paper is related to the strand of literature investigating the asymmetry of business cycles or monetary policy effects. Tenreyro and Thwaites (2016); Vavra (2013) find that monetary policy is less effective in stimulating investment and output during recessions or when the volatility is high. Caggiano et al. (2017) find similar results analyzing the effects of uncertainty shocks and monetary policy jointly. Berger and

⁷See Anderson and Cesa-Bianchi (2020); Bougheas et al. (2006); Cloyne et al. (2018); Gertler and Gilchrist (1994); Jeevas (2018); Ottonello and Winberry (2020).

⁸See Bassetto et al. (2015); Buera and Karmakar (2019); Buera and Moll (2015); Buera et al. (2015); Khan and Thomas (2013); Khan et al. (2016); Mehrotra and Sergeyev (2020).

Vavra (2015) show that durable purchases are less sensitive to subsidies during recessions. Caggiano et al. (2014) find that the response of unemployment conditional on recessions is substantially larger to uncertainty shocks. In recent work, Cheng and Chiu (2020) document that mortgage spread shocks hitting in a recessionary phase create significantly deeper and more protracted declines in consumption and housing market than in an expansionary phase in the US. Different from the focus of the above literature on the aggregate economy, my work documents the asymmetry of heterogeneous effects to credit supply shocks using firm-level data.

2.3 Credit Supply Shock Identification

The key challenge in identifying the credit supply shock is to successfully separate it from other structural shocks. As shown in a highly-stylized credit market structure in Figure 2.1, firms are on the demand side while both financial intermediaries and monetary authority are on the supply side. The first challenge is to isolate credit shocks on the supply side from the demand side using aggregate data. For example, when the credit market is hit by a negative shock, it is often impossible to tell whether it is because the firms are unwilling to borrow or the banks are unwilling to lend. Besides, the credit market will propagate and amplify the monetary policy shock through the credit channel. How to separate credit supply shocks from monetary policy shocks? Also, how to disentangle credit supply shocks from other aggregate structural shocks, such as aggregate supply, aggregate demand, and TFP shocks? As suggested by the theoretical models, these aggregate structural shocks

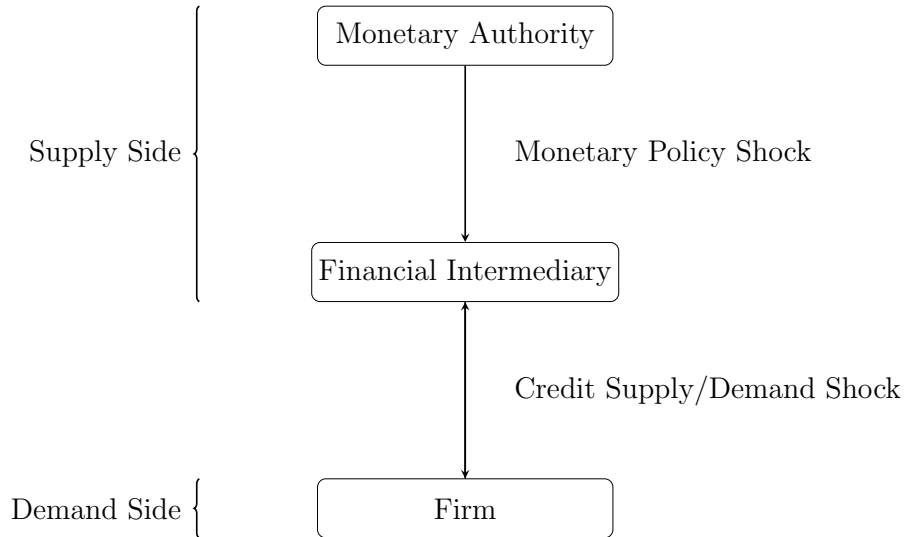


Figure 2.1: Credit Market Structure

will also influence the credit market through various channels.

In this section, I will first describe the econometric models and data used to identify the credit supply shock. Then I will provide evidence that the credit supply shock is well-identified and is not contaminated by other structural shocks.

2.3.1 Identification Strategy

2.3.1.1 Sign Restriction VAR

I identify credit supply shocks using sign restriction VAR proposed by [Uhlig \(2005\)](#). The advent of the sign restriction VAR approach brings a new tool that could be used to disentangle the credit supply shock from other structural shocks using aggregate data and has been employed in an emerging strand of literature studying the aggregate effects of credit supply shocks.

Consider a structural VAR model below

$$AY_t = \sum_{k=1}^K B_k Y_{t-k} + \varepsilon_t$$

where Y_t is a $n \times 1$ vector of endogenous variables, A and B_k are $n \times n$ coefficient matrix, and ε_t is a $n \times 1$ vector of structural shocks we seek to identify (Ramey (2016)). ε_t is assumed to be i.i.d, orthogonal, and standardized such that $\mathbb{E}[\varepsilon_t \varepsilon_t'] = I$, $\mathbb{E}[\varepsilon_t' \varepsilon_s] = 0$ for $s \neq t$, where I is identity matrix. The exogeneity of the structural shocks ε_t are guaranteed by construction in the structural VAR model. For simplicity, I further assume that each element of ε_t only affects one equation, i.e., only one of the elements to be one and all the rest zero.

The reduced form representation can be re-written as

$$Y_t = \sum_{k=1}^K F_k Y_{t-k} + \mu_t,$$

where $F_k = A^{-1}B_k$ and $\mu_t = A^{-1}\varepsilon_t$, which is the reduced-form estimation residual. Due to the symmetry of the covariance matrix $\Sigma_\mu = \mathbb{E}[\mu_t \mu_t'] = A^{-1}A^{-\prime}$, the identification problem in VAR estimation is to put extra restrictions in identifying A^{-1} , and then map between the reduced-form residuals μ_t and structural shocks ε_t we are interested in. The insight of sign restriction VAR is to simulate the estimated VAR by an orthogonal random matrix S ($\mathbb{E}[SS'] = I$ and $A^{-1} = PS$, where P is the Cholesky decomposition of Σ_μ), and keep the ones that make the impulse responses of key variables consistent with the sign restrictions we impose. The sign

restriction choices are usually guided by economic intuitions or theories. We keep simulating the random draws of S until we get enough draws that satisfy the sign restrictions. Compared to recursive identification, sign restriction identification avoids the causal ordering of endogenous variables which is often hard to defend, especially when financial variables are involved as in this paper. Also, [Mumtaz et al. \(2018\)](#) show that sign restriction identification delivers better performance than recursive identification in identifying credit supply shocks.

2.3.1.2 Sign Restriction Choices

In the benchmark identification VAR, I employ a four-variable VAR including credit volume, credit price, output, and monetary policy rate as the endogenous variables. For the credit volume, I use nonfinancial corporate business credit from the US Financial Account.⁹ Nonfinancial corporate business credit includes public firms and large private firms that are active both in the loan and corporate bond market. Therefore, the identified credit supply shock captures the exogenous fluctuations in the corporate credit market and is valid to match with the Compustat data. For the credit price, I use [Gilchrist and Zakrajsek \(2012a\)](#) excess bond premium following [Gertler and Karadi \(2015\)](#). There are several advantages of the excess bond premium over other credit price measures. First, the excess bond premium has a longer horizon since 1973 while other widely used credit spreads, such as Moody's AAA-treasury or BAA-treasury spread, start in the 1980s. Second, the maturity mismatch problem is also well-addressed, since the excess bond premium

⁹I take out commercial mortgages to match the credit price.

is constructed by matching with synthetic risk-free security that mimics exactly the cash flows of the corresponding corporate debt instrument. Third, it covers the entire spectrum of credit quality – from single D to triple A. Lastly, the default risk from the firm side is carefully taken off from the spread. By construction, the excess bond premium is the component of the spread between rates of return on corporate securities and a similar maturity risk-free rate that is left after the component due to default risk is removed. Therefore, the fluctuations of the credit price are not caused by the risk premium imposed on the firms. The output is real GDP from BEA and the monetary policy rate is the federal funds rate. The details of the aggregate data used in the benchmark identification can be found in Appendix [B.1.1](#).

The sign restriction choices are mostly guided by the theoretical models featuring financial intermediaries.¹⁰ Intuitively, I assume that credit supply innovations drive credit volume and credit price in opposite directions, which is a sufficient condition for separating credit supply shocks from credit demand shocks. As implied by the structural literature, a credit expansion would also boost the output. Therefore, I further assume that credit volume and output will move in the same direction.

Next, I will elaborate on how to isolate credit supply shocks from monetary policy shocks. As shown in both theoretical and empirical works, monetary authority will endogenously respond to credit shocks. On the theoretical side, as implied in [Curdia and Woodford \(2010\)](#); [Gertler and Karadi \(2011\)](#); [Gilchrist et al. \(2009a\)](#), a credit expansion will lead to an economic boom, and therefore, monetary

¹⁰[Gambetti and Musso \(2017\)](#); [Hristov et al. \(2012\)](#) provide excellent summaries of model predictions on credit supply shocks in the structural literature.

authority will respond by raising the policy rate. On the empirical side, [Caldara and Herbst \(2019\)](#) document a negative elasticity between corporate spread and monetary policy. They find that an increase in corporate spread, measured by BAA-treasury spread, elicits an immediate monetary policy accommodation. To put it another way, monetary policy moves in a counter-cyclical pattern in response to credit shocks. When there is a credit expansion, credit price declines, and output increases, meanwhile, the monetary policy rate will also rise. In contrast, a credit and real activity boom induced by a monetary expansion will be accompanied by a policy rate decline. As a result, assuming the same signs on credit volume and policy rate would allow us to uniquely identify credit supply shocks from monetary policy shocks.¹¹ Table 2.1 summarizes the sign restrictions in the benchmark identification VAR. The intuition of the imposed sign restrictions operates as follows: when there is a positive credit supply shock, credit volume expands and credit price declines. This will lead to an output boom and as a result, monetary authority will tighten the policy rate. To alleviate the concern that monetary authority might behave slowly in response to credit supply shocks, the sign restrictions are imposed for four quarters. This is consistent with [Hristov et al. \(2012\)](#); [Uhlig \(2017\)](#), which argue that the effects of real shocks on the economy can be quite persistent.

¹¹An impression about the relationship between credit spread and the monetary policy rate is that they are highly positively correlated. However, it is not always the case. As shown in Figure B.1 and Table B.2 in Appendix B.2, there are deviations between the excess bond premium changes and the monetary policy rate changes, and the moving correlation between the monetary policy rate and the excess bond premium is not always positive and significant. This identification reasoning is also supported by the data. As shown in the Figure B.2 in Appendix B.2, I only impose sign restrictions on credit volume, credit price, and output as specified above, and leave the sign restrictions on the monetary policy rate open. The median impulse response of the federal funds rate moves up in response to a credit expansion though not significantly.

Variables	Credit Volume	Credit Price	Output	Monetary Policy Rate
Sign Restrictions	+	-	+	+

Note: This table summarizes the sign restrictions imposed on the benchmark identification for the case of an expansionary credit supply shock. Credit volume is the nonfinancial corporate business credit after removing commercial mortgages from the US financial Account and is deflated by CPI. Credit price is the excess bond premium constructed by [Gilchrist and Zakrajsek \(2012a\)](#) and updated by [Favara et al. \(2016\)](#). The output is GDP deflated by GDP deflator from BEA. The monetary policy rate is the federal funds rate. The sign restrictions are imposed for four quarters.

Table 2.1: Sign Restrictions

The above argument explains how the benchmark identification could separate credit supply shocks from credit demand shocks and monetary policy shocks. Since the benchmark VAR has four variables, and I can identify up to four structural shocks. Yet I only identify one credit supply shock and leave other structural shocks unidentified. How is the benchmark identification able to prevent contamination from other aggregate structural shocks, such as aggregate demand, aggregate supply, or productivity shocks? The underlying assumption is that both households and firms are on the demand side of the credit market. Therefore, whether it is an aggregate demand shock happening in the household sector, or an aggregate supply shock or TFP shock happening in the production sector, they both operate through the demand side of the credit market. As a result, the opposite signs on the credit volume and credit price will exclude the above aggregate shocks in this specification. At the end of this section, I will show that the identified credit supply shock has no implications on the price level, housing price, and productivity to exclude the possibility that the identified credit supply shock is contaminated by either monetary policy shocks or other aggregate structural shocks.

After specifying the identification strategy, we can now discuss what the credit

supply shock that we are identifying is and where it comes from. As implied by the sign restrictions, the credit supply shock and the credit channel of monetary policy shock are mutually exclusive in the benchmark identification. The credit expansion induced by monetary expansion would be the case where monetary rate and credit volume moving in opposite directions. Instead, the identified credit supply shock falls in the case where credit volume and monetary rate are moving in the same direction. Therefore, we are identifying exogenous credit fluctuations that are not caused by monetary policy movements. The credit supply shock can be associated with various events. It could be the unexpected tightening or relaxing of banking sector regulations; unanticipated changes in bank funding such as a bank run or a systematic financial crisis; unexpected changes in risk aversion or lending standards due to management or technology adoptions; or unexpected changes of the degree of competition in the banking sector. However, the restrictions imposed on the aggregate data could only enable us to identify exogenous shocks in the corporate credit supply as opposed to endogenous reactions of corporate lending to other structural shocks but will not allow us to disentangle the specific reasons of the credit supply shock listed above. In the structural literature, the credit supply shock is often associated with unexpected changes in financial constraints such as [Buera and Moll \(2015\)](#); [Jermann and Quadrini \(2012\)](#), in financial sector net worth such as [Gerali et al. \(2010\)](#); [Gertler and Karadi \(2011\)](#), or in credit risk such as [Atta-Mensah and Dib \(2008\)](#); [Christiano et al. \(2010\)](#); [Gilchrist et al. \(2009a\)](#).

One last note on the benchmark identification strategy is about the price level. I do not impose restrictions on price levels for two reasons. First, the struc-

tural models make inconsistent predictions on the responses of inflation to credit supply shocks. For example, [Curdia and Woodford \(2010\)](#); [Gertler and Karadi \(2011\)](#); [Gilchrist et al. \(2009a\)](#) predict an inflation caused by credit expansion while [Atta-Mensah and Dib \(2008\)](#); [Gerali et al. \(2010\)](#) predict the opposite. Second, as argued in [Mian et al. \(2017, 2020\)](#), credit supply shock may operate through either production capacity channel or local demand channel, where the former is deflationary while the latter is inflationary. Moreover, unlike other literature which uses both household and corporate credit (except [Hristov et al. \(2012\)](#)), I only include corporate credit in the credit volume and the impact of credit supply shocks on the price level is less clear. As suggested in [Uhlig \(2017\)](#), *if you do not know it, do not impose it!* I do not impose any sign restrictions on the price level in the benchmark model and leave the identification including price level for robustness check. This is consistent with [Eickmeier and Ng \(2015\)](#); [Hristov et al. \(2012\)](#) who also leave the sign restrictions in price level open to credit supply shocks. Overall, my benchmark identification strategy is the same as in [Hristov et al. \(2012\)](#) since we both only use corporate credit. The difference is that they also identify other aggregate structural shocks while I only identify one credit supply shock.

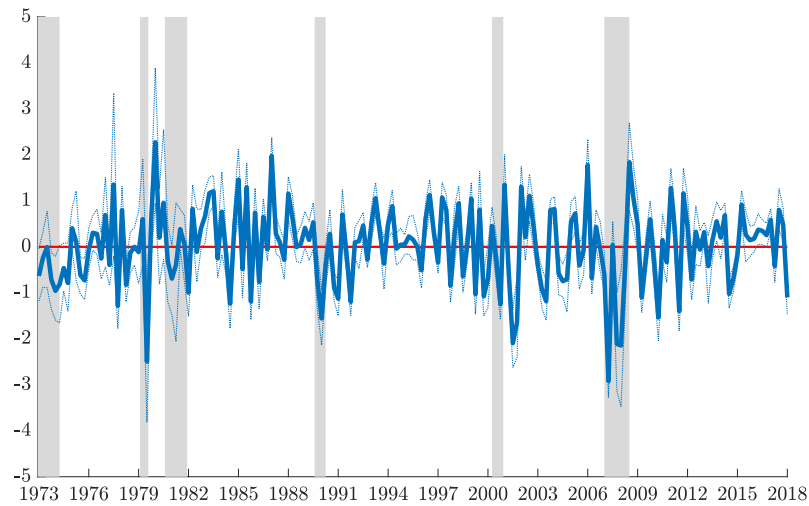
2.3.2 Credit Supply Shocks

I estimate the sign restriction VAR following the algorithm in [Rubio-Ramirez et al. \(2010\)](#).¹² The credit volume and the GDP are in real terms and log-levels.

¹²For details, refer to [Rubio-Ramirez et al. \(2010\)](#); [Uhlig \(2005\)](#) and the VAR toolbox developed by Ambrogio Cesa-Bianchi.

The excess bond premium and federal fund rate are in percentage points. The lag of the VAR model is set to be 3 quarters following the Akaike information criterion (AIC). I keep 1000 successful draws that satisfy the sign restrictions in Table 2.1.

Figure 2.2 shows the identified credit supply shock extracted from the benchmark identification VAR. One unit of a credit supply shock corresponds to one standard deviation movement of credit volume (0.39% of corporate credit). The identified credit supply shock starts from 1973Q4 until 2018Q4. Notably, each NBER recession is accompanied by a negative credit supply shock in the past 45 years. The three largest negative credit supply shock periods occurred in 1980, 2002, and 2007–2008. The negative spike in 1980 is mainly due to the 1980 recession and monetary policy fluctuations; the negative shock in 2002 is largely determined by the spike in the credit spread; the largest negative shocks happened during the Great Recession

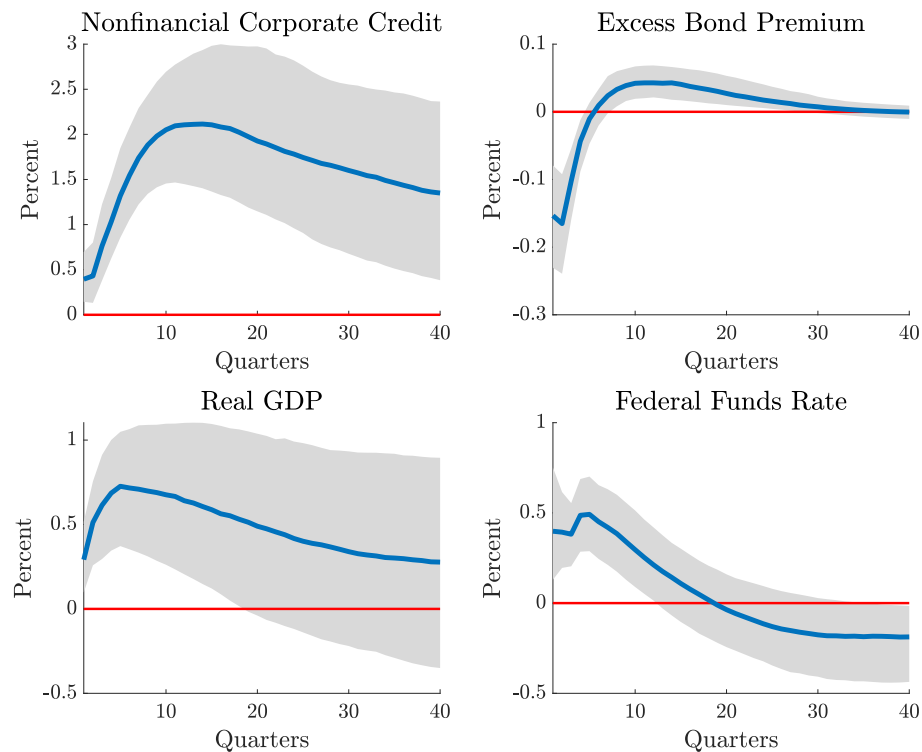


Note: This figure displays the identified credit supply shock extracted from the benchmark identification VAR from 1973Q4 to 2018Q4. The solid line is the median of valid credit supply shock and the dotted lines are the 68% confidence interval. The shaded area is the NBER recession. The unit of the credit supply shock is in standard deviations of credit volume. The benchmark identification successfully captures the negative credit supply shocks in each NBER recession.

Figure 2.2: Identified Credit Supply Shocks

when the whole financial sector in the US collapsed. The confidence interval tracks the median value of the credit supply shock closely in a narrow band, indicating the benchmark model is stable and well-specified. I will use the median credit supply shock for the rest of the analysis.

One of the advantages of identifying credit supply shocks using VAR structure is that the identified shocks are measured in multiple dimensions, associated with both credit volume and price, and other key macro variables. Figure 2.3 displays the impulse responses of macro variables to credit supply shocks in the benchmark identification for up to 40 quarters. In response to one unit of a positive credit



Note: This figure displays the impulse responses of the endogenous variables to one unit of a positive credit supply shock in the benchmark identification. The solid line is the median impulse response and the shaded area is the 68% confidence interval. The sign restrictions are imposed for four quarters. This figure shows the significant and persistent effects of credit supply shocks on macro variables beyond the restricted periods.

Figure 2.3: Impulse Responses to Credit Supply Shocks

supply shock, nonfinancial corporate business credit increases 0.39% on impact and then gradually rises to over 2% ten quarters after the shock; excess bond premium declines 0.15% and then quickly bounces back; the output increases 0.29% on impact and reaches 0.7% five quarters after the shock; the federal funds rate rises 0.4% and then gradually decays. The credit supply shock has significant and large effects on the aggregate economy. The sign restrictions are imposed for four quarters yet the effects are persistent and hold much longer than the restricted periods.

Table 2.2 reports the summary statistics of the identified credit supply shock. As shown in Panel (A), the mean of the credit supply shocks is around zero, and there are slightly more positive shocks than negative shocks. Overall, the credit expansions and contractions are approximately symmetric over the past 45 years. Panel (B) displays the correlation of the identified credit supply shock with widely used high-frequency identified monetary policy shocks. The first monetary policy shock measure follows [Gorodnichenko and Weber \(2016\)](#); [Gurkaynak et al. \(2005\)](#),

Panel (A): Summary Statistics							
Time	Mean	Median	S.D.	Min	Max	Expansions	Contractions
1973Q4 – 2018Q4	0.0035	0.0650	0.848	-2.9214	2.2748	97	84

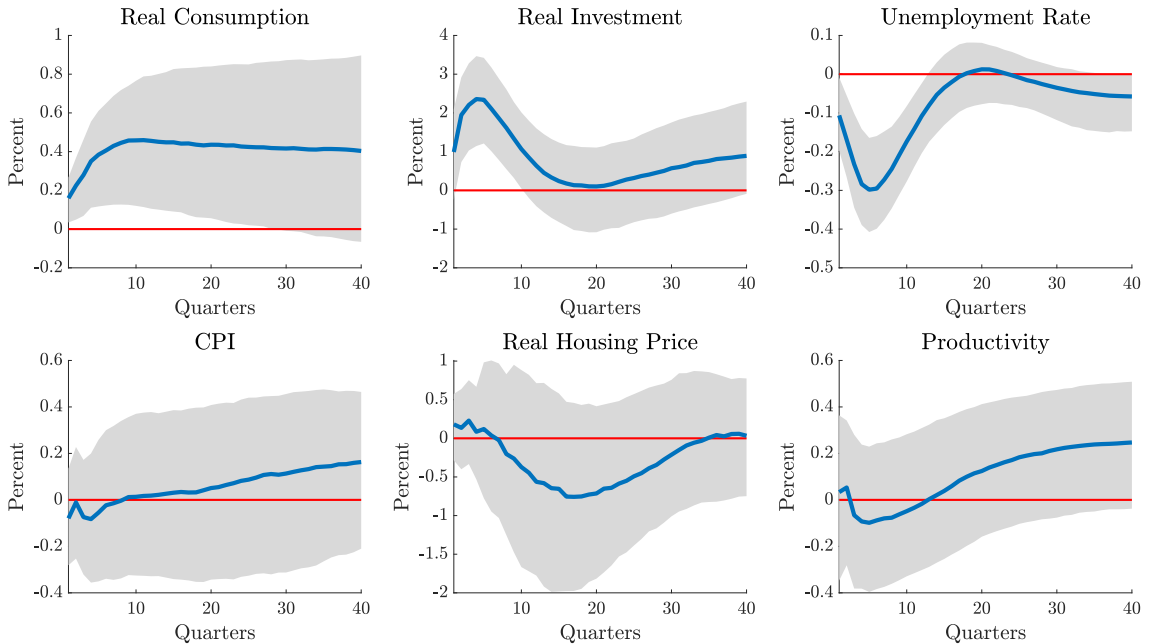
Panel (B): Correlation with HFI Monetary Policy Shock		
	Gorodnichenko and Weber (2016) (1990-2009)	Nakamura and Steinsson (2018) (1995–2013)
Correlation	-0.1825	-0.0454

Note: This table presents the summary statistics of the identified credit supply shock from 1973Q4 to 2018Q4. Panel (A) reports the simple summary statistics, and Panel (B) reports the correlation between the identified credit supply shock and the high-frequency identified monetary policy shocks. The monetary policy shock is normalized so that a positive shock is a monetary expansion. The identified credit supply shock is approximately symmetric in expansions and contractions in the past 45 years and are barely correlated with monetary policy shocks.

Table 2.2: Summary Statistics of Credit Supply Shocks

and the second measure follows [Nakamura and Steinsson \(2018\)](#). The high-frequency monetary policy shocks are aggregated into quarterly series after adjustment for the timing of FOMC announcement as in [Gorodnichenko and Weber \(2016\)](#); [Ottonello and Winberry \(2020\)](#). I normalize the sign of the monetary policy shocks so that a policy rate cut is a positive monetary shock. The correlation between the credit supply shock and monetary policy shocks is low and slightly negative, implying that the credit supply shock identified in the paper is a different structural shock from the monetary policy shock.

To assess the predictive power of the identified credit supply shock, I present



Note: This figure displays the impulse responses of additional macro variables based on the benchmark identification. The solid line is the median impulse response and the shaded area is the 68% confidence interval. The consumption is deflated personal consumption expenditures on non-durable goods and services, and investment is deflated gross private investment. Productivity is utilization-adjusted TFP from [Fernald \(2014\)](#) and real housing price is from [Shiller \(2015\)](#). This figure shows that the identified credit supply shock has no implications for the price level, housing price, and productivity, implying that the identified shock is not contaminated by aggregate demand/supply or monetary policy shocks.

Figure 2.4: Impulse Responses of Other Macro Variables to Credit Supply Shocks

the impulse responses of additional macro variables to the shocks, including consumption, investment, unemployment rate, CPI, housing price, and utilization-adjusted productivity. The details of the construction of the macro variables can be found in Appendix [B.1.1](#). I re-estimate the benchmark VAR by adding the macro variables of interest one at a time, and leave the sign restriction on them open and let it be determined by the data. The benchmark identification is robust to the inclusion of additional macro variables and the behavior of benchmark variables is essentially invariant. Thus, the sequence of VARs reveals the impulse responses of additional macro variables, holding constant the behavior of variables in the benchmark identification. Figure [2.4](#) displays the impulse responses of the macro variables of interest. In the top row, the consumption increases over 0.4% one year after one unit of a credit supply shock (0.39% increase in corporate credit); investment rises over 2% and unemployment declines around 0.3% within the same year of the credit supply shock. The effects are significant for over 10 quarters for investment and unemployment, and for a much longer period, around 30 quarters, for consumption. Though I do not impose any restrictions on these variables, the credit supply shock has large and persistent effects on consumption, investment, and unemployment. The bottom row shows the responses of the price level, housing price, and utilization-adjusted productivity. None of the impulse responses are significant. If the benchmark identification for credit supply shocks is contaminated by aggregate demand or monetary policy shocks, the CPI is supposed to rise in response to the structural shock; if the identification fails to exclude aggregate supply shocks, the CPI should decline. However, the price level barely moves in the short to medium run and the responses

are imprecisely estimated lying in a wide confidence interval. Moreover, I study two specific cases for aggregate demand and aggregate supply shocks: housing price and productivity. Similarly, both the housing price and productivity are not significantly responsive to the identified credit supply shock, excluding the case that the credit supply shock is misspecified with the aggregate demand shock from the housing market or TFP shock from the supply side. Since monetary policy shocks will only have short-term effects on real variables but long-term effects on price levels, combining Figure 2.3 and Figure 2.4 together, the identified credit supply shock has a persistent influence on real variables like output and consumption, and a negligible impact on the price level, exactly the opposite of the implications of monetary policy shocks. Overall, the benchmark identification is able to isolate the credit supply shock from the demand side, and the identified credit supply shock is not contaminated by either monetary policy shocks or other aggregate structural shocks.

2.4 Firm-level Data

The firm-level data is drawn from quarterly Compustat, a long panel of publicly listed firms in the US. It matches the data frequency of the identified credit supply shock and is consistent with the credit data used in benchmark identification, both of which mainly cover public and large private firms in the US. Most importantly, it contains rich balance-sheet information, allowing me to construct a variety of firm characteristic measures of interest. Though the Compustat data set

is unsatisfactory in not including small private firms, it is the only available data set that meets all the requirements above and serves the purpose of this paper well.¹³

The main response variable is the firm investment, measured by changes of firm real capital stock. The book value of the firm capital stock is constructed following a perpetual inventory method as commonly used in the literature.¹⁴ For each firm i , the capital stock is recursively defined as

$$K_{i,t} = K_{i,t-1} + \text{PPEGTQ}_{i,t} - \text{PPENTQ}_{i,t-1}$$

where the initial value of capital stock $K_{i,t}$ is set to be the first available value of gross value of property, plant and equipment ($\text{PPEGTQ}_{i,t}$), and $\text{PPENTQ}_{i,t}$ is firms' net value of property, plant and equipment. I interpolate linearly for $\text{PPENTQ}_{i,t}$ wherever $\text{PPENTQ}_{i,t}$ is missing and $\text{PPENTQ}_{i,t-1}$ and $\text{PPENTQ}_{i,t+1}$ are available. Thus, the firm investment is defined as

$$\Delta \log(k_{i,t}) = \log(k_{i,t}) - \log(k_{i,t-1})$$

where $k_{i,t}$ is real capital stock of firm i at the end of period t , constructed by deflating $K_{i,t}$ using nonfarm business sector implicit price deflator.

The main explanatory variables are firm characteristics measured by four vari-

¹³The main alternatives, covering a much broader set of firm sizes than Compustat, are Quarterly Financial Reports as in [Crouzet and Mehrotra \(2020\)](#) and the LOCUS data set constructed in [Dinlersoz et al. \(2018\)](#) (combining the US Census Longitudinal Business Database, Orbis, and Compustat). However, [Crouzet and Mehrotra \(2020\)](#) only follow small firms for eight quarters, while [Dinlersoz et al. \(2018\)](#) is at an annual frequency.

¹⁴See [Jeenas \(2018\)](#); [Mongey and Williams \(2016\)](#); [Ottonello and Winberry \(2020\)](#).

ables: distance-to-default, size, age, and volatility.¹⁵ I will mainly focus on firm default risk (distance-to-default) and leave the results on other firm characteristics as robustness checks since the firm characteristics are endogenously interlinked and generate consistent results.

The distance-to-default measures a firm's possibility of default at each point in time, developed in the seminal work of Merton (1974) and widely used in the financial industry. Intuitively, it describes how far away a firm is from its default point, which is the face value of its total debts. The key insight of this measure of corporate credit risk is that the equity of a firm can be viewed as a call option on the underlying value of the firm with a strike price equal to the value of its debts. Though neither the underlying value of a firm nor its volatility is directly observable, they can be inferred from the value and volatility of a firm's equity and its capital structure, under certain assumptions. Suppose the value of a firm follows a Brownian motion

$$dV = \mu_V V dt + \sigma_V V dW$$

where V denotes the total value of the firm, μ_V the expected continuously compounded return on V , σ_V the volatility of the firm's value, and dW an increment of the standard Weiner process. Assume the firm has an outstanding debt of face value D that will mature in T periods, then the value of the firm's equity E can be viewed as a call option on the underlying value of the firm V , with a strike price

¹⁵I leave firm leverage and liquidity in the appendix for two reasons: first, they do not show state-dependence of heterogeneous responses of firm investment to credit supply shocks on impact; second, the two measures are highly endogenous and generate counter-intuitive results in dynamic estimations.

equal to the face value of the firm's debt D and a time to maturity of T . According to the Black-Scholes-Merton option-pricing equation, the value of the firm's equity E satisfies

$$E = V\Phi(\delta_1) - e^{-rT}D\Phi(\delta_2) \quad (2.1)$$

where r is the risk-free interest rate, $\Phi(\cdot)$ is the cumulative standard normal distribution function, and

$$\delta_1 = \frac{\ln(V/D) + (r + 0.5\sigma_V^2)T}{\sigma_V\sqrt{T}}, \quad \text{and} \quad \delta_2 = \delta_1 - \sigma_V\sqrt{T}$$

Following Ito's Lemma, the relationship between the volatility of the firm's value σ_V and the volatility of its equity σ_E , within Black-Scholes-Merton option-pricing framework, is given by

$$\sigma_E = \frac{V}{E}\Phi(\delta_1)\sigma_V \quad (2.2)$$

The value of firm equity E and its volatility σ_E , the face value of firm debt D , and the risk-free interest rate r are observable from the data, and we end up with two variables V and σ_V and two equations (2.1) and (2.2) that could be solved numerically. The value of firm equity E is proxied by its market capitalization from CRSP, and the value of firm debt is from the merged CRSP-Compustat data sample. In addition, the forecasting horizon is set to be 1 year ($T = 1$). Thus, the risk-free interest rate is the daily 1-year constant-maturity treasury rate, and the volatility of firm equity is estimated by the standard deviation of the daily stock returns using

a 250-day moving window. In the end, the firm’s distance-to-default is defined as

$$dd = \frac{\ln(V/D) + (\mu_V - 0.5\sigma_V^2)}{\sigma_V}$$

A larger distance-to-default value means it needs a larger negative shock to drive a firm into default. Therefore, a firm with a larger distance-to-default is considered to have lower default risk. The detailed numerical techniques closely follows [Gilchrist and Zakrajsek \(2012a\)](#); [Ottonello and Winberry \(2020\)](#) and can be found in the Appendix [B.1.2](#).

The firm size and volatility are characterized by firm real sales following [Gertler and Gilchrist \(1994\)](#); [Ottonello and Winberry \(2020\)](#). The firm size is defined as the average real sales in the past 40 quarters in log-levels, and the firm volatility is defined as the standard deviation of year-on-year real sales growth for the same period. As for the firm age, I follow [Cloyne et al. \(2018\)](#) and measure firm age since its year of incorporation, which is available from Datastream. A firm is classified as mature if it exists for over 10 years or above, and young otherwise, following [Haltiwanger et al. \(2013\)](#).

Other control variables include firm real total assets, real sales growth, and firm current asset as a share of total assets. Both firm total assets and sales are deflated by nonfarm business sector implicit price deflator. The firm real total asset is in log-levels and the real sales growth is quarter-on-quarter. More details of the construction of firm-level variables can be found in Appendix [B.1.2](#).

I exclude financial (SIC code: 6000-6799), utility (SIC code: 4900 – 4999),

and non-classifiable (SIC code: ≥ 9900) firms in the data sample. The firms are kept in the sample if they are incorporated in the US and have observations for more than 40 quarters. To eliminate the impacts from outlier observations, I drop the firm-quarter observation and the subsequent observation if its capital, assets, or sales is negative, leverage ratio higher than 10 or negative, liquidity ratio above 2 or below 0, quarterly real sales growth above 2 or below -2, or net current assets as a share of total assets is higher than 10 or below -10. In order to remove the extensive margins of firm investment movements, I drop firm-quarter observations if the investment rate lies in the top and bottom 0.5% of the sample distribution, or the acquisitions are larger than 5% of the total assets. Since the data on acquisitions becomes available in late 1983 and there are only a few observations in 1984, in the end, I keep the data sample from 1985Q1 to 2018Q4. This results in an unbalanced panel of 331,812 firm-quarter observations in total. Appendix [B.1.2](#) reports further information about the data selection process.

Table [2.3](#) presents the summary statistics of the final firm-level data sample used for the rest of the analysis. The top panel shows the simple summary statistics, and the bottom panel shows the cross-section correlations of firm distance-to-default with other firm characteristics. The average distance-to-default indicates that a 6 standard deviation negative shock in a given year will drive the average firm into default, consistent with [Gilchrist and Zakrajsek \(2012a\)](#); [Ottonello and Winberry \(2020\)](#). The median firm age is 16.5 years, indicating that over half of the firms will be classified as mature based on the criterion described above. Indeed, only 27% of the firms in the sample will be classified as young. The firms exhibit large volatility

1985Q1–2018Q4	Dist. to Default	Age	Volatility	Size	Total Assets	$\Delta \log k_{it}$
Mean	5.974	21.9	0.342	493.3	2351.1	0.004
Median	4.903	16.5	0.234	44.3	190.1	-0.004
S.D.	5.194	19.3	0.348	2301.09	10811.5	0.089
95th Percentile	15.558	59.5	1.032	2106.3	9580.2	0.123
Observations	231130	331812	331165	331812	331812	331812
corr(dd, ·)	1	0.231 (0.000)	-0.202 (0.000)	0.145 (0.000)	0.149 (0.000)	0.125 (0.000)

Note: This table summarizes the firm-level variables from 1985Q1 to 2018Q4. In the top panel, distance-to-default is constructed following [Gilchrist and Zakrajsek \(2012a\)](#); age is in years since firm incorporation; volatility is the 10-year standard deviation of firm year-on-year real sales growth; size is the 10-year average of firm real sales; both total assets and size are in millions of 2012 real US dollars; $\Delta \log k_{it}$ is the log-difference of real capital stock. The bottom panel shows the cross-section correlations between firm distance-to-default and other firm variables, with p -values in parentheses.

Table 2.3: Summary Statistics of Firm-level Data

measured by real sales growth. The average year-on-year real sales growth in the sample is 0.05 and the standard deviation of the real sales growth within a 10-year window is 0.342. The firm size and total assets are in millions of 2012 real US dollars, and both of them are in levels for display here but will enter the regressions in log-levels in the next section. Due to the usage of data mainly on public firms, the firm size in the sample is large measured by either sales or total assets. The 10-year average real sales are \$493.3 million and the total assets are much larger, around \$2351.1 million, both of which exhibits considerable cross-section variations. The median of firm size and total assets are far smaller, indicating that the distribution of firm size is highly right-skewed. The response variable – firm investment, is summarized in the last column. The average real capital growth is 0.4% and the median -0.4% for the US public firms in the past thirty decades. The investment also exhibits significant variations across firms, with a standard deviation of 8.9%.

The first row in the bottom panel presents the cross-section correlations between the firm default risk and other variables, and the bottom row the corresponding p -values. It implies that a low default risk firm tends to be large in either sales or total assets, exist for a longer period, suffer smaller volatility, and experience a faster investment growth. The full correlation matrix of firm variables is presented in Table [B.1](#) in Appendix [B.1.2](#).

2.5 Empirical Panel Regression

In this section, I address the main question of this paper: how firms respond to credit supply shocks conditional on their differential characteristics. I decompose this question into two parts. First, I show that firm investment responds significantly and persistently to the identified credit supply shock. It validates the approach employed in this paper – applying the identified credit supply shock from a sign restriction VAR using aggregate data to the firm-level data. Second and foremost, I show that the differential responses of firm investment to the credit supply shock conditional on firm characteristics are state-dependent. The firm with lower default risk will increase their investment more during credit expansions, and contract their investment less during credit contractions. I also investigate the mechanism of the state-dependence of heterogeneous responses due to default risk. The results reveal that low default risk firms consistently have lower borrowing costs and better access to external financing through credit cycles. The results also hold for large, mature, and less volatile firms. In the end, I will provide evidence that the results are robust

to alternative credit supply shock identifications.

2.5.1 Average Firm Investment Responses

As a novel approach to apply the credit supply shock extracted from a VAR structure to the firm-level data, I first provide some evidence that it is valid to do so, by presenting the average firm investment responses to the identified credit supply shock without considering firm heterogeneity. The impulse responses of firm investment are estimated using the panel local projection method as specified below

$$\Delta \log k_{it+h} = \alpha_{ih} + \alpha_{sqh} + \beta_h \varepsilon_t + \Gamma_h Z_{it-1} + \Omega_h Y_{t-1} + e_{ith} \quad (2.3)$$

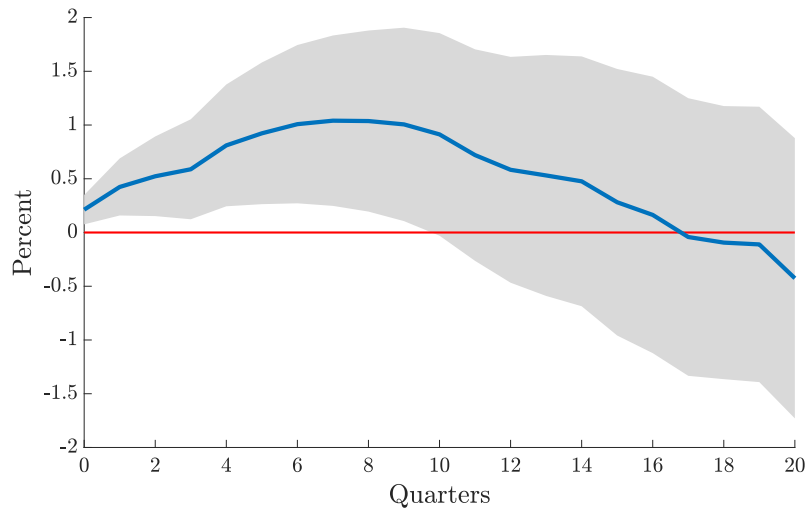
where the response variable on the left-hand side (LHS) is the cumulative firm investment over the forecast horizon h , and the coefficient of interest is β_h measuring how the cumulative firm investment $\Delta \log k_{it+h}$ in quarter $t+h$ responds to the credit supply shock ε_t in quarter t on average. I also include firm fixed effect α_{ih} and sector-by-quarter fixed effect α_{sqh} .¹⁶ The former captures permanent differences in investment behavior across firms, while the latter captures that across sectors and seasons. The firm control variables Z_{it-1} include firm total assets, sales growth, current assets as a share of total assets, and a fiscal quarter dummy. The aggregate control variables Y_{it-1} is a vector with four lags of output growth, inflation, unemployment rate, and e_{ith} is the residual. The firm control variables are standardized

¹⁶The sectors I consider, based on SIC codes, are: agriculture, forestry, and fishing; mining; construction; manufacturing; transportation communications, electric, gas, and sanitary services; wholesale trade; retail trade; and services.

and the regression removes the Great Recession period. Throughout the analysis, the standard errors are two-way clustered at the firm and quarter levels.

Figure 2.5 shows the average impulse responses of firm investment to credit supply shocks for up to 20 quarters. On average, one unit of a credit supply shock (0.39% movement of credit volume) induces a 0.21% movement of firm investment on impact, and the effect slowly rises to over 1% after five quarters and stays for another year. The effects on firm investment are significant and persistent for around ten quarters after the shock. In Table B.3 in Appendix B.2, the impact of the credit supply shock on firm investment remains positive and significant even after controlling for individual firm characteristics. Also, the effects are robust to various credit supply shock identifications as will be shown in section 2.5.3.2.

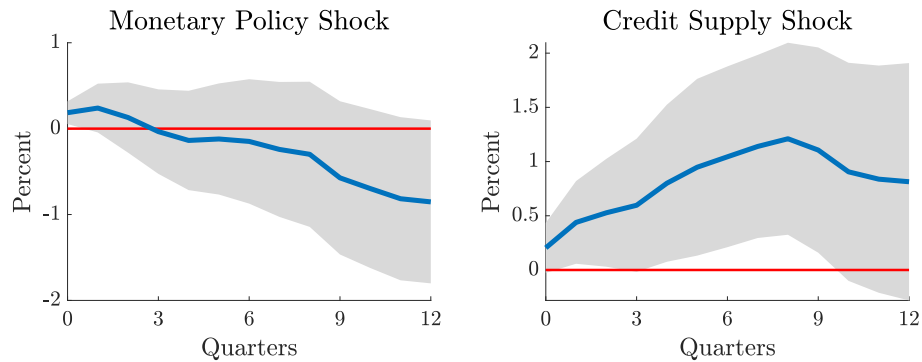
To offer an intuitive understanding of the magnitude of firm investment re-



Note: This figure displays the average impulse responses of firm investment to credit supply shocks. The solid line is the impulse response and the shaded area is the 90% confidence interval. The regression is controlled for firm fixed effects, section-by-quarter fixed effects, aggregate trends, and the standard errors are two-way clustered at the firm and quarter levels. This figure shows that the identified credit supply shock has a significant and persistent impact on firm investment.

Figure 2.5: Average Responses of Firm Investment to Credit Supply Shocks

sponses to credit supply shocks, I compare the results above to [Ottonello and Winberry \(2020\)](#). Similar to this paper, they study the firm investment responses to high-frequency identified monetary policy shocks using Compustat data from 1990Q1 to 2007Q4. As in [Ottonello and Winberry \(2020\)](#), the monetary policy shock is constructed following [Gorodnichenko and Weber \(2016\)](#); [Gurkaynak et al. \(2005\)](#). Besides, the monetary policy shock is normalized and standardized such that a positive shock is a monetary expansion and the unit of monetary policy shocks become standard deviations of federal funds rate. The average firm investment responses to monetary policy shocks and credit supply shocks are presented in [Figure 2.6](#). One unit of a monetary policy shock (11bp of federal funds rate) induces a 0.19% firm investment movement on impact, but quickly decays after the initial shock. In contrast, one unit of a credit supply shock (15bp of excess bond premium) leads to a 0.22% firm investment movement on impact, but then grad-



Note: This figure displays the average impulse responses of firm investment to monetary policy shocks (left panel) and credit supply shocks (right panel) following the specification in [Equation \(2.3\)](#). The monetary policy shock is constructed following [Gorodnichenko and Weber \(2016\)](#); [Gurkaynak et al. \(2005\)](#) and the data sample runs from 1990Q1 to 2007Q4 as in [Ottonello and Winberry \(2020\)](#). The monetary policy shock is normalized and standardized. The solid line is the impulse response and the shaded area is the 90% confidence interval. This figure shows that both monetary policy shocks and credit supply shocks have strong implications for firm investment, yet the former has a short-lived impact while the latter has a persistent impact.

Figure 2.6: Average Responses to Monetary Policy and Credit Supply Shocks

ually rises to above 1.3% seven quarters after the shock. In terms of magnitude, both credit supply shocks and monetary policy shocks have strong implications for firm investment though they have different patterns. In line with the conventional wisdom, monetary policy shocks have only short-lived effects on real variables, while the effects of credit supply shocks are persistent over time. This again verifies that the credit supply shock identified in the benchmark identification is a real shock, while the monetary policy shock is nominal and only has impacts in the short-term.

It is hard to directly compare the results to other related literature that studies the impacts of credit supply shocks on firm investment for two reasons. First, I use a different data set from other literature. For example, [Kalemli-Ozcan et al. \(2018\)](#) use data for European countries, [Cingano et al. \(2016\)](#) for Italy, and [Amiti and Weinstein \(2018\)](#) for Japan. Second, most literature identifies the credit supply shock using the event study approach or granular methods. They either focus on the Great Recession period ([Duchin et al. \(2010\)](#)), which is removed in the regression in this paper, or they identify the idiosyncratic credit supply shock while I focus on the common credit supply shock that hits the whole banking sector.

2.5.2 Heterogeneous Firm Investment Responses

To study the heterogeneous firm investment responses to credit supply shocks conditional on their individual characteristics, I estimate panel regressions projecting the measure of firm investment on the intersection term of firm characteristics and the credit supply shock, conditional on a set of firm and aggregate control variables.

I estimate variants of the baseline empirical specification shown below

$$\Delta \log k_{it} = \alpha_i + \alpha_{st} + \beta x_{it-1} \times \varepsilon_t + \Gamma Z_{it-1} + e_{it} \quad (2.4)$$

where the LHS variable is the investment of firm i at the end of period t ; $x_{i,t-1}$ is one of the firm characteristic measures in the previous period to ensure exogeneity, and ε_t is the credit supply shock. x_{it} is a firm's distance-to-default (dd), size, age, or volatility. As mentioned in the previous section, these measures are endogenously interlinked to each other and the results conditional on each measure are similar and consistent. Therefore, I will mainly focus on the distance-to-default and leave the rest for robustness checks. The main coefficient of interest is β , which measures how the semielasticity of firm investment in response to credit supply shocks depends on the firm characteristics. To control for the factors that may simultaneously affect firm investment and characteristics, I include firm-fixed effect α_i , sector-by-time fixed effect α_{st} , and a vector of firm controls Z_{it-1} . The firm control variables are the same as in Equation (2.3). In addition, it also includes the level of firm characteristics x_{it-1} , and its intersection term with the previous period's output growth to control for differences in cyclical sensitivities across firms. The idea to control for the cyclical sensitivity is to avoid the bias in the results caused by the fact that firms with different characteristics may be differentially exposed to business cycles. The firm characteristics x_{it-1} are winsorized at the top and bottom 0.5% and standardized over the entire sample, and thus the units become standard deviations in the sample.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
dd × credit shock	0.002 (0.068)	0.003 (0.065)	0.004 (0.065)	0.010 (0.060)				
dd (firm mean) × credit shock					-0.005 (0.048)			
dd (firm variation) × credit shock					0.009 (0.056)			
size × credit shock						0.033 (0.039)		
volatility × credit shock							-0.022 (0.048)	
age × credit shock								-0.187 (0.124)
Observations	221035	221035	221035	221035	221035	316641	316001	316642
R^2	0.099	0.104	0.104	0.129	0.104	0.086	0.081	0.082
Firm Controls	no	yes	yes	yes	yes	yes	yes	yes
Additional Controls	yes	yes	no	$\Delta \log k_{it-1}$	yes	yes	yes	yes
Time Sector FE	yes	yes	yes	yes	yes	yes	yes	yes
Two-way Clustering	yes	yes	yes	yes	yes	yes	yes	yes

Note: This table reports the results from estimating Equation (2.4) (columns other than (5)) and Equation (2.5) (column (5)). Firm characteristics are winsorized and standardized. In columns other than (5), firm control variables include the level of firm characteristics in the previous period x_{it-1} , total assets, sales growth, current assets as a share of total assets, and a fiscal quarter dummy; additional controls include the intersection of x_{it-1} with output growth to control for cyclical sensitivity; in column (5), dd_{it-1} in the firm controls is replaced by $\mathbb{E}[dd_{it}]$ and $(dd_{it-1} - \mathbb{E}[dd_{it}])$, and the cyclical sensitivity control is replaced by their intersections with output growth, respectively. Column (4) adds $\Delta \log k_{it-1}$ as an additional firm control besides the cyclical sensitivity control. The standard errors are two-way clustered at the firm and quarter levels and are shown in parentheses. The table shows that the firm characteristics do not play a significant role in determining firm investment to credit supply shocks in the entire sample period.

Table 2.4: Heterogeneous Responses of Firm Investment to Credit Supply Shocks

Table 2.4 reports the results from estimating the baseline specification (2.4). The first four columns show that firm distance-to-default has no implications for firm investment in response to credit supply shocks. Column (1) and column (2) estimate the empirical model with and without firm controls respectively. Column (3) removes the control for cyclical sensitivity and column (4) adds lagged firm investment as an additional firm control variable. The results are robust to each variant estimation. The coefficient on the intersection term is negligible in magnitude and imprecisely estimated.

Column (5) re-estimates the baseline specification by decomposing the firm distance-to-default into a permanent component and a within-firm variation component as suggested by [Ottonello and Winberry \(2020\)](#)

$$\Delta \log k_{it} = \alpha_i + \alpha_{st} + \beta \mathbb{E}[dd_{it}] \times \varepsilon_t + \gamma (dd_{it-1} - \mathbb{E}[dd_{it}]) \times \varepsilon_t + \Gamma Z_{it-1} + e_{it} \quad (2.5)$$

where $\mathbb{E}[dd_{it}]$ is the mean of an individual firm's distance-to-default during the sample period that captures the permanent differences across firms, and $(dd_{it-1} - \mathbb{E}[dd_{it}])$ is the demeaned firm distance-to-default that captures the within-firm variation over time. Accordingly, the firm control variables replace dd_{it-1} and its intersection with lagged output growth with the corresponding decomposed terms. The insignificant effects of firm default risk on firm investment to credit supply shocks do not change.

Columns (6) to (8) estimate the baseline model with firm age, volatility, and size, and the results do not change either.

This finding is inconsistent with a series of related literature, which finds that firm characteristics such as default risk, size, or age will affect firm activities differentially in response to monetary policy shocks or over the business cycles, such as [Cloyne et al. \(2018\)](#); [Crouzet and Mehrotra \(2020\)](#); [Gertler and Gilchrist \(1994\)](#); [Ottonello and Winberry \(2020\)](#). Does this mean that these firm characteristics do not play a role in firm investment responses to credit supply shocks? Not necessarily. The underlying assumption in the baseline specification is that the firm characteristics will influence firm investment in the same manner independent of the credit cycle phases. To put it another way, Equation (2.4) assumes that β is the same

for both positive and negative credit supply shocks. This is an assumption usually imposed in the literature and it may not hold in all scenarios. As will be shown in the next subsection, the assumption fails in the settings in this paper, and the insignificance of the coefficients in Table 2.4 is caused by this misspecification.

2.5.2.1 State-dependence

To address the misspecification caused by not disentangling credit expansions and contractions, I estimate the following specification

$$\Delta \log k_{it} = \alpha_i + \alpha_{st} + \beta^+ dd_{it-1} \times \varepsilon_t^+ + \beta^- dd_{it-1} \times \varepsilon_t^- + \Gamma Z_{it-1} + e_{it} \quad (2.6)$$

The only difference from Equation (2.4) is that I decompose the credit supply shock ε_t into credit expansions ε_t^+ and contractions ε_t^- . I construct positive credit supply shocks $\varepsilon_t^+ = \varepsilon_t$ if $\varepsilon_t > 0$ and $\varepsilon_t^+ = 0$ otherwise. Similarly, $\varepsilon_t^- = \varepsilon_t$ if $\varepsilon_t < 0$ and $\varepsilon_t^- = 0$ otherwise. β^+ measures the relevance of firm distance-to-default in characterizing firm investment responses to a positive credit supply shock, and β^- measures that to a negative shock.

Table 2.5 reports the coefficients of interest β^+ and β^- from Equation (2.6). Noticeably, the coefficients have flipped signs and commensurate magnitudes during credit expansions and contractions, and they are significant and robust to variant specifications. Recall that the firm characteristic measures are standardized, thus dd_{it-1} is positive if it is larger than the sample mean and negative otherwise. In column (1), the positive coefficient in the top row implies that a firm with one std

	(1)	(2)	(3)	(4)
dd × pos credit shock	0.314** (0.141)	0.291** (0.133)	0.290** (0.130)	0.266** (0.124)
dd × neg credit shock	-0.299** (0.118)	-0.275** (0.113)	-0.272** (0.113)	-0.237** (0.104)
Observations	221035	221035	221035	221035
R^2	0.099	0.104	0.104	0.129
Firm Controls	no	yes	yes	yes
Additional Controls	yes	yes	no	$\Delta \log k_{it-1}$
Time Sector FE	yes	yes	yes	yes
Two-way Clustering	yes	yes	yes	yes

Note: This table reports the results from estimating Equation (2.6). Positive credit supply shocks are set to be the original credit shock if it is positive and zero otherwise, analogously to the negative supply shocks. The standard errors are two-way clustered at the firm and quarter levels and are shown in parentheses. This table shows that the heterogeneous response of firm investment to credit supply shocks conditional on firm distance-to-default are state-dependent.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.5: State-dependent Responses Conditional on Firm Default Risk

higher distance-to-default than the sample mean will increase 0.314% more investment to one unit of a positive credit supply shock, while the negative coefficient in the bottom row implies that the same firm will contract its investment 0.299% less to one unit of a negative credit supply shock. Adding firm control variables in column (2) does not change the results significantly. The result is also robust to variant specifications by removing cyclical sensitivity control in column (3), or by adding firm lagged investment in column (4). Overall, the results indicate that a low default risk firm will consistently have higher investment relative to average firms – its investment increases more in credit expansions and decline less during credit contractions.

The results suggest that firm default risk does play a role in affecting firm investment in response to credit supply shocks. However, the reason why we barely find any significant results in Table 2.4 is that the heterogeneous effects are state-

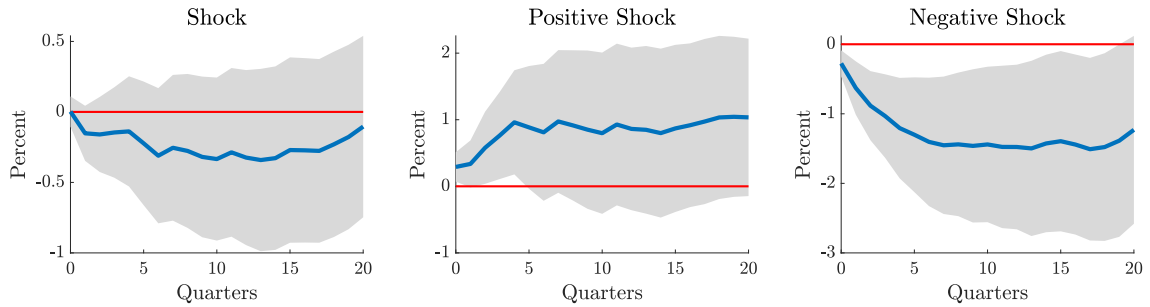
dependent. During credit expansions, firms with low default risk are able to expand more aggressively and invest more; during credit contractions, they could smooth their investment by cutting investment less. Table B.4 in Appendix B.2 reports the results from estimating the specification (2.6) with alternative cyclical sensitivity controls and along with firm leverage and liquidity ratios. The results are robust to controlling for these factors.

In order to estimate the dynamic heterogeneous responses conditional on firm default risk, I estimate a dynamic version of the specification (2.6) as follows

$$\Delta \log k_{it+h} = \alpha_{ih} + \alpha_{sth} + \beta_h^+ dd_{it-1} \times \varepsilon_t^+ + \beta_h^- dd_{it-1} \times \varepsilon_t^- + \Gamma_h Z_{it-1} + e_{ith} \quad (2.7)$$

where h is the forecast horizon, and β_h^+ measures the effects of a firm's distance-to-default dd_{it-1} on the cumulative response of firm investment $\Delta \log k_{it+h}$ in period $t+h$ to a positive credit supply shock in period t , and β_h^- measures the effects to a negative shock. Other settings are the same as in Equation (2.6).

Figure 2.7 presents the impulse responses from estimating Equation (2.7). For comparison, the left column shows the impulse responses of firm investment without decomposing credit supply shocks into expansions and contractions. During the entire sample period, the coefficient on the intersection term is small in magnitude and imprecisely estimated. In contrast, the middle column shows that one unit of a credit expansion will induce a firm with one std higher distance-to-default to invest 0.29% more on impact, and the effect grows to around 1% three quarters after the shock. The right column shows that in response to one unit of a credit contraction,



Note: This figure displays the impulse responses of firm investment conditional on firm distance-to-default to the credit supply shock in the entire sample (left panel), credit expansions (middle panel), and credit contractions (right panel). The solid line is the impulse response and the shaded area is the 90% confidence interval. This figure shows that the heterogeneous effects of the firm default risk on firm investment are state-dependent.

Figure 2.7: State-dependent Responses Conditional on Firm Default Risk

a firm with one std higher distance-to-default will cut its investment 0.28% less on impact, and the effect reaches around 1.5% five quarters after the shock. The effects are persistent throughout the forecast horizons. Both Table 2.5 and Figure 2.7 convey a consistent message that the firm default risk has a significant and large impact on firm investment to credit supply shocks, and the heterogeneous effects depend on the credit cycle phases. Firms with lower default risk consistently have higher investment relative to average firms through credit cycles.

2.5.2.2 Mechanism Inspection

To investigate the reasons for the state-dependent heterogeneous responses of firm investment to credit supply shocks due to default risk, I provide evidence on the responses of firm borrowing cost and external financing over credit cycles. The borrowing cost is measured as average interest payment scaled by lagged total assets, and the external financing is defined as the sum of cumulative changes of total debts and equities scaled by lagged total assets.

First, I re-estimate the specification (2.6), replacing the LHS variables with either firm borrowing cost or external financing and keeping other settings invariant. Table 2.6 reports the estimation results. In column (1), the top row shows that a firm with one std higher distance-to-default will have a 0.013% lower average interest payment as a share of total assets relative to average firms in response to one unit of a positive credit supply shock, and the same firm will have a 0.015% lower borrowing cost to a negative shock. The mean of average interest payment over the total asset in the data sample is 0.6374%, and the back-of-the-envelope calculation suggests the low default risk firm will have a roughly 2% lower borrowing cost relative to average firms in either credit expansions or contractions. Columns (2) to (4) estimate the responses of the overall external financing, the external debt and equity respectively to credit supply shocks. Column (2) implies that a firm with one std higher distance-

	(1)	(2)	(3)	(4)
	Interest Payment	External Financing	External Debt	External Equity
dd × pos credit shock	-0.013* (0.008)	0.459*** (0.171)	0.172*** (0.058)	0.255* (0.147)
dd × neg credit shock	0.015 (0.009)	-0.449*** (0.149)	-0.100* (0.053)	-0.314*** (0.110)
Observations	193758	220399	220419	221014
R^2	0.533	0.084	0.055	0.075
Firm Controls	yes	yes	yes	yes
Time Sector FE	yes	yes	yes	yes
Two-way Clustering	yes	yes	yes	yes

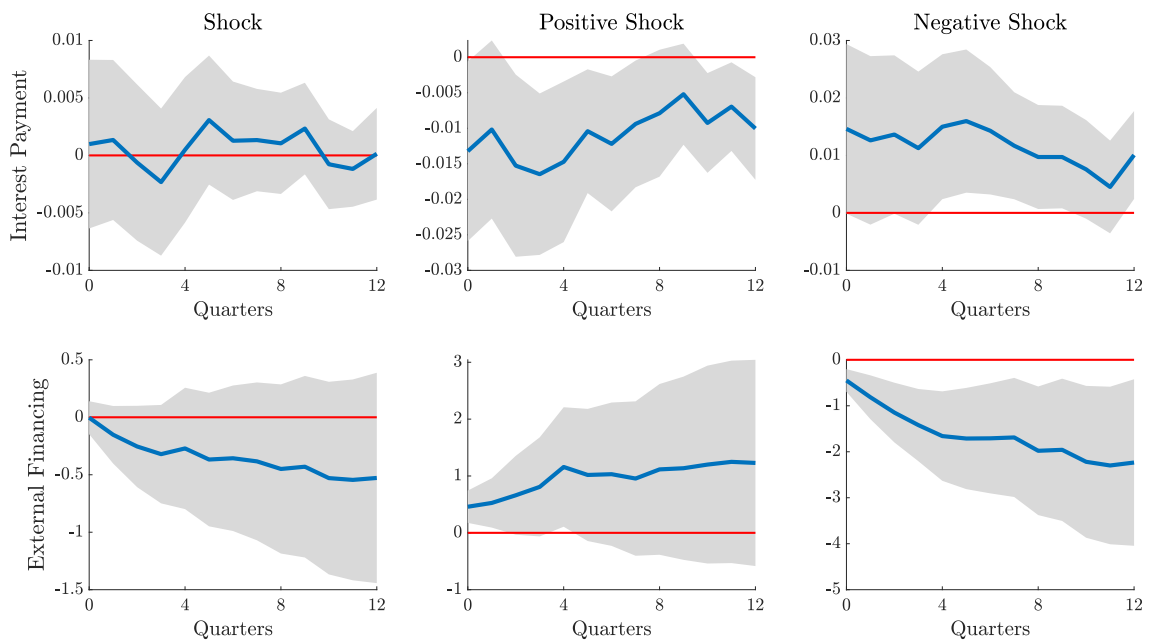
Note: This table reports the results from estimating Equation (2.6), replacing the LHS variables with firm borrowing cost or external financing. The firm borrowing cost is measured by average interest payment, and the firm external financing is defined as the sum of cumulative changes of total debts and equities, both scaled by lagged total assets. The standard errors are two-way clustered at the firm and quarter levels and are shown in parentheses. This table shows that low default risk firms consistently have lower borrowing costs and better access to external financing in both credit expansions and contractions.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.6: Responses of Firm Borrowing Cost and External Financing

to-default will in total borrow 0.459% more from outside relative to average firms, scaled by total assets, to one unit of a positive credit supply shock and borrow 0.449% more to one unit of a negative shock. Specifically, similar results hold for both external debt and equity financing. The results imply that firms with lower default risk will always have better access to external resources including both debt instruments and equities through credit cycles.

Second, I estimate the dynamic responses of firm borrowing cost and external financing following specification (2.7), and the impulse responses are reported in Figure 2.8. The forecast horizon is set to be 12 quarters since financial variables respond to credit supply shocks more rapidly and it is also approximately the aver-



Note: This figure displays the state-dependent impulse responses of firm borrowing cost and overall external financing to credit supply shocks conditional on firm default risk. The solid line is the impulse response and the shaded area is the 90% confidence interval. This figure shows that low default risk firms have consistently low borrowing cost and better access to external financing over credit cycles.

Figure 2.8: Dynamic Responses of Firm Borrowing Cost and External Financing

age maturity of debt in Compustat. The left column shows the impulse responses in the entire sample period without distinguishing between credit expansions and contractions; the middle column shows the results for positive credit supply shocks and the right column for the negative shocks. The left column indicates that the impulse responses of neither interest payments nor the overall external financing are significantly affected by the firm default risk to credit supply shocks. However, in the middle column, the top row shows that during a credit expansion, a low default risk firm has a lower borrowing cost than average firms. This advantage also holds during credit contractions as shown in the right column. The pattern is similar for overall firm external financing in the bottom row. During a credit expansion, the external financing as a share of total assets is about 1% larger for firms with one std higher distance-to-default than average firms four quarters after the shock. The differential effect is more than doubled, above 2% for low default risk firms during credit contractions. I also provide evidence on the responses of external debt and equity respectively in Figure B.3 in Appendix B.2.

Overall, the evidence implies that a firm with lower default risk will consistently have lower borrowing costs and better access to external resources over credit cycles, in both credit expansions and contractions. The effects are significant and persistent, holding for over 3 years after the shock. It explains the state-dependence of the differential responses of firm investment to credit supply shocks in the previous section. During a credit expansion, low default risk firms have lower borrowing costs and can borrow from outside more easily to expand their investment relative to average firms. During a credit contraction, their borrowing cost is still lower

and they still have better options in financing from outside, which enables them to smooth their investment during downturns and contract their investment less compared to average firms.

2.5.2.3 Implications

The state-dependence of heterogeneous responses of firm activity to structural shocks conditional on firm characteristics is a fact that has been overlooked in the literature and has important implications on both empirical and theoretical sides for future research.

On the empirical side, there is a possibility of misspecification when investigating the role of firm characteristics in determining firm activities to exogenous shocks if one does not carefully distinguish between different phases of exogenous shocks. As shown in Table 2.4, the coefficients on the intersection term of firm characteristics with credit supply shocks are negligible in magnitude and imprecisely estimated without separating credit expansions and contractions. The insignificance of the heterogeneity comes from the improperly imposed assumption that the effects of firm characteristics on firm activity are invariant to credit cycle phases. The absence of any findings when estimating during the entire sample period is not the absence of the heterogeneity caused by firm characteristics in response to credit supply shocks. Instead, it conceals the fact that the heterogeneous responses have flipped signs and commensurate magnitudes during credit expansions and contractions. To rephrase this from another perspective, even if one finds significant effects

of firm characteristics on firm activities, it would be best to assure this effect holds in both phases of exogenous shocks. For example, [Jeenas \(2018\)](#) documents that firms with lower liquid asset holdings will be more responsive to monetary policy shocks in a specification including both monetary expansions and contractions, and then he focuses on the monetary tightening scenario, arguing that lower liquid asset ratios are associated with less investment after a contractionary monetary policy shock. The evidence from my paper suggests that it is valid to re-check the estimation by distinguishing between expansionary and contractionary monetary shocks and ensure it is the case. Also, [Crouzet and Mehrotra \(2020\)](#) argue that small firms are more cyclically sensitive than large firms by estimating the semi-elasticity of firm-level growth to GDP growth conditional on firm size, and then they emphasize that small firms would contract more during downturns, though they do not intentionally distinguish between positive and negative GDP growth in their estimation. Again, it is valid to ask whether the larger sensitivity of small firms holds both in surges and downturns over the business cycles.

On the theoretical side, the evidence from this paper is consistent with the financial friction literature yet it proposes new questions. This paper suggests that a firm with higher default risk will incur a higher borrowing cost and be less able to borrow from outside during a credit contraction, and thus be more negatively impacted and cut investment by more. This is consistent with the financial accelerator theory in [Bernanke et al. \(1999\)](#) that a financially constrained firm will contract more during economic downturns. There is a long literature studying the role of financial frictions in amplifying negative shocks during recessions such as [Jensen](#)

et al. (2020); Mendoza (2010). Khan and Thomas (2013); Khan et al. (2016) introduce firm heterogeneity in a financial friction model and find that a negative shock to borrowing conditions can generate a large and persistent recession via capital misallocation. On the other hand, there is another strand of literature emphasizing that financial friction might also dampen the effects of exogenous shocks. For example, Ottonello and Winberry (2020) build a heterogeneous firm New Keynesian model and show that the investment of financially constrained firms is less responsive to monetary expansionary shocks. The state-dependent heterogeneous responses of firm activity in my paper proposes two questions that are challenging for existing models to explain. First, for models featuring default risk as in Khan et al. (2016); Ottonello and Winberry (2020), they are successful in matching firm dynamics in the data during either a contractionary or expansionary period in response to an exogenous shock. Yet their results will be mirrored if they flip the sign of exogenous shocks. To put it another way, these works argue that financial frictions will consistently either amplify or dampen the exogenous shocks independent of whether it is expansionary or contractionary. However, my paper suggests that financial frictions do not systematically amplify or dampen the credit shocks. The direction of the effects of financial frictions on firm activity depends on the phases of the credit cycles. It amplifies the effects of negative credit supply shocks but dampens that of the positive shocks. These models would not be able to generate state-dependent heterogeneous responses of firm activity to credit supply shocks. Second, for models featuring occasionally binding constants such as Jensen et al. (2020); Khan and Thomas (2013); Mendoza (2010), they could generate the asym-

metric effects of financial frictions over business cycles in the settings where the financial frictions become not binding during expansions. However, the evidence in my paper implies that financial frictions are always binding in both expansions and contractions. This paper shows that low default risk firms consistently have lower borrowing costs and more external resources in both expansions and contractions, and therefore, they could invest more when credit conditions ease and contract less when credit conditions tighten, which is not consistent with the occasionally binding constraint mechanism. Though both strands of literature characterize the financial frictions in their models, there is not an active role played by the financial intermediaries. The evidence in this paper suggests that banks consistently favor low default risk firms while making lending decisions during both credit expansions and contractions. A model aiming to match the state-dependent heterogeneous effects of financial frictions shall take this fact into account.

2.5.3 Additional Empirical Results

In this section, I provide additional evidence reinforcing the findings of state-dependent heterogeneous responses of firm activity to credit supply shocks. First, I will show that firms that are larger, older, and less volatile also consistently have advantages over average firms through credit cycles. They have lower borrowing costs and better access to external resources in both credit expansions and contractions, and therefore, they can expand their investment more during credit expansions and cut their investment less during credit contractions. Second, I show that the re-

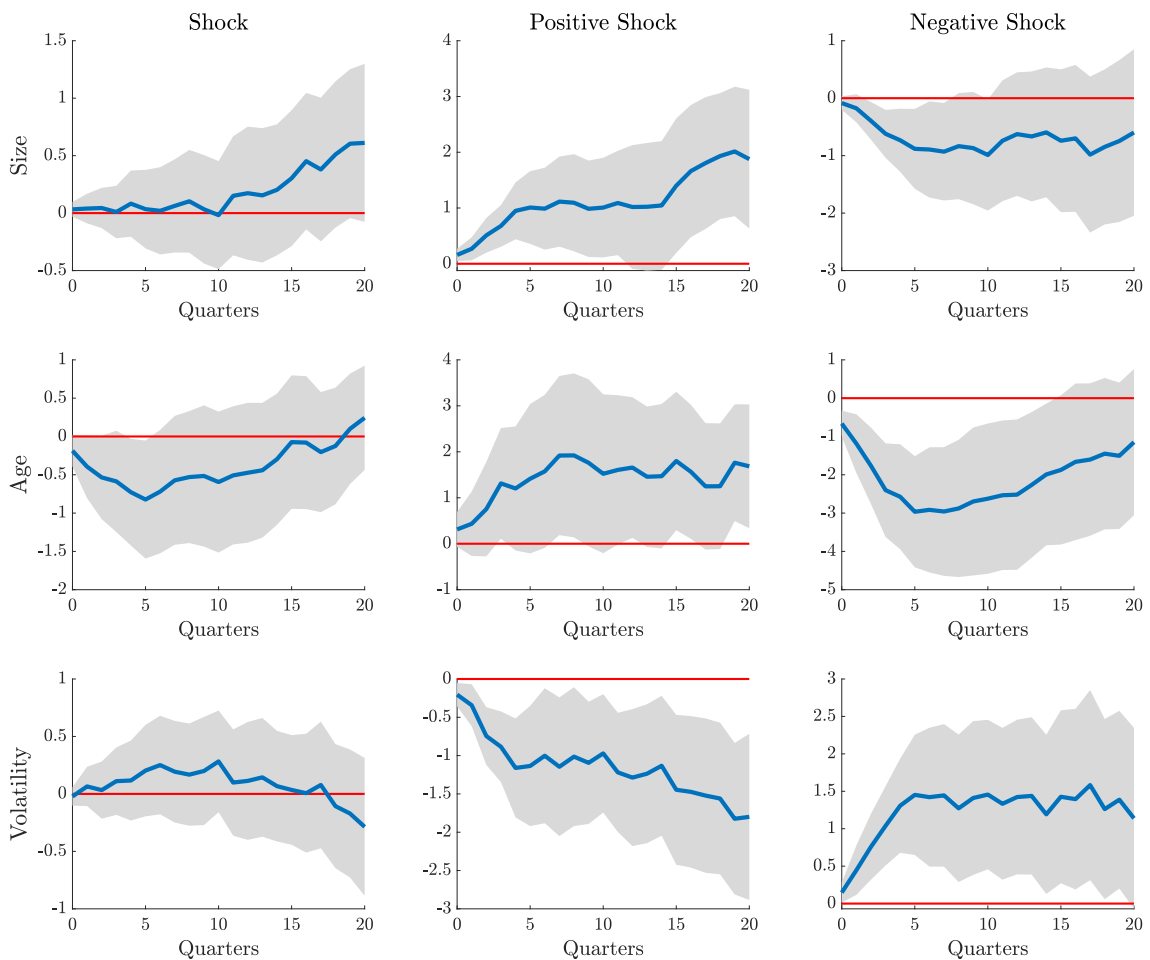
sults are robust to alternative credit shock identifications. I use alternative data for both credit volume and credit price and alternative VAR sign restrictions choices inspired by [Mian et al. \(2017\)](#). The state-dependence of heterogeneous effects is largely invariant to these variations.

2.5.3.1 Firm Size, Age and Volatility

There has been a long tradition in the literature using firm size as a proxy for firm financial frictions and studying its impacts on firm activity to exogenous shocks since [Gertler and Gilchrist \(1994\)](#). In a recent work, [Cloyne et al. \(2018\)](#) argue that young firms are more responsive to monetary shocks in the US and the UK. There is also a growing strand of literature arguing that firm-level volatility is an important determinant of firm responses to exogenous shocks, for example, [Vavra \(2013\)](#). Motivated by these works, I explore the empirical link between firm size, age, and volatility and their investment response to credit supply shocks.

Figure [2.9](#) presents the impulse responses of firm investment to credit supply shocks conditional on firm size, age, and volatility following the specification [\(2.7\)](#). The firm control variables do not include firm total assets when estimating the specification for firm size due to collinearity concerns, since firm sales and total assets are highly correlated as shown in [Table B.1](#) in [Appendix B.1](#). The top row shows the impulse responses of firm investment conditional on firm size, the middle row on firm age, and the bottom row on firm volatility. The left panel displays the impulse responses without distinguishing between credit expansions and contractions.

Again, the heterogeneous effects of firm characteristics on firm investment to credit supply shocks are barely significant during the entire sample period. However, the middle column implies that during a credit expansion, larger, older, and less volatile firms will expand their investment more relative to average firms. In the right column, these firms will cut their investment less during credit contractions. Firms that are one std larger measured by average real sales will increase their investment



Note: This figure displays the state-dependent impulse responses of firm investment to credit supply shocks conditional on firm size, age, and volatility. The solid line is the impulse response and the shaded area is the 90% confidence interval. This figure shows that the investment of larger, older, and less volatile firms will increase more during credit expansions and decline less during credit contractions.

Figure 2.9: State-dependent Responses Conditional on Other Characteristics

1% more than average firms one year after a positive credit shock, and contract their investment 1% less after a negative shock. The investment of a mature firm, existing for 10 years or older, will increase 2% more than young firms six quarters after a credit expansion, and decline 3% less five quarters after a credit contraction. A firm that has one std smaller volatility measured by the standard deviation of real sales growth will increase its investment 1% more than average firms four quarters after a positive credit supply shock, and contract its investment 1.5% less five quarters after a negative shock. The state-dependent heterogeneous effects are large, significant, and persistent throughout the forecast horizons.

Figure B.4 and Figure B.5 in Appendix B.2 present the evidence on dynamic responses of firm borrowing cost and external financing to credit supply shocks. The mechanism investigation reveals consistent findings to the state-dependent heterogeneous responses of firm investment conditional on firm characteristics. Larger, older, and less volatile firms consistently have lower borrowing costs and better access to external resources in both credit expansions and contractions.

To summarize, the results of the state-dependent heterogeneous responses of firm investment to credit supply shocks also hold for firm size, age, and volatility. The investment of firms that are larger, older, and less volatile will increase more during credit expansions and decline less during credit contractions, since they benefit from lower borrowing costs and more external financing options consistently through credit cycles.

2.5.3.2 Alternative Shock Identifications

We have established the main results of state-dependent heterogeneous responses of firm investment to credit supply shocks extracted from the benchmark identification. In this section, I will show that the results are invariant to credit supply shocks extracted from alternative identifications using either alternative credit data or alternative sign restriction choices.

First, I identify the credit supply shock employing alternative credit volume and price data. In the first variation, I use only corporate bonds in the nonfinancial corporate business sector as the credit volume measure; in the second variation, I use [Gilchrist and Zakrajsek \(2012a\)](#) credit spread as the credit price measure. Second, I employ an alternative identification strategy by introducing a price level index in the benchmark identification. As argued by [Mian et al. \(2017\)](#), in an open economy, a credit supply shock would shift out the aggregate supply, and therefore, it has a deflationary effect on the nontradable goods sector. For the price level index, I use the services CPI (less energy services) as a proxy for nontradable sector price index following [Mian et al. \(2017\)](#) and additionally, I use the producer price index for robustness check. I add the price level variable into the benchmark VAR model, and impose a negative sign on the price level for a credit expansion, while keeping the sign restrictions on other variables invariant. In sum, I extract four more credit supply shock series based on the benchmark identification by using an alternative credit volume measure, an alternative credit price measure, and using an alternative identification strategy by adding a price level index from two candidates.

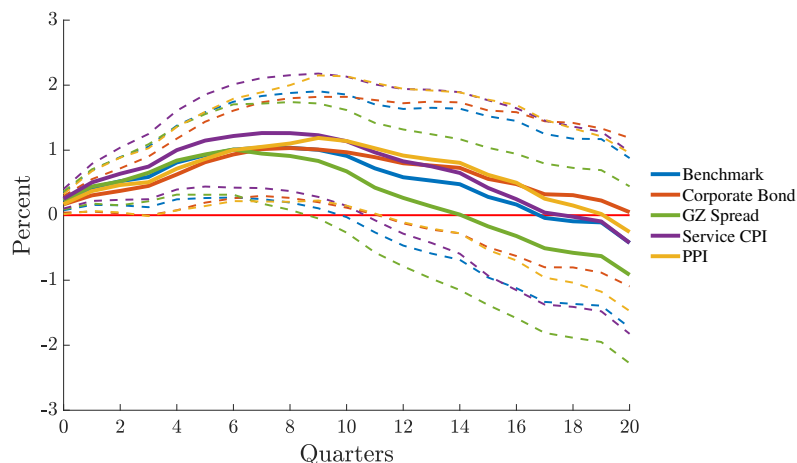
Table 2.7 reports the correlations between the credit supply shock from the benchmark identification and the shock series from the alternative identifications. The correlation is 0.834 between the benchmark credit supply shock and the alternative identification replacing the credit volume with only corporate bonds, 0.904 if I replace the credit price with Gilchrist and Zakrajsek (2012a) spread, 0.798 if I add price index in the alternative identification strategy using services CPI (less energy services), and 0.84 if using producer price index instead. It shows that the credit supply shock extracted from the benchmark identification and the alternatives are highly correlated in the past 45 years, implying that the identification structural model is stable to the variant identifications.

	(1) Corporate Bond	(2) GZ Spread	(3) Services CPI	(4) PPI
Correlation	0.834	0.904	0.798	0.840

Note: This table reports the correlation of the credit supply shocks identified from the benchmark identification and the alternative specifications. Column (1) replaces the credit volume with only nonfinancial corporate bonds. Column (2) replaces the credit price with the Gilchrist and Zakrajsek (2012a) spread. Column (3) adds price level in the benchmark identification using services CPI (less energy services), Column (4) using the producer price index. This table shows that the credit supply shocks from the benchmark and alternative identifications are highly positively correlated.

Table 2.7: Correlation of Credit Supply Shocks Between Identifications

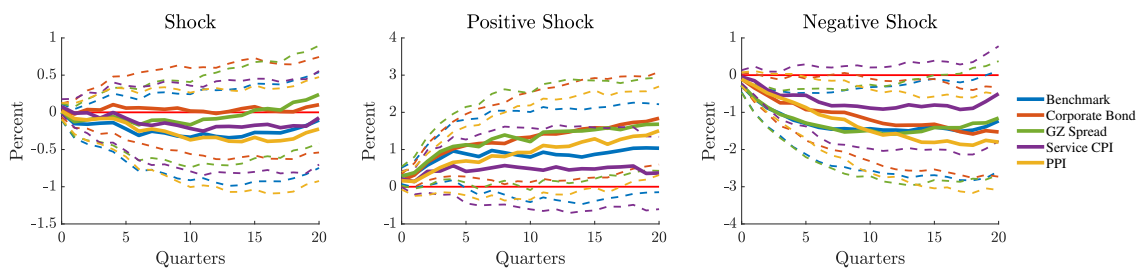
Figure 2.10 shows the average impulse responses of firm investment to the credit supply shocks extracted from various identifications by estimating Equation (2.3). The impulse responses are similar across identification specifications. The credit supply shock has significant and persistent effects on the firm investment. The effects grow gradually in the first ten quarters after the shock, and then decays slowly in the next ten quarters.



Note: This figure displays the average impulse responses of firm investment to credit supply shocks from both the benchmark identification and alternative specifications. The solid lines are impulse responses and the dashed lines are the 90% confidence intervals. The identified credit supply shock has large and persistent impacts on firm investment despite the identification specifications.

Figure 2.10: Responses of Firm Investment to Alternative Credit Supply Shocks

Figure 2.11 shows the state-dependent heterogeneous responses of firm investment conditional on distance-to-default to credit supply shocks from alternative identifications by estimating Equation (2.7). In the left column, the impulse responses of firm investment to credit supply shocks conditional on firm default risk are insignificant in any identifications over the entire sample period. The middle column shows that during a credit expansion, firms with lower default risk will in-



Note: This figure displays the state-dependent impulse responses of firm investment to credit supply shocks from both benchmark identification and alternative specifications conditional on firm default risk. The solid lines are impulse responses and the dashed lines are 90% confidence intervals. This figure shows that the state-dependent heterogeneous responses of firm investment to credit supply shocks conditional on default risk are robust to alternative identifications.

Figure 2.11: State-dependent Responses to Alternative Credit Supply Shocks

vest more relative to average firms for each identification throughout the forecast horizons. The confidence interval band becomes narrower if I use alternative credit volume or credit price data, but becomes wider and loses its significance if I use alternative identification strategies by introducing a price level index. The right column shows that in each alternative identification, low default risk firms will cut their investment less during credit contractions. The only identification that loses significance is the one when I introduce services CPI in the identification.

Overall, identifying the credit supply shocks using either alternative data or alternative identification strategies does not change the main results significantly. Low default risk firms have consistent advantages over average firms through credit cycles. Their investment increases more during credit expansions and declines less during credit contractions. However, the heterogeneous effects of firm default risk on firm investment to credit supply shocks will disappear if we estimate without disentangling credit expansions and contractions.

2.6 Conclusion

In this paper, I identify a series of credit supply shocks in the US since the 1970s and apply the identified shock to firm-level data. I document two main findings. First, the identified credit supply shock has a significant and persistent impact on firm investment. Different from monetary policy shocks, the credit supply shock has medium- and long-term effects on real variables. Second, the heterogeneous responses of firm investment to credit supply shocks conditional on firm character-

istics are state-dependent. Firms with lower default risk, larger size, older age, and smaller volatility will consistently have lower borrowing costs and better access to external financing over credit cycles, and therefore, always have a higher investment relative to average firms. Their investment increases more during credit expansions and declines less during credit contractions. This finding has both empirical and theoretical implications for future research. Empirically, it highlights the possibility of misspecification when investigating the effects of firm characteristics on firm activity to exogenous shocks without disentangling expansionary and contractionary phases. Theoretically, it implies that financial frictions do not systematically amplify or dampen the effects of credit supply shocks. It amplifies the effects of the negative shocks as the financial friction literature emphasizes; however, it dampens the effects of the positive shocks. The state-dependence of heterogeneous effects could not be explained by the existing models that are linear to expansionary and contractionary shocks. A future model featuring credit cycles and heterogeneous financial frictions should take this observation into account.

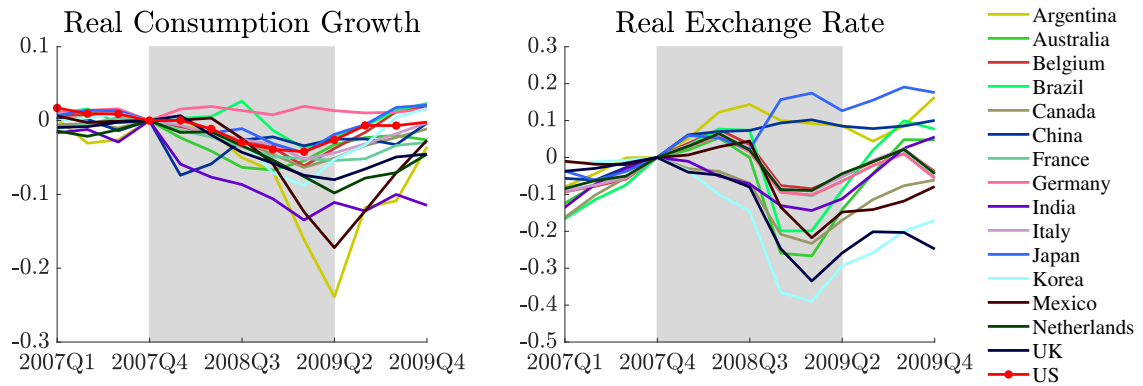
Appendix A: Chapter 1

A.1 Data Construction

1. Consumption: nominal consumption from IMF IFS private sector final consumption expenditure (except China), deflated by CPI from IMF IFS. China consumption is from Oxford Economics via Datastream.
2. GDP: nominal GDP from IMF IFS, and converted to US dollars by spot exchange rate when necessary
3. CPI: consumer price index from IMF IFS (except Argentina). Argentina CPI is from Oxford Economics via Datastream.
4. Exchange rate: nominal national currency per US dollar from IMF IFS, converted to real exchange rate by CPI
5. Bilateral balance of payment vis-à-vis the US: BEA International Transactions Table 1.3
6. The US balance of payment: BEA International Transactions Table 1.1
7. The US net foreign asset: BEA International Investment Position Table 1.2

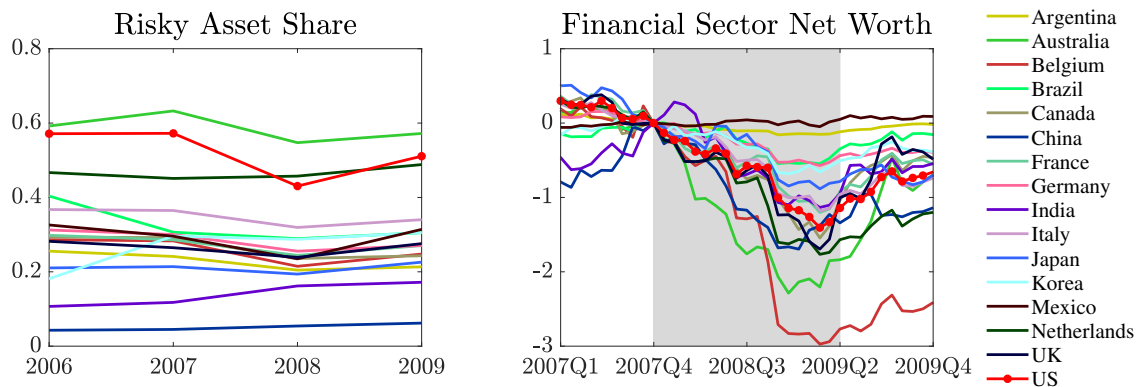
8. Risky asset share: total equity asset holdings (FDI, portfolio equity, and other equity) scaled by total asset net of derivatives from IMF IFS
9. Financial sector value: the market value of public financial firms listed in domestic market existing before 2007 via Datastream, scaled by GDP, including banks, life and non-life insurance, real estate investment & services, real estate investment trusts, financial services, and equity investment instruments following Industry Classification Benchmark jointly created by FTSE and Dow Jones
10. VIX: volatility index from CBOE

A.2 Additional Figures



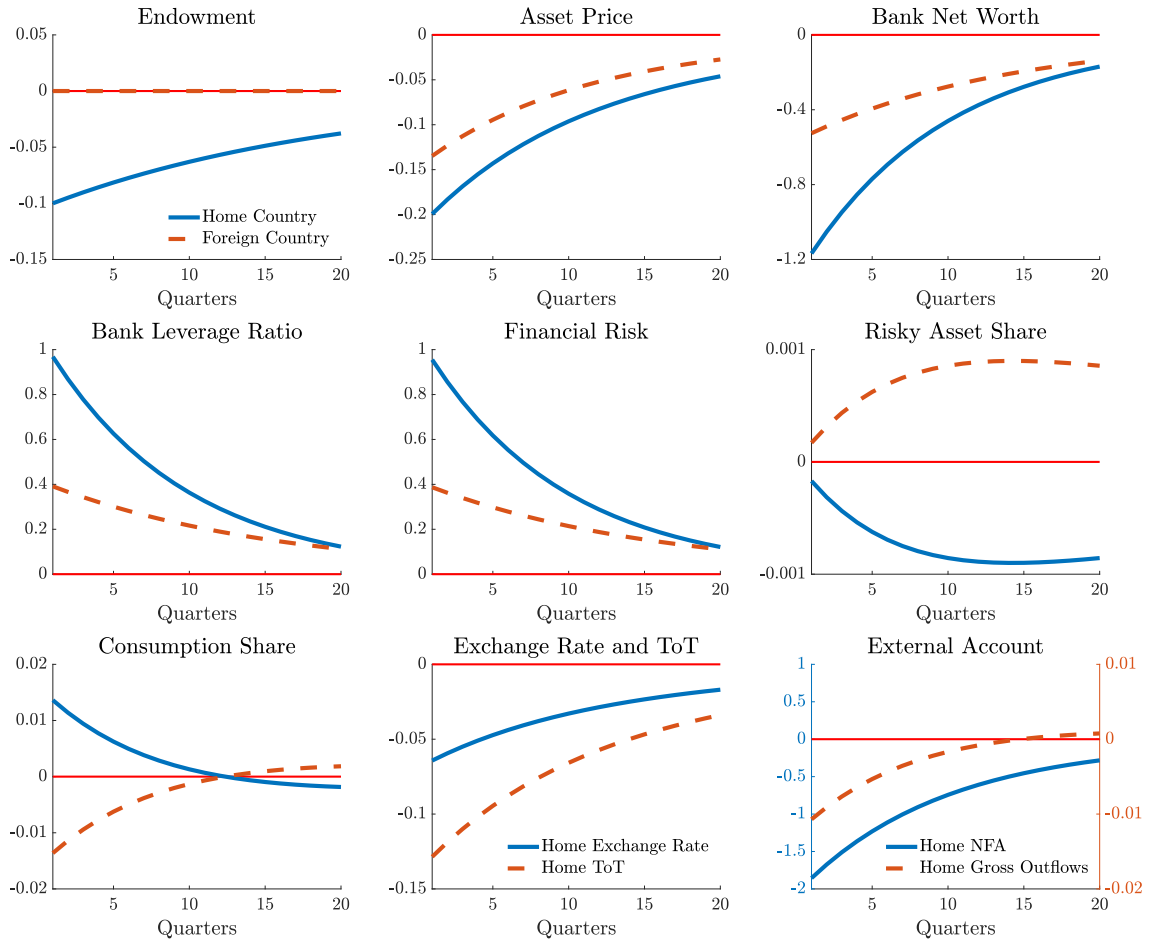
Note: This figure displays the global real consumption growth and exchange rate dynamics at the country level during the GFC. The real consumption growth rates and exchange rates are normalized to zero in 2007Q4. Real consumption growth is year-on-year log-difference. Only Brazil, China, and Germany had a smaller real consumption growth decline than the US during the GFC. The real exchange rates vis-à-vis the US dollar are in log-levels. Only Argentina, China, and Japan have appreciated currencies during GFC.

Figure A.1: Real Consumption and Exchange Rate Dynamics at Country Level



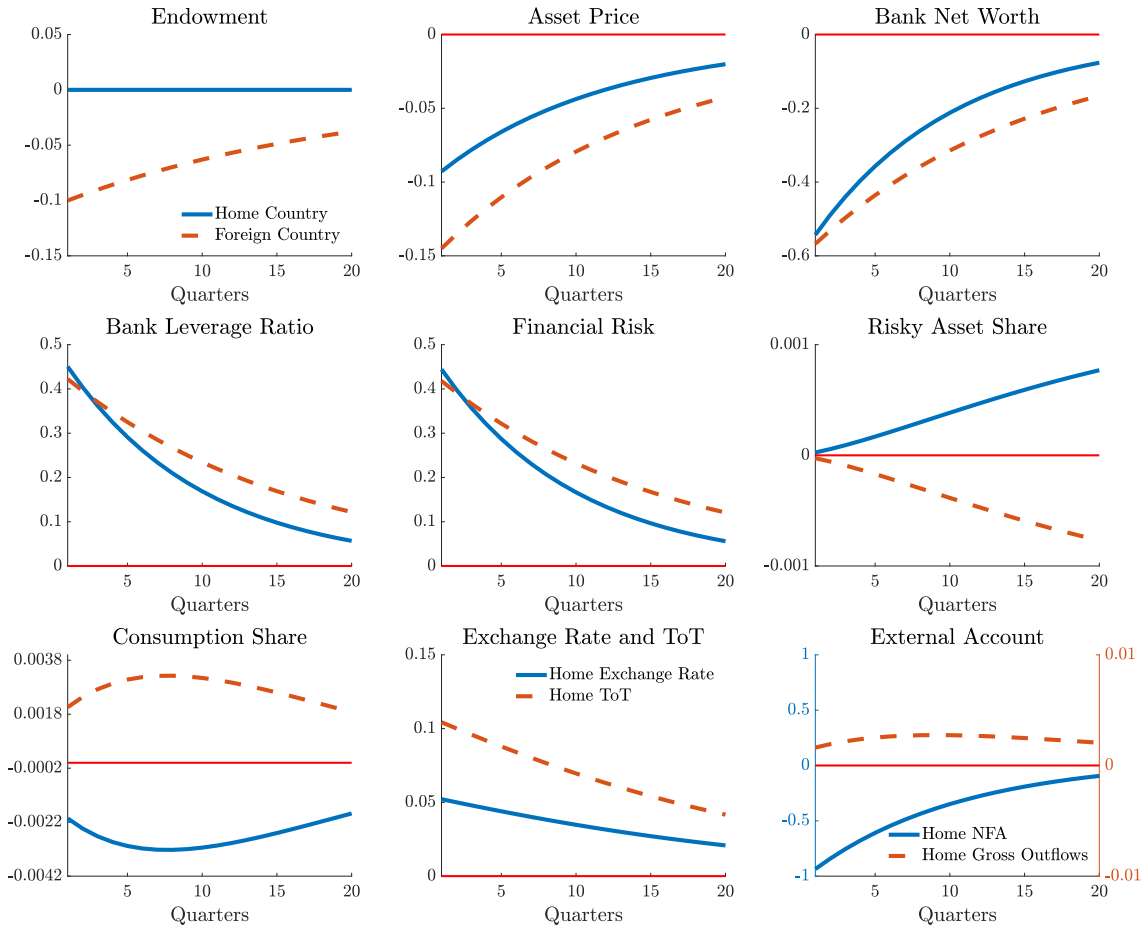
Note: This figure displays the external portfolio and financial sector market value at the country level during the GFC. The risky asset share is calculated as the equity asset holdings (FDI, portfolio, and other equity investments) over the total asset net of derivatives. The financial sector market value is scaled by output, and normalized to zero in 2007M10. The financial sector includes banks, life and non-life insurance, real estate investment & services, real estate investment trusts, financial services, and equity investment instruments. I only include the financial firms that already exist before 2007. The US suffered the largest risky asset share drop, and bore more capital losses in the financial sector than two-thirds of the countries in the sample during the GFC.

Figure A.2: Risky Asset Share and Financial Sector Net Worth at Country Level



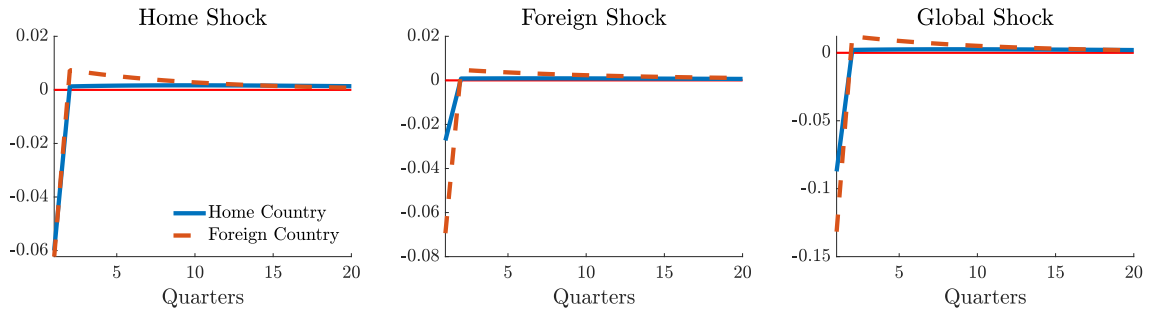
Note: The figure displays the key variables' impulse responses to a 10% Home endowment decline. Blue solid lines are the Home country variables and the orange dashed lines are the Foreign country variables. The figure highlights the deleveraging process in the Home country in response to a Home endowment shock. As a result, the fire sales by the Home country will smooth its consumption, and increase its currency value.

Figure A.3: Impulse Responses to a Home Endowment Shock



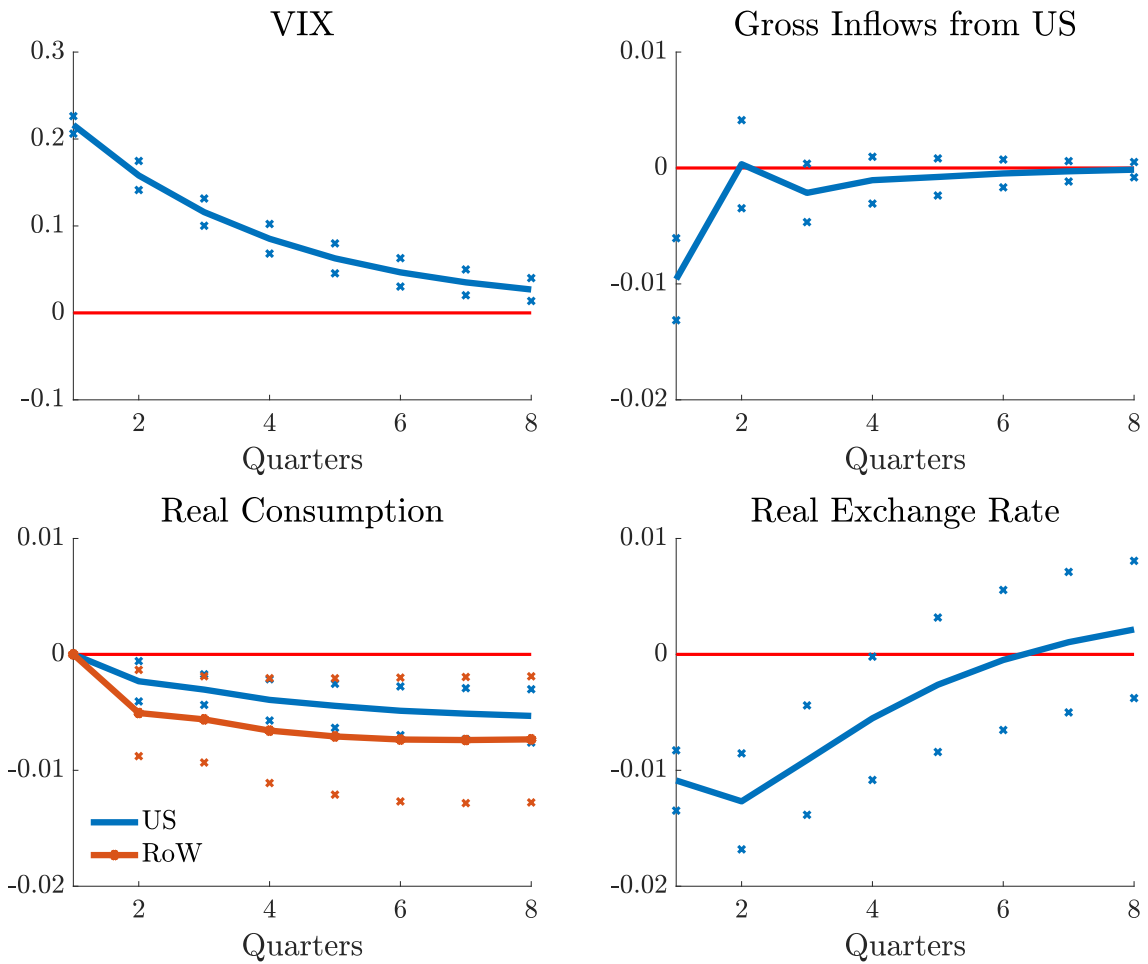
Note: The figure displays the key variables' impulse responses to a 10% Foreign endowment decline. Blue solid lines are the Home country variables and the orange dashed lines are the Foreign country variables. Unlike the impulse responses to a global or Home endowment shock, Foreign banks will suffer heavier capital losses and fire sell their risky asset holdings in response to a negative Foreign endowment shock. The relative consumption in the Foreign country increases and the Home currency depreciates.

Figure A.4: Impulse Responses to a Foreign Endowment Shock



Note: This figure displays the impulse responses of real consumption growth in the Home and Foreign country to exogenous endowment shocks in the model. Blue solid lines are the Home country variables and the orange dashed lines are the Foreign country variables. The Foreign country consumption growth declines more than the Home country in response to each endowment shock. This figure shows that the two measures of consumption dynamics, consumption share and consumption growth, predict consistent implications to a Home and global endowment shock, and inconsistent predictions to a Foreign endowment shock since consumption quantity and exchange rate dynamics move in opposite directions in this scenario. However, we mainly focus on the first two scenarios and the main results do not change employing either measure.

Figure A.5: Impulse Responses of Consumption Growth



Note: This figure displays the impulse responses of VIX, the gross capital inflows from the US in foreign countries, the US and foreign countries' real consumption, and the real exchange rates to a positive one standard deviation in VIX in an alternative VAR specification. I order the US and foreign countries' consumption first, and then the VIX, the gross inflows from the US in foreign countries, and the real exchange rate. The ordering follows the idea that "slow-moving" variables first and then "fast-moving" variables. I count the real variables (real consumption) as "slow-moving" variables and the financial variables (VIX, capital inflow and real exchange rate) as "fast-moving". As documented in the literature (Chari et al. (2002)), the real exchange rate is very volatile and I count it as a "fast-moving" variable. The figure implies a capital retrenchment in the US during a crisis, a deeper consumption decline and a currency depreciation in foreign countries, consistent with Figure 1.7 in the main text.

Figure A.6: Impulse Responses to VIX in an Alternative VAR Specification

A.3 Proof of Portfolio Share $\chi = 1 - \alpha$

In this section, I will show that the foreign asset portfolio share $\chi = 1 - \alpha$ in steady state, where α is the domestic consumption bias.

From the Home country households' budget constraint, we have

$$C + D = \Pi + RD$$

$$\begin{aligned} C &= (1 - \sigma)[(R_k - R)\phi + (R_k^* - R_k)\chi\phi + R]N - \xi U + (R - 1)D \\ &= [(R_k - R)\phi + R]N - \sigma[(R_k - R)\phi + R]N - \xi U + (R - 1)D \\ &= [(R_k - R)\phi + R]N - N + (R - 1)D \\ &= [(R_k - R)\phi + R - 1]N + (R - 1)D \\ &= (R_k - R)U + (R - 1)N + (R - 1)D \\ &= (R_k - R)U + (R - 1)U \\ &= (R_k - 1)U \end{aligned}$$

From the equilibrium condition, we have

$$\begin{aligned} \chi &= \frac{Q - U}{\mathcal{E}U^* - U} \\ &= \frac{\frac{p}{P}Y}{R_k - 1} - \frac{C}{R_k - 1} \\ &= \frac{P^*}{P} \frac{C^*}{R_k^* - 1} - \frac{C}{R_k - 1} \\ &= \frac{\frac{p}{P}Y - C}{\frac{P^*}{P}C^* - C} \end{aligned}$$

we know

$$\begin{aligned}
Y &= C^H + C^{*H} \\
C^H &= C \left(\frac{\alpha\tau}{1-\alpha} \cdot T o T \right)^{1-\alpha} \\
C^{*H} &= C^* \left(\frac{\alpha}{1-\alpha} \cdot \frac{1}{T o T} \right)^{-\alpha} \\
\frac{p}{P} &= \frac{\left(\frac{1-\alpha}{\tau} \right)^{1-\alpha} \alpha^\alpha}{T o T^{1-\alpha}} \\
\frac{P^*}{P} &= T o T^{2\alpha-1} \tau^{\alpha-1}
\end{aligned}$$

plug in the equation above to the portfolio equation

$$\begin{aligned}
\chi &= \frac{\frac{\left(\frac{1-\alpha}{\tau} \right)^{1-\alpha} \alpha^\alpha}{T o T^{1-\alpha}} (C^H + C^{*H}) - C}{T o T^{2\alpha-1} \tau^{\alpha-1} C^* - C} \\
&= \frac{\frac{\left(\frac{1-\alpha}{\tau} \right)^{1-\alpha} \alpha^\alpha}{T o T^{1-\alpha}} \left(C \left(\frac{\alpha\tau}{1-\alpha} \cdot T o T \right)^{1-\alpha} + C^* \left(\frac{\alpha}{1-\alpha} \cdot \frac{1}{T o T} \right)^{-\alpha} \right) - C}{T o T^{2\alpha-1} \tau^{\alpha-1} C^* - C} \\
&= \frac{(1-\alpha) T o T^{2\alpha-1} \tau^{\alpha-1} C^* - (1-\alpha) C}{T o T^{2\alpha-1} \tau^{\alpha-1} C^* - C} \\
&= 1 - \alpha
\end{aligned}$$

A.4 Proof of Equation (1.10)

In this section, I provide the proof for Equation (1.10). The Home and Foreign country budget constraints denoted in Home currency are

$$C_t + U_t = R_{kt}(1 - \chi_{t-1})U_{t-1} + \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}R_{kt}^*\chi_{t-1}U_{t-1}$$

$$\mathcal{E}_t C_t^* + \mathcal{E}_t U_t^* = \mathcal{E}_t R_{kt}^*(1 - \chi_{t-1}^*)U_{t-1}^* + R_{kt}\mathcal{E}_{t-1}\chi_{t-1}^*U_{t-1}^*$$

Subtract the two country budget constraints, we have

$$\begin{aligned} & C_t - \mathcal{E}_t C_t^* \\ &= -U_t + \mathcal{E}_t U_t^* + R_{kt}(1 - \chi_{t-1})U_{t-1} - \mathcal{E}_t R_{kt}^*(1 - \chi_{t-1}^*)U_{t-1}^* + \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}R_{kt}^*\chi_{t-1}U_{t-1} - R_{kt}\mathcal{E}_{t-1}\chi_{t-1}^*U_{t-1}^* \\ &= -\underbrace{(\chi_t U_t - \mathcal{E}_t \chi_t^* U_t^*)}_{\text{NFA}_t} + \underbrace{(R_{kt}(1 - \chi_{t-1})U_{t-1} - (1 - \chi_t)U_t)}_{R_{kt}\mathcal{W}_{t-1} - \mathcal{W}_t} \\ &\quad - \mathcal{E}_t \underbrace{(R_{kt}^*(1 - \chi_{t-1}^*)U_{t-1}^* - (1 - \chi_t^*)U_t^*)}_{R_{kt}^*\mathcal{W}_{t-1}^* - \mathcal{W}_t^*} + \underbrace{\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}R_{kt}^*\chi_{t-1}U_{t-1} - R_{kt}\mathcal{E}_{t-1}\chi_{t-1}^*U_{t-1}^*\right)}_{\mathcal{R}_t \text{NFA}_{t-1} = \text{NFA}_{t-1} + \text{VA}_t} \end{aligned}$$

The Home country net foreign asset position is defined as the difference between foreign asset and foreign liability in the Home country:

$$\text{NFA}_t = \chi_t U_t - \mathcal{E}_t \chi_t^* U_t^*$$

From [Gourinchas and Rey \(2007b\)](#),

$$\begin{aligned}\text{NFA}_t &= \mathcal{R}_t \text{NFA}_{t-1} + \text{NX}_t \\ &= \text{NFA}_{t-1} + \text{VA}_t + \text{NX}_t\end{aligned}$$

where \mathcal{R}_t is the gross returns on NFA from $t - 1$ to t , and VA_t is the valuation gain on NFA. Also,

$$\mathcal{R}_t \text{NFA}_{t-1} = R_t^A \text{FA}_{t-1} - R_t^L \text{FL}_{t-1}$$

where R_t^A and R_t^L are gross returns on foreign asset FA_t and foreign liabilities FL_t .

In the model,

$$R_t^A = \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} R_{kt}^*, \quad R_t^L = R_{kt}$$

$$\text{FA}_{t-1} = \chi_{t-1} U_{t-1}, \quad \text{FL}_{t-1} = \mathcal{E}_{t-1} \chi_{t-1}^* U_{t-1}^*$$

the relative consumption equation can be simplified into

$$\begin{aligned}C_t - \mathcal{E}_t C_t^* &= -\Delta \text{NFA}_t + \text{VA}_t + \underbrace{(R_{kt} \mathcal{W}_{t-1} - \mathcal{W}_t)}_{\tilde{C}_t} - \mathcal{E}_t \underbrace{(R_{kt}^* A_{t-1}^* - A_t^*)}_{\tilde{C}_t^*} \\ &= -\text{NX}_t + \tilde{C}_t - \mathcal{E}_t \tilde{C}_t^*\end{aligned}$$

Appendix B: Chapter 2

B.1 Data Construction

B.1.1 Aggregate Data

1. GDP: nominal GDP from BEA NIPA Table 1.1.5, deflated by gross domestic product implicit price deflator (FRED: GDPDEF)
2. Consumption: the sum of personal consumption expenditures on nondurable goods and services from BEA NIPA Table 1.1.5, deflated by nondurable goods implicit price deflator (FRED: DNDGRD3Q086SBEA) and services implicit price deflator (FRED: DSERRD3Q086SBEA), respectively
3. Investment: gross private domestic investment from BEA NIPA Table 1.1.5, deflated by gross private domestic investment implicit price deflator (FRED: A006RD3Q086SBEA)
4. Unemployment rate: end of quarter unemployment rate from BLS (FRED: UNRATE)
5. Productivity: utilization-adjusted TFP from [Fernald \(2014\)](#), converted to log-levels

6. Housing price: end of quarter real housing price from [Shiller \(2015\)](#)
7. Nonfinancial corporate business credit: nonfinancial corporate business debt securities (FL104122005) plus loans (FL104123005) minus mortgages (FL103165005) from US Financial Accounts Table L.103, deflated by CPI (FRED: CPI-AUCSL)
8. Excess bond premium: originally constructed by [Gilchrist and Zakrajsek \(2012a\)](#) and updated by [Favara et al. \(2016\)](#)
9. CPI: end of quarter consumer price index for all urban consumers (FRED: CPIAUCSL)
10. Nontradable sector price index: end of quarter consumer price index for all urban consumers: services less energy services in US city average (FRED: CUUR0000SASLE)
11. PPI: end of quarter producer price index of all commodities (FRED: PPIACO)
12. Nonfarm business sector implicit price deflator: quarterly (FRED: IPDNBS)
13. Federal funds rate: end of quarter effective federal funds rate (FRED: FED-FUNDS)
14. 1-Year treasury constant maturity rate: daily (FRED: DGS1)

B.1.2 Firm-level Data

This subsection describes the construction of firm-level variables used in the empirical analysis of the paper, based on quarterly Compustat data. The definition of the variables and sample selection process follow standard practices in the literature (see, for example, [Clementi and Palazzo \(2019\)](#); [Eisfeldt and Rampini \(2006\)](#); [Gomes \(2001\)](#); [Jeenas \(2018\)](#); [Ottonello and Winberry \(2020\)](#)).

- **Variables:**

1. Real total assets: total assets (ATQ) deflated by nonfarm business sector implicit price deflator
2. Real sales growth: quarter-on-quarter log differences in sales (SALEQ) deflated by nonfarm business sector implicit price deflator
3. Distance-to-default ([Gilchrist and Zakrajsek \(2012a\)](#); [Ottonello and Winberry \(2020\)](#)):

$$dd = \frac{\ln(V/D) + (\mu_V - 0.5\sigma_V^2)}{\sigma_V}$$

where V is the total value of the firm, μ_V the annual expected return on V , σ_V the annual volatility of the firm's value, and D the firm's total debt. The face value of debt D is defined as the sum of the firm's short-term debt and one half of long-term debt following [Gilchrist and Zakrajsek \(2012a\)](#). To estimate the firm's value V , I follow an iterative procedure:

- (a) Set an initial value for the firm value equal to the sum of firm debt and equity, $V = E + D$, where E is measured as the firm's stock price times the number of shares from CRSP and D is the sum of the firm's short-term debt and one half of long-term debt following [Gilchrist and Zakrajsek \(2012a\)](#).
- (b) Estimate the mean and variance of return on firm value over a 250-day moving window. The return on firm value is measured as the daily log differences of firm value $\Delta \log V$.
- (c) Obtain a new estimate of V for every day of the 250-day moving window from the Black-Scholes-Merton option-pricing equation $E = V\Phi(\delta_1) - e^{-rT}D\Phi(\delta_2)$, where $\delta_1 = \frac{\ln(V/D) + (r + 0.5\sigma_V^2)T}{\sigma_V\sqrt{T}}$, and $\delta_2 = \delta_1 - \sigma_V\sqrt{T}$. The forecast horizon is assumed to be one year ($T=1$) and thus r is the daily one-year constant maturity treasury-yield.
- (d) Iterate on steps (b) and (c) until the firm value converges.

4. Size ([Gertler and Gilchrist \(1994\)](#)):

$$\log\left(\sum_{q=0}^{39} \text{Real Sales}_{t-q}/40\right)$$

5. Age ([Haltiwanger et al. \(2013\)](#)): young firms ($< 10y$), or mature firms ($\geq 10y$). Firm incorporation year is extracted from Datastream (WC18273 – Date of Incorporation).

6. Volatility ([Ottonello and Winberry \(2020\)](#)):

$$\text{std}\left(\sum_{q=0}^{39} \Delta_{\text{yoy}} \log(\text{Real Sales})_{t-q}\right)$$

7. Leverage ratio:

$$\frac{\text{Total Debt}}{\text{Total Asset}} = \frac{\text{DLCQ} + \text{DLTTQ}}{\text{ATQ}}$$

8. Liquidity ratio:

$$\frac{\text{Liquid Asset}}{\text{Total Asset}} = \frac{\text{CHEQ}}{\text{ATQ}}$$

9. Sectoral dummies: (i) agriculture, forestry, and fishing: SIC < 999; (ii) mining: SIC ∈ [1000; 1499]; (iii) construction: SIC ∈ [1500; 1799]; (iv) manufacturing: SIC ∈ [2000; 3999]; (v) transportation, communications, electric, gas, and sanitary services: SIC ∈ [4000; 4999]; (vi) wholesale trade: SIC ∈ [5000; 5199]; (vii) retail trade SIC ∈ [5200; 5999]; (viii) services: SIC ∈ [7000; 8999]

• **Sample Selection:** the empirical analysis excludes the following observations

1. Firms in finance, insurance, and real estate sectors (SIC ∈ [6000-6799]), utilities (SIC ∈ [4900-4999]), and nonclassifiable establishment (SIC ∈ [9900-9999])
2. Firms not incorporated in the USA
3. Firm-quarter observations that satisfy one of the following conditions, aimed at excluding outlier observations (also the subsequent quarter observations):
 - Negative capital, assets, or sales
 - Acquisitions larger than 5% of total assets
 - Investment rate in the top and bottom 0.5% of the distribution
 - Net current assets as a share of total assets higher than 10 or below -10

- Leverage higher than 10 or negative
- Quarterly real sales growth above 2 or below -2
- Liquid assets as a share of total assets above 2 or below 0
- Firm capital observations less than 40 quarters

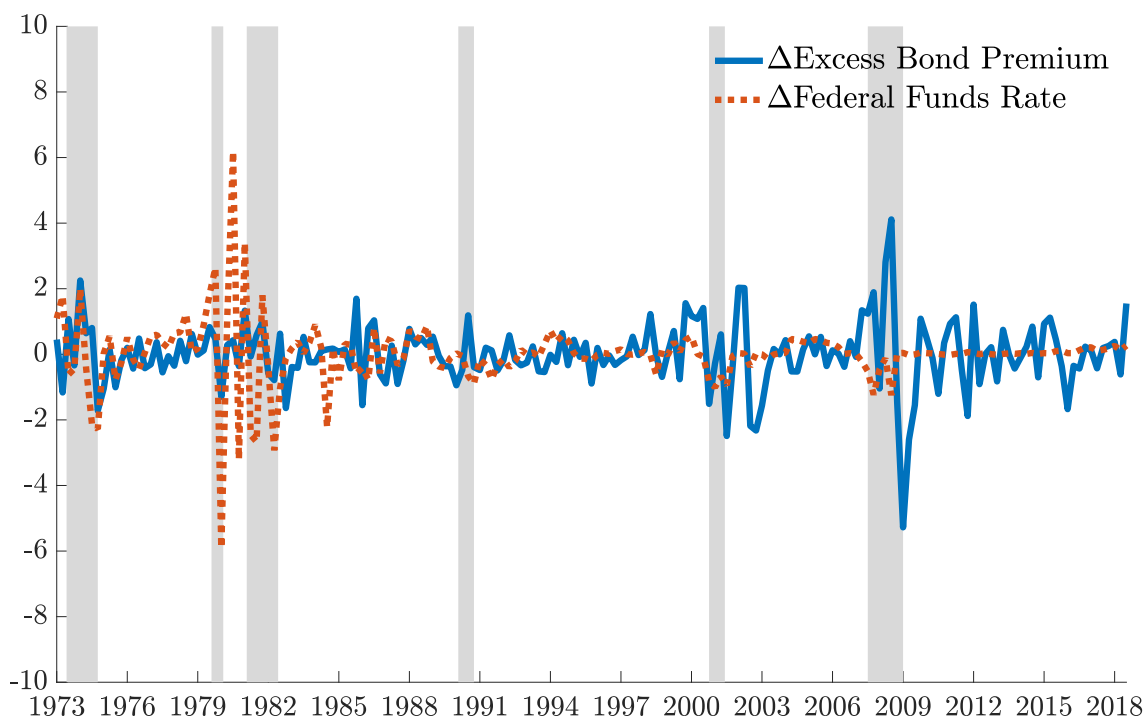
	Dist. to Default	Age	Volatility	Size	Total Assets	$\Delta \log k_{it}$
Dist. to Default	1.000					
Age	0.231 (0.000)	1.000				
Volatility	-0.202 (0.000)	-0.208 (0.000)	1.000			
Size	0.145 (0.000)	0.256 (0.000)	-0.103 (0.000)	1.000		
Total Assets	0.149 (0.000)	0.236 (0.000)	-0.092 (0.000)	0.820 (0.000)	1.000	
$\Delta \log k_{it}$	0.125 (0.000)	-0.046 (0.000)	-0.014 (0.000)	-0.007 (0.000)	0.002 (0.357)	1.000

Note: This table reports correlation matrix of firm-level variables across-sections before winsorization and standardization. p -values are in parentheses.

Table B.1: Correlation Matrix of Firm-level Data

B.2 Empirical Evidence

B.2.1 VAR Identification



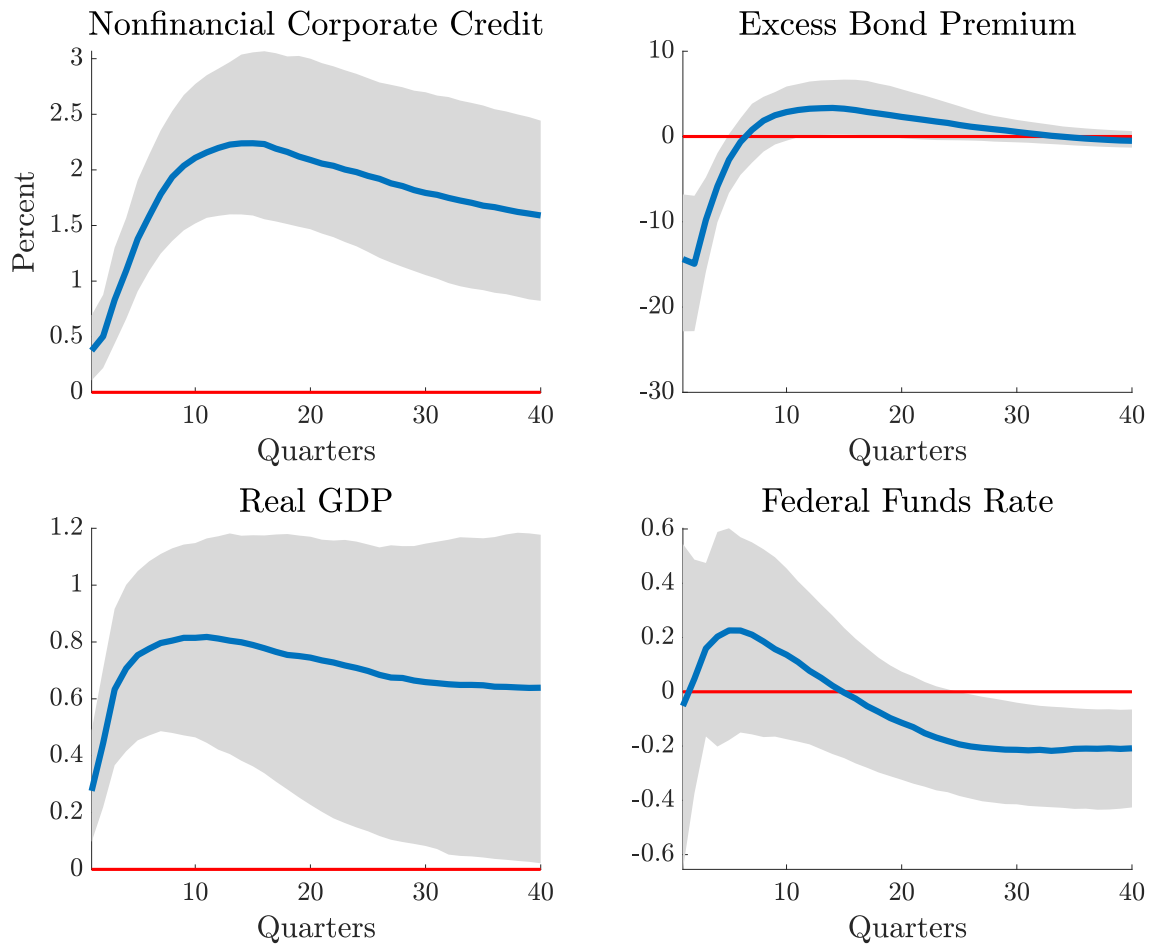
Note: This figure displays the quarter-on-quarter changes of the excess bond premium and the federal funds rate. The changes are standardized, and the units become standard deviations. The shaded areas are the NBER recessions.

Figure B.1: Excess Bond Premium and Federal Funds Rate

	MP(t-4)	MP(t-3)	MP(t-2)	MP(t-1)	MP(t)	MP(t+1)	MP(t+2)	MP(t+3)	MP(t+4)
EBP(t)	0.2944	0.2703	0.234	0.1803	0.1289	0.0481	-0.0148	-0.0468	-0.0864
	(0.0001)	(0.0003)	(0.0018)	(0.0166)	(0.0882)	(0.5261)	(0.8451)	(0.5371)	(0.254)

Note: This table reports the moving correlation between excess bond premium and the federal funds rate from 1973Q1 to 2018Q4. The correlation between leading federal funds rate and the excess bond premium is positive, and the correlation between lagged federal fund rate and excess bond premium becomes negative. The overall trend of moving correlation is declining as the federal funds rate moves from leading to lagging.

Table B.2: Correlation Between Excess Bond Premium and Federal Funds Rate



Note: This figure displays the impulse responses of benchmark variables in the VAR. A credit expansion is assumed to induce an increase on both credit volume and output, a decline on credit price. The sign restriction on the federal funds rate is left open. The solid line is the median impulse response and the shaded area is the 68% confidence interval. This figure shows that the monetary policy rate will endogenously rise to a credit expansion though not significantly.

Figure B.2: Impulse Responses to Credit Supply Shocks (Agnostic on Federal Funds Rate)

B.2.2 Extra Empirical Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
credit shock	0.236** (0.091)	0.212** (0.082)	0.261*** (0.076)	0.151* (0.079)	0.213** (0.082)	0.234* (0.126)	0.209** (0.094)
dd × credit shock			-0.009 (0.064)				-0.025 (0.056)
size × credit shock				0.051 (0.042)			0.078* (0.044)
volatility × credit shock					-0.044 (0.051)		0.010 (0.054)
age × credit shock						-0.052 (0.099)	-0.032 (0.073)
Observations	251641	251641	177123	251641	251641	251641	177123
R^2	0.063	0.074	0.104	0.081	0.075	0.075	0.111
Firm Controls	no	yes	yes	yes	yes	yes	yes
Quarter Sector FE	yes	yes	yes	yes	yes	yes	yes
Two-way Clustering	yes	yes	yes	yes	yes	yes	yes

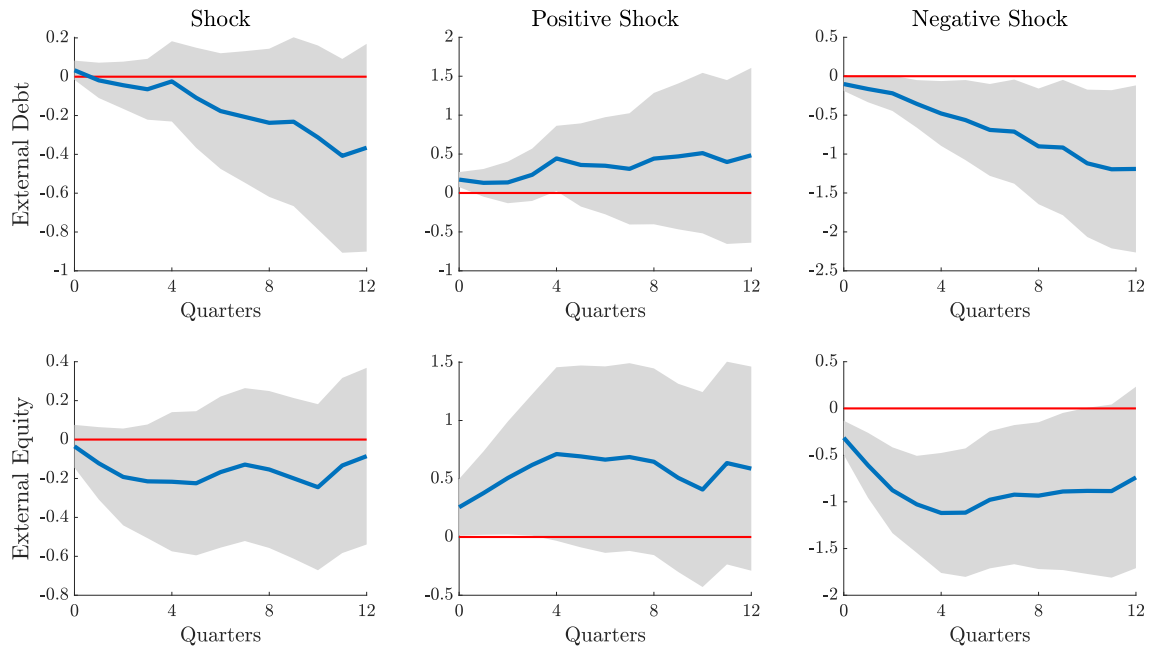
Note: This table reports the average responses of firm investment to the identified credit supply shock considering firm individual characteristics. Firm distance-to-default, size, and volatility is winsorized and standardized. Firm age is a dummy variable. The standard errors are two-way clustered at the firm and quarter levels and are shown in parentheses. This table shows that the identified credit supply shock has a significant impact on firm investment.

Table B.3: Average Responses of Firm Investment to Credit Supply Shocks

	(1)	(2)	(3)	(4)	(5)	(6)
dd × pos credit shock	0.301** (0.131)	0.290** (0.132)	0.264* (0.151)	0.301* (0.159)	0.305** (0.132)	0.308* (0.158)
dd × neg credit shock	-0.272** (0.113)	-0.281** (0.111)	-0.203* (0.121)	-0.319** (0.133)	-0.269** (0.111)	-0.316** (0.133)
leverage × pos credit shock				0.063 (0.118)		0.047 (0.119)
leverage × neg credit shock				-0.156 (0.129)		-0.176 (0.130)
liquidity × pos credit shock					-0.099 (0.115)	-0.089 (0.114)
liquidity × neg credit shock					-0.042 (0.107)	-0.073 (0.104)
Observations	221035	221035	191338	221035	221035	221035
R^2	0.104	0.104	0.112	0.105	0.105	0.106
Firm Controls	yes	yes	yes	yes	yes	yes
Additional Controls	CPI	Unrate	VIX	GDP	GDP	GDP
Time Sector FE	yes	yes	yes	yes	yes	yes
Two-way Clustering	yes	yes	yes	yes	yes	yes

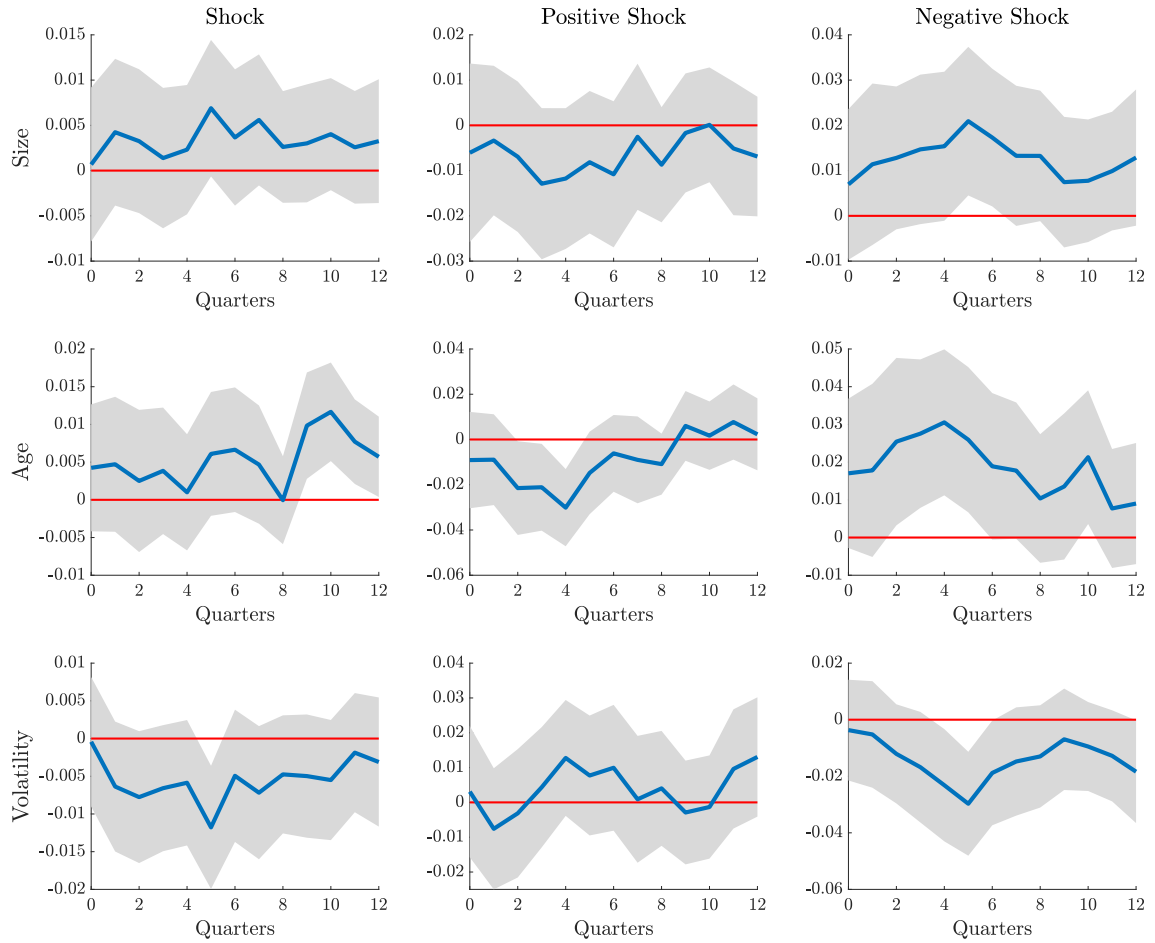
Note: This table reports the state-dependent heterogeneous responses of firm investment to credit supply shocks conditional on firm default risk controlling for alternative cyclical sensitivity and financial positions. Column (1) uses the intersection term between firm distance-to-default and CPI for cyclical sensitivity control, Column (2) replacing CPI with unemployment rate, and Column (3) replacing CPI with VIX. Columns (4) to (6) introduce firm financial positions as additional control variables. The standard errors are two-way clustered at the firm and quarter levels and are shown in parentheses. This table shows that the state-dependent heterogeneous responses conditional on firm default risk are invariant to these variations.

Table B.4: State-dependent Responses to Credit Supply Shocks



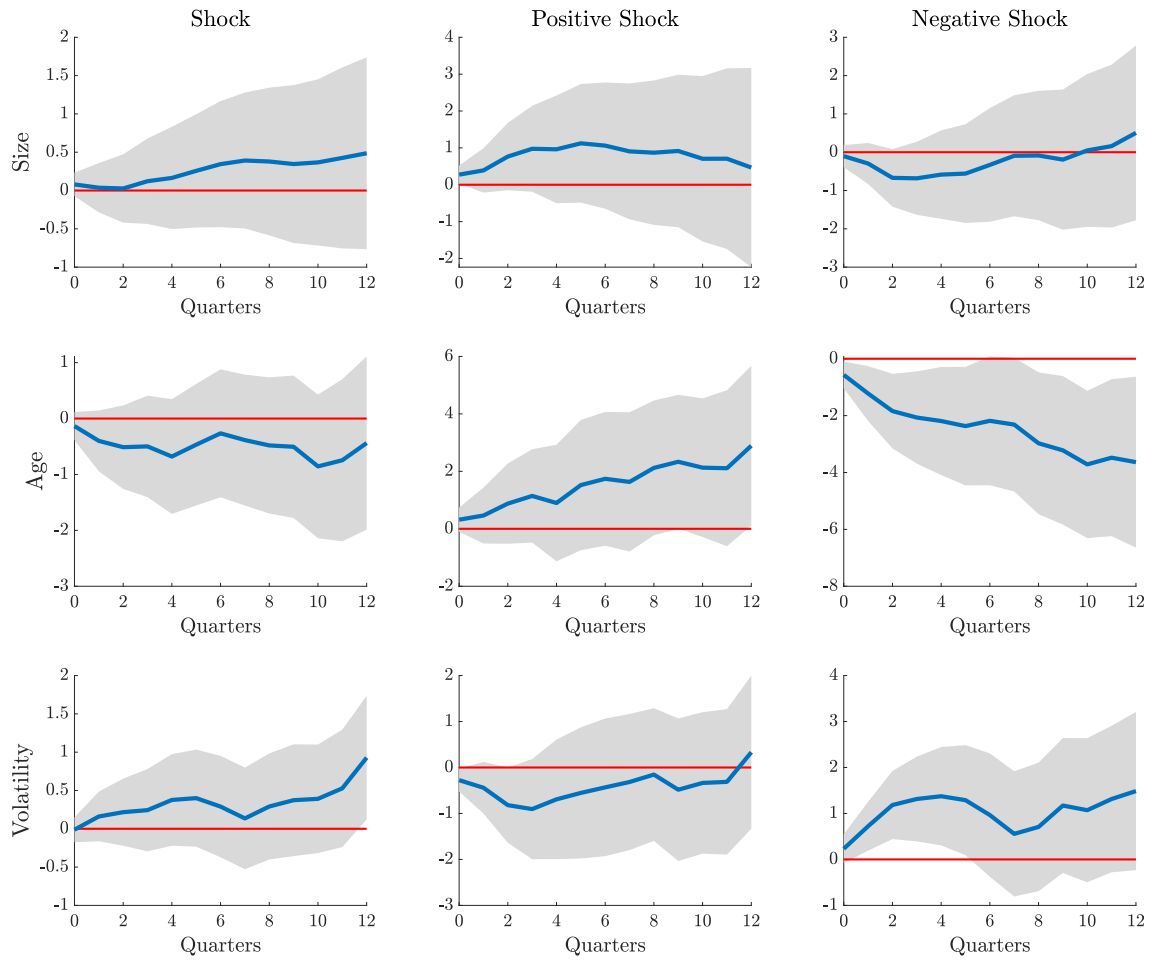
Note: This figure displays the state-dependent heterogeneous responses of firm external debt and equity to credit supply shocks conditional on firm distance-to-default. The solid line is the median impulse response and the shaded area is the 90% confidence interval. The left column displays the responses without disentangling credit expansions and contractions for comparison. This figure shows that low default risk firm have consistently better external resources in both debt instruments and equities in both credit expansions and contractions.

Figure B.3: State-dependent Responses of Firm External Debt and Equity



Note: This figure displays the state-dependent heterogeneous responses of firm borrowing cost to credit supply shocks conditional on firm characteristics. The borrowing cost is measured as average interest payment scaled by lagged total assets. The solid line is the median impulse response and the shaded area is the 90% confidence interval. The left column displays the responses without disentangling credit expansions and contractions for comparison. This figure shows that larger, older, and less volatile firms have consistently lower borrowing costs in both credit expansions and contractions.

Figure B.4: State-dependent Responses of Firm Borrowing Cost



Note: This figure displays the state-dependent heterogeneous responses of firm external financing to credit supply shocks conditional on firm characteristics. The external financing is defined as the sum of cumulative changes of total debts and equities scaled by lagged total assets. The solid line is the median impulse response and the shaded area is the 90% confidence interval. The left column displays the responses without disentangling credit expansions and contractions for comparison. This figure shows that larger, older, and less volatile firms have consistently better access to external financing in both credit expansions and contractions.

Figure B.5: State-dependent Responses of Firm External Financing

B.2.3 The Role of Firm Leverage and Liquidity

In this subsection, I study the role of firm financial positions (leverage and liquidity) in determining firm investment responses to credit supply shocks. First, I will show that firms with higher leverage and lower liquidity ratios will be less responsive to credit supply shocks, and the heterogeneous effects mainly come from the within-firm variation component. Second, I will show that the heterogeneous effects due to firm leverage and liquidity do not show state-dependence to credit supply shocks.

I decompose firm financial positions into a permanent component and a within-firm variation component, similar to Equation (2.5) in the main text. The specification is shown below

$$\Delta \log k_{it} = \alpha_i + \alpha_{st} + \beta \mathbb{E}[x_{it}] \times \varepsilon_t + \gamma \underbrace{(x_{it-1} - \mathbb{E}[x_{it}])}_{\mathbf{x}_{it-1}} \times \varepsilon_t + \Gamma Z_{it-1} + e_{it}$$

where x_{it-1} is winsorized and standardized firm leverage or liquidity ratios. $\mathbb{E}[x_{it}]$ is the mean of an individual firm's financial position during the sample period, and \mathbf{x}_{it-1} is the demeaned firm financial position over time. Other settings are the same as in Equation (2.5).

Table B.5 presents the estimation results. First, the first and third row shows that the permanent differences of firm leverage and liquidity across firms barely affect firm investment in response to credit supply shocks. In contrast, the heterogeneous responses of firm investment mainly come from the within-firm variations as shown

in the second and fourth row. Second, firms with higher leverage ratios or less liquid asset holdings than usual will be less responsive to credit supply shocks. In response to one unit of credit supply shocks, the investment of firms with one std higher leverage ratio than they typically are will be 0.088% less responsive; the effect would be 0.069% for firms with one std less liquid asset holdings than usual.

	(1)	(2)	(3)
leverage (firm mean) \times credit shock	-0.024 (0.036)		-0.039 (0.026)
leverage (firm variation) \times credit shock	-0.088*** (0.027)		-0.076*** (0.023)
liquidity (firm mean) \times credit shock		-0.031 (0.059)	-0.045 (0.055)
liquidity (firm variation) \times credit shock		0.069* (0.040)	0.050 (0.038)
Observations	316642	316642	316642
R^2	0.085	0.084	0.087
Firm Controls	yes	yes	yes
Time Sector FE	yes	yes	yes
Two-way Clustering	yes	yes	yes

Note: This table reports the heterogeneous responses of firm investment to credit supply shocks by decomposing the firm financial positions into a permanent component and a within-firm variation component. The explanatory variables are winsorized and standardized. The standard errors are two-way clustered at the firm and quarter levels and are shown in parentheses. This table shows that firms with a higher leverage ratio or less liquid asset holdings than they typically are will be less responsive to credit supply shocks, and the heterogeneity mainly comes from the within-firm variation component.

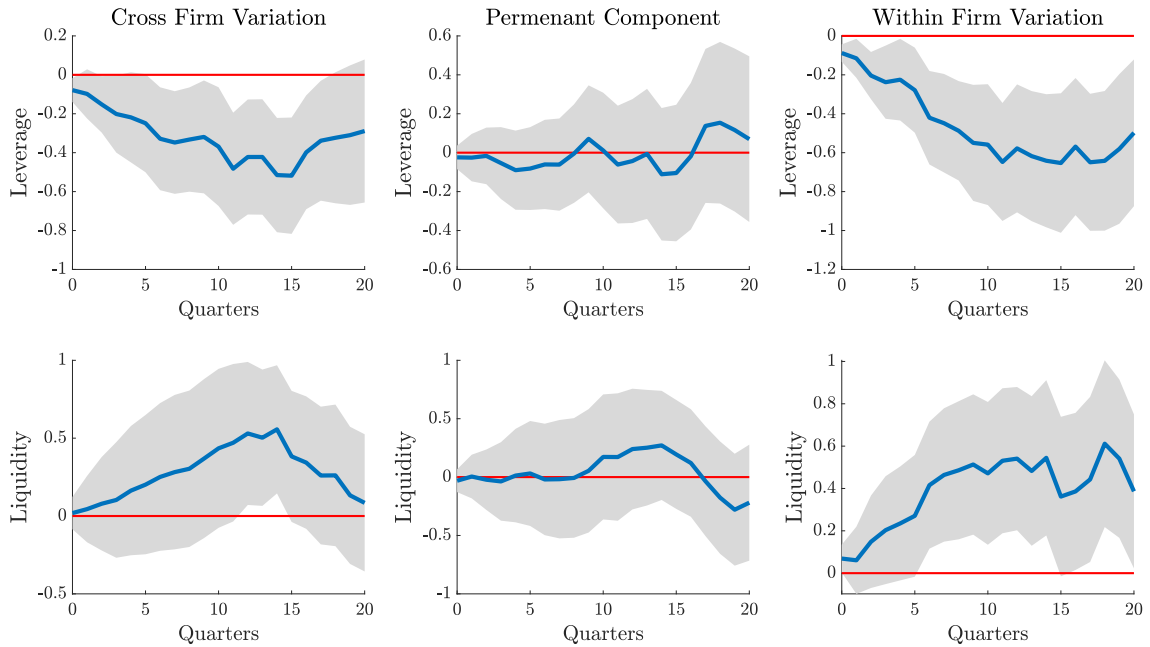
Table B.5: Decomposed Heterogeneous Responses to Credit Supply Shocks

The phenomenon is more obvious in the dynamic responses estimated in the specification below

$$\Delta \log k_{it+h} = \alpha_{ih} + \alpha_{sth} + \beta_h \mathbb{E}[x_{it}] \times \varepsilon_t + \gamma_h \mathbf{x}_{it-1} \times \varepsilon_t + \Gamma_h Z_{it-1} + e_{ith}$$

where h denotes the forecast horizons and other specification details are invariant to the static estimation.

The impulse responses are shown in Figure B.6. The left column shows the impulse responses without financial position decomposition for comparison. The first column shows that firms with higher leverage or lower liquidity ratios will be less responsive to credit shocks. The differences rise slowly over time and reach the peak three years after the shock. However, the effects are imprecisely estimated with wide confidence intervals. The middle column shows that the permanent component of firm leverage or liquidity ratios barely contributes to the differential firm investment responses. The magnitude is small and insignificant. However, if we move to the right column, we can see that the within-firm variation component, for both leverage and liquidity ratios, has a large and significant impact on differential firm investment



Note: This figure displays the impulse responses of firm investment to credit supply shocks conditional on firm financial positions. The financial position is decomposed into a permanent component and a within-firm variation component. The solid line is the median impulse response and the shaded area is the 90% confidence interval. This figure shows that firms with a higher leverage ratio or less liquid asset holdings than they typically are will be less responsive to credit supply shocks, and the heterogeneity mainly comes from the within-firm variation component.

Figure B.6: Decomposed Dynamic Responses to Credit Supply Shocks

responses. Firms with a higher leverage ratio or less liquid asset holdings than usual will be less responsive to credit supply shocks. The heterogeneous responses of firm investment mainly come from the within-firm variation instead of the permanent firm characteristics. In the medium run, both leverage and liquidity have persistent effects on heterogeneous firm investment responses.

I re-estimate Equation (2.6), replacing the firm distance-to-default with financial positions. The results are shown in Table B.6. The heterogeneous responses of firm investment conditional on firm financial frictions to credit supply shocks do not show significant state-dependence on impact.

	(1)	(2)	(3)
leverage \times pos credit shock	-0.040 (0.071)		-0.065 (0.057)
leverage \times neg credit shock	-0.114 (0.077)		-0.090 (0.062)
liquidity \times pos credit shock		-0.075 (0.114)	-0.096 (0.108)
liquidity \times neg credit shock		0.106 (0.116)	0.078 (0.108)
Observations	316642	316642	316642
R^2	0.085	0.084	0.087
Firm Controls	yes	yes	yes
Time Sector FE	yes	yes	yes
Two-way Clustering	yes	yes	yes

Note: This table reports the state-dependent heterogeneous responses of firm investment conditional on firm financial positions to credit supply shocks. The credit supply shocks are decomposed into positive and negative shocks. Positive credit supply shocks are set to be the original credit shock if it is positive and zero otherwise, analogously to the negative supply shocks. The standard errors are two-way clustered at the firm and quarter levels and are shown in parentheses. This table shows that firm financial positions do not exhibit significant state-dependent heterogeneous effects on firm investment to credit supply shocks.

Table B.6: State-dependent Responses Conditional on Financial Positions

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