Bank deposits, liquidity management and macroeconomy

LUO, KAISHENG

Bank Deposits, Liquidity Management and Macroeconomy

By
Kaisheng Luo

Completed under the Supervision of
Dr Nikos Paltalidis
And
Dr Anamaria Nicolae

A thesis submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy
in the
Department of Economics and Finance
Durham University Business School
Durham University
August 2022

Bank Deposits, Liquidity Management and Macroeconomy

Kaisheng Luo

Abstract

In this thesis, we investigate the role of deposits in bank liquidity management and macroeconomy empirically. The thesis is comprised of three main chapters as follows.

This first chapter investigates how banks managed their liquidity during the COVID-19 pandemic. We evaluate three potential channels banks manage their liquidity: the supply-side through the exercise of market discipline, the demand-side through internal capital markets, and the balance-sheet channel through unused credit commitments and wholesale funding. We provide novel empirical evidence on the absence of market discipline theory and internal capital market theory during the pandemic. Furthermore, it is shown that banks exposed to higher liquidity risk tend to experience larger deposit outflows and increased their exposure in Fed's liquidity facilities during the pandemic.

The second chapter examines the US tri-party repo market operation by investigating the role of dealer's riskiness on the repo volume and rate during the post-crisis period (2010:Q2-2019:Q4) and the starting quarter of the pandemic (2020:Q1). We find the market perception of dealer's risk has negative impact on the reverse repo amount the dealer undertake. In addition, the second chapter investigates the relationship between bank Liquidity Mismatch Index (LMI) and the repo volume and rate banks undertake. We provide empirical evidence on LMI has good explanatory power on both banks' repo volume and rate.

Finally, this chapter investigates the role of heterogeneity in deposit rates on predicting the severity of crisis and output. We show an increase in the heterogeneity has strong predicting power on the future economic downturns. More importantly, it is found an increase in the heterogeneity in deposit rates coupled with a fragile financial condition, leads to a more severe crisis. In addition, we show the changes in effective federal funds rate and deposit rates have significant negative impact on household's consumption and income, and this effect is heterogeneous among households according to balance sheet positions.

This thesis contributes to the ongoing debates on bank liquidity management and the deposits channel of monetary policy transmission. The findings have important policy implications by showing the unique role of bank deposits in bank liquidity management and macroeconomy. Our main findings suggest that policy makers should be aware of the importance of liquidity facilities provided by the Federal Reserve and the repo market, especially during the liquidity stressed periods, as they are playing an essential role in funding bank's liquidity. Moreover, our findings relating to households suggest policy makers should aware that the effects on households' consumption from interest rate changes are heterogeneous among households based on their balance sheet positions.

Table of Contents

List of Tables

List of Figures

Declaration

I declare that no part of this thesis has been submitted elsewhere for any other degree or qualification at this or any other institution. I confirm that it is all my own work except where acknowledgment has been made in the text.

Statement of Copyright

Acknowledgements

First of all, I would like to express my sincerest thankfulness to my supervisors, Dr Nikos Paltalidis and Dr Anamaria Nicolae for their continual guidance and supports during my journey pursuing the degree. They are both always very helpful and willing to share useful and constructive suggestions and comments. I must admit I cannot finish without their assistance.

I would also like to thank Dr Majid Al Sadoon and Prof. Tatiana Damjanovic for providing insightful feedback during my annual reviews, I also acknowledge the valuable comments I received from the 7th IYFS Conference.

Also, words are powerless to express my gratitude to Durham University Business School, especially the Quantitative Research in Financial Economics (QRFE) for the provision of financial support, the organization of seminars on frontier research, and great opportunities of training and workshops, especially during the difficult COVID-19 pandemic period.

In addition, I would like to thank my colleagues and friends in Durham University, for their friendship and collaboration. I appreciate our econometrics workshop, which greatly improved my skills and knowledge in econometrics.

Lastly, I would like to express my thankfulness to my dearest fiancée Violette Bu for her support during this journey as well.

Chapter 1 Introduction

1.1 Introduction

Bank liquidity crises can induce or exacerbate deep recessions. It is widely documented the US banking liquidity event threw the global economy into severe crisis, see Ivashina and Scharfstein (2010) and Lucas and Stokey (2011) for example. The burst of subprime mortgages, preceded by a credit boom in 2007, raised the concerns about the liquidity management of financial institutions. As a result, more consideration is given to liquidity management of banking sector as it is playing an enormous role in financial crisis. On the other hand, bank deposits are the primary and the most stable funding source for banks (Hanson et al., 2015). Also, according to Cecchetti and Schoenholtz (2011), one of the most significant financial risk banks exposed to is liquidity risk. Liquidity risk suggests the chance that depositors will suddenly withdraw their deposits during the stressed periods, which will directly contribute to the failures of banks. In the classical model of Diamond and Dybvig (1983), deposits are considered as liquidity promised through bank liabilities. With an increased in the illiquid bank assets such as loans and loan commitments, banks are vulnerable to bankruptcies and crises during the stressed period. In addition, banks are relied heavily on repo (repurchase agreement) market to meet their short-term liquidity demand. Fed also conducts large amount of repo operation with the aim to inject liquidity to the banking system during the liquidity stressed period. For instance, on 16^{th} September of 2019, Secured Overnight Financing Rate (SOFR) experienced sharp increase from 2.43% to 5.25% as banks tried to fulfill their reserve needs through repo market. In response to the increase in the SOFR, which indicates a shortfall in short-term liquidity, Fed conducts $75 billion overnight repo operation to inject liquidity and the repo market was stabilized gradually (Anbil, Anderson and Senyuz, 2020). However, little attention has been paid to bank liquidity management by investigating the role of deposits.

This thesis extends the literature on the bank liquidity management. The first chapter asks how banks managed their liquidity during the COVID-19 pandemic. By using data from the US, we evaluate three theories through which banks manage their liquidity: market discipline theory, internal capital market theory and bank balance-sheet theory. The first chapter finds during the pandemic: i) the depositors do not discipline banks by asking higher deposit rates from weakly-capitalized banks; ii) Although a positive relationship is captured between deposit growth and loan growth of banks, there is no significant positive relationship between deposit rates and loan growth, suggesting an absence of internal capital market theory; iii) In the midst of the pandemic, weakly-capitalized banks cut back in new lending origination and increase their exposure to Fed's liquidity facilities.

The second chapter of this thesis investigates how the US tri-party repo market before and during the pandemic. We firstly ask whether the risk of dealers, which is proxied by credit default swap data, can affect the volume and the rate of repo the dealers undertake in US tri-party repo market. Then, following Bai, Krishnamurthy and Weymuller (2017), we construct Liquidity Mismatch Index (LMI) as a measurement of bank liquidity condition. The study furthermore investigates the effects of liquidity condition of banks on the volume and the rate of repo the banks undertake. Our results show the market perception of dealer's risk has negative impact on the reverse repo amount the dealer undertake. In addition, LMI has good explanatory power on banks' repo volume and rate during the post-crisis period.

The third chapter aims at revealing the empirical relationship among deposits, credit and macroeconomy. Using the deposit rates data from Ratewatch, we construct heterogeneity in deposit rates at state level and provide novel empirical evidence that the heterogeneity in deposit rates has strong explanatory power on both future output and the severity of two economic downturns. Furthermore, Krishnamurthy and Muir (2017) have shown that the crises are often preceded by unusually high credit growth and a sharp increase in the credit spreads", documented as "FZ" model. Based on "FZ" model, we create "FD" model which shows "an increase in the heterogeneity of deposit rates, coupled with a fragile financial condition leads to a more severe crisis". The third chapter also finds the heterogeneity in deposit rates is on average higher 1-5 quarters prior to crisis, compared to the rest of periods. In addition, we also investigate the effects of deposit rate on household's consumption and salary. This chapter finds an increase in the deposit rates has negative impact on both household's consumption and salary. In addition, this chapter splits households into three different cohorts according to their balance sheet positions following Cloyne, Ferreria and Surico (2020). We find the mortgagor cohort experiences the largest declines when faced with an increase in deposit rate among three cohorts.

Overall, the main findings from the thesis can be summarized as the follows:

- Depositors demand a higher rate from riskier banks, especially during the crises episodes, as a form to discipline the banks (Calomiris and Kahn, 1991; Calomiris, 1999; and Hett and Schmidt, 2017). However, this study finds the absence of market discipline theory and internal capital market theory during the pandemic.
- Banks use deposits as an internal capital market, the increase in deposit rates should base on their internal capital needs (Diamond and Dybvig, 1983, Houston, James, and Markus, 1997 and Aschraft and Campello, 2007). This study finds the internal capital market theory does not exist during the pandemic either.
- Banks create and manage liquidity through loan commitments (Diamond and Dybvig, 1983; Holstrom and Tirole, 1998; and Kashyap, Rajan, and Stein, 2002). The existing literature also suggests during the 2007 financial crisis, banks with high exposure to unused loan commitments cut lending/failed to meet their obligations (Acharya and Mora, 2015). This study finds banks exposed to high unused loan commitments increase their exposures to the liquidity facilities offered by the Federal Reserve.
- US banks rely heavily on repo market for short-term liquidity. The existing literature asks how US repo market behave during the 2008 crisis (Gorton and Metrick,2010, 2012 and Copeland, Martin and Walker, 2014). My study investigates on how the repo market operates during the post-crisis and finds market perception of riskiness plays an important role in determining the amount of repo (and reverse repo) banks undertook.
- Liquidity Mismatch Index (LMI) measures the mismatch between the market liquidity of assets and the funding liquidity of liabilities, according to Bai, Krishnamurthy and Weymuller (2018). This study finds that Liquidity Mismatch Index (LMI) has some degree of explanatory power over the repo volume banks undertake.
- Money and banking have profound influences on macroeconomy, credit condition and the household sector (Bernanke, 1983., Jorda, Schularick and Taylor, 2013., and Berger, Irresberger and Roman, 2020). This study suggests the heterogeneity in deposit rates (measured by standard deviation in deposit rates) has good predicting power over the future crisis. Moreover, contributing to Krishnamurthy and Muir (2017), this study shows an increase in the heterogeneity in deposit rates coupled with a high financial fragile condition will lead to a more severe economic downturn ("FD" model).
- Finally, this study investigates the role of deposits on US households, it is found that an increase in deposit spreads is associated with a decrease in households' expenditure. This effect is heterogenous among households based on their balance sheet position.

Our main findings suggest that policy makers should be aware of the importance of liquidity facilities provided by the Federal Reserve and the repo market, especially during the liquidity stressed periods, as they are playing an essential role in funding banks' liquidity. Furthermore, this thesis also highlights an increase in the heterogeneity in deposit rates, coupled with an increase in the financial fragility (measured by the credit growth) has good predicting power over the future crises. This market participants should take additional cautions and swift responses when they observe an increase in the heterogeneity in deposit rates, especially during the credit growth periods. Lastly, our findings relating to households suggest policy makers should aware that the effects on households' consumption from interest rate changes are heterogeneous among households based on their balance sheet positions.

The thesis is organised as follows: Chapter 2 provides the first study of the thesis in which we investigate how banks managed their liquidity during the COVID-19 pandemic. Chapter 3 is the second study of the thesis which examines how US tri-party repo market operates and its relationship with bank liquidity condition. Chapter 4 is the third study of the study with the aim to investigate the role of deposits on output, economic downturns and households. Chapter 5 concludes the thesis with a summary of the findings.

Chapter 2 Banks' Liquidity Management in the COVID-19 Crisis[1]

Abstract

How banks managed the COVID-19 pandemic shock? The eruption of the financial crisis in 2007 evolved to a crisis of banks as liquidity providers (Acharya and Mora, 2015). The COVID-19 pandemic shock was associated with a surge in households' deposits and a subsequent liquidity injection by the Federal Reserve. We show how the pandemic affected banks' liquidity management and therefore by extension, the creation of new loans. We evaluate three channels through which banks create and manage their liquidity: The supply-side through the exercise of market discipline, the demand-side through internal capital markets, and the balance-sheet channel through unused credit commitments and wholesale funding. We provide novel empirical evidence that: Depositors did not discipline riskier banks, and hence, weakly-capitalized banks were not forced to offer higher deposit rates to stem deposits outflow. Also, the internal capital market through which banks create liquidity was not in work. Furthermore, weakly-capitalized banks increased lending in the first phase of the pandemic. In the midst of the pandemic, weakly-capitalized banks cut back in new lending origination and increase their exposure to Fed's liquidity facilities. Well-capitalized banks increased lending in line with the increase in their deposits. Banks with higher exposure to liquidity risk experience are more vulnerable to deposit outflows and increased their exposure in Fed's liquidity facilities significantly more than low commitments exposed banks.

[1] This chapter is a joint work with Dimitrios Gounopoulos, Anamaria Nicolae and Nikos Paltalidis, and has been sumbitted to CEPR Covid Economics Working Paper Series Issue 80 (2021) in June 2021.

2.1 Introduction

In December 2019, a novel coronavirus was detected in Wuhan, China and spread worldwide within less than three months causing a global health crisis. To contain the COVID-19 virus, governments launched unprecedented measures, including partial (work-from-home policies) or even full shutdown of businesses and economic activities. In the United States the COVID- 19 pandemic triggered a severe economic downturn of uncertain duration. At the first phase of the pandemic-induced crisis firms drew heavily on credit lines. As a result, banks faced unprecedented credit line drawdowns which caused a dramatic spike in loan growth and stressed their liquidity. As a response, the Federal Reserve introduced liquidity schemes to facilitate financial institutions in distress condition. In the 2007 Global Financial Crisis, increased takedown demand for unused credit lines displaced lending capacity, and consequently banks exposed to liquidity risk adjusted their credit exposures and did not honor their credit commitments to firms (Ivashina 2009; Cornett et al. 2011; Acharya and Mora, 2015).

In this paper, we investigate how the COVID-19 pandemic shock affected banks' liquidity management and consequently, the supply of new loans? More specifically, we investigate how banks adjusted their lending, their deposit rates, and their exposure to Federal Reserve's liquidity facilities in response to the pandemic. We investigate these questions by studying both the supply and the demand side of banks' liquidity creation through three mechanisms: i. the market-discipline theory (supply-side); ii. the internal capital markets theory (demand-side); and iii. the balance sheet channel, which captures banks' exposure to liquidity demand risk.

The supply determinant of banks' liquidity management investigates how banks' depositors reacted during the pandemic. Deposits are a critical source of funding for banks since an increase (decrease) in deposit rates reflects a rise (drop) in banks' cost-of-credit.

As figure A1 shows, households increased bank deposits for the whole period of 2020, with most notable the dramatic increase that took place in the first phase of the pandemic (quarter 1, 2020). Theory suggests that households increase bank savings either as a precaution against uncertainty in future income ("precautionary savings" theory, Browning and Lusardi, 1996), or as a shift to safer investments ("flight to safety" theory, Bernanke, Gertler, and Gilchrist, 1996). We show that the increase in deposits is a result of precautionary savings since households increased the inflow of deposits for both risky and safe banks. Furthermore, we find that in states with higher COVID-19 cases, banks experienced a significantly higher increase in deposit amount, and they offered significantly lower deposits rates than in states with lower COVID-19 cases. These results support the suggestion that households increased savings as a precaution against uncertainty in future income.

Financial intermediation theory suggests that depositors exercise market discipline by demanding higher deposit rates from weakly capitalized (hence, riskier) banks (e.g., see Diamond and Rajan, 2000). We use branch-level data of deposit rates in Certificate of Deposits (CDs) of U.S. banks from 2016 (pre-pandemic era) till the end of 2020 (pandemic era) to identify whether riskier banks offered higher rates to depositors. To effectively investigate the hypothesis, we test for both insured ($10,000 and $100,000) and uninsured CDs with amounts higher than $250.000, and we measure banks' riskiness based on their equity-to-assets ratio in line with the literature (e.g., see Ben-David, Palvia, and Spatt, 2017; and Brown and Dinc, 2017). If flight to safety and market discipline are exercised by depositors, then deposit rates should be higher for weakly capitalized (i.e., riskier) banks. We find that the coefficient on the equity-to-assets ratio is not negative implying that deposit rates are actually lower on average for weakly capitalized banks during the pandemic. This result indicates the absence of market discipline and provides further support to our suggestion that households increase savings as precaution against uncertainty in future income. Our results remain similar across different deposit sizes.

Next, we investigate the demand determinant for deposits which suggests that banks adjust deposit rates based on their internal funding needs, which is the triple interaction between deposit growth, deposit rates and lending growth. Concretely, this mechanism suggests that banks use deposits as an internal capital market, which is they increase deposit rates based on their internal funding needs, such as to attract new deposits in order to originate new loans. Theory suggests that during distress conditions, banks have a sui generis advantage of using deposit inflows to fund their liabilities or to grant new loans (see for example Diamond and Dybvig 1983, and Diamond 1984). To tackle endogeneity concerns, we test the relation between bank-level deposit rates and loan growth based on the state-level loan growth. This approach has also been implemented by Ben-David, Palvia, and Spatt (2017), and one of its advantages is that it is based on market-level lending activity rather than on the bank's endogenous lending decisions. We measure state-level loan growth as the median loan growth of single-state banks for states in which the bank operates.

Our expectation is to find a positive relationship between bank-level deposit rates and loan growth during stressful financial conditions, if the hypothesis holds and banks determine deposit rates based on their funding needs. We find that before the pandemic, an increase in the flow of deposits is positively related with both loan growth and deposit rates. Although this result is consistent with the internal capital market theory which suggests that banks offer higher deposit rates to attract more deposits, during the COVID-19 pandemic this relationship changes. Precisely, deposit flows are positively correlated with loan growth, but negatively correlated with deposit rates, which indicates that the internal capital market was not in work during the pandemic. The results remain similar across different categories of loans, such as for Net Loans and Leases, and for Commercial and Industrial (C&I) loans.

The third mechanism through which banks create and manage their liquidity is the off- balance-sheet unused credit commitments that can be converted to loans and therefore, represent liquidity risk for banks. In addition, we employ banks' exposure in wholesale funding that represents short-term liquidity commitments. In line with Acharya and Mora (2015), and Acharya, Engle and Steffen (2021), we define liquidity demand risk as banks' undrawn lending commitments and wholesale funding that exceed their deposits. We find that commitments- exposed banks with a liquidity shortage during the pandemic offered higher deposit rates to axe deposit outflows. Further, we document that bank with high liquidity risk increased their exposure in Fed's liquidity facilities significantly more than banks exposed to low liquidity risk. We also test whether banks responded to the liquidity shock by cutting back new credit to meet increased loan commitment. The results reveal that banks with high exposure in credit commitments reduced the provision of new loans and leases. In contrast, banks with low credit commitments increased the supply of new loans and leases to firms.

Our paper contributes in four ways in the empirical literature that investigates how banks manage their liquidity and adjust their lending during crisis episodes. First, our work shows that during the COVID-19 crisis a precautionary savings effect is in work: in states with high COVID-19 cases deposit amounts increase significantly more and deposit rates decrease significantly more than in banks exposed to states with low COVID-19 cases. In a recent work, Hasan, Politsidis, and Sharma (forthcoming) find that syndicated loan spreads rise for lenders with exposure to COVID-19, a result which supports our suggestion that households increased deposits as a precaution to future declines in income caused by the COVID-19 shock. Second, we show that banks with high liquidity risk honored their credit commitments by adjusting their lending, in contrast to the 2007 Global Financial Crisis (Ivashina 2009; Cornett et al. 2011; Acharya and Mora, 2015). We also find that banks with low liquidity risk expanded the supply of commercial and industrial loans during the COVID-19 crisis. In a similar vein, Li, Strahan study. Section 2.4 presents and discusses the main empirical results. Section 2.5 provides additional tests for the robustness of our findings. Finally, section 2.6 concludes.

2.2 Literature Review

According to the financial intermediation theory, a fundamental feature of banks is the creation of liquidity and the subsequent transformation of risk, jointly referred to as banks' qualitative asset transformation (QAT) function (Bhattacharya and Thakor, 1993). Banks' risk transformation refers to the issuance of riskless deposits to finance risky loans. This theory argue that banks create liquidity when they issue riskless deposits to fund illiquid loans (Diamond 1984; Ramakrishnan and Thakor 1984; Boyd and Prescott 1986). Banks have two ways to create and manage liquidity through deposits: i. by rising rates to stem deposit outflows or to increase inflows, which is the supply of deposits by households (the market discipline channel); and ii. by rising rates to attract new deposits with the intention to increase their lending, which is the demand for deposits by banks (the internal capital markets channel). Banks' exposure to risky loans is associated with a third channel of liquidity pressure, the so-called liquidity demand risk (Acharya and Mora 2015). Unused credit lines are commitments that banks have to honor and especially during stressful conditions, corporation's drawdown these loans to mitigate liquidity problems. Below we provide more analysis and develop our hypotheses.

2.2.1 Market discipline

More concretely, the financial intermediation theory suggests that during crises episodes, depositors are concerned about the safety of their deposits. Therefore, they punish riskier banks by requiring a higher rate, giving rise to the market discipline theory. In the empirical literature, Gorton (1988), Saunders and Wilson (1996), and Calomiris and Mason (1997), document that banks with worse fundamentals experience greater deposit outflows in a crisis. Calomiris and Kahn (1991), and Calomiris (1999) argue that the market discipline theory operates as a regulatory tool where depositors demand a higher rate or withdraw their deposits as a form of discipline on risky banks. Park and Peristiani (1998), Peria and Schmukler (2001), and Hett and Schmidt (2017) provide empirical evidence that riskier institutions provide higher deposit rates. Also, the empirical literature in market discipline finds that larger banks experience higher deposit growth in a crisis (Martinez-Peria and Schmukler (2001), and that larger banks suffer fewer withdrawals than smaller ones (Billett, Garfinkel, and O'Neal, 1998; Goldberg and Hudgins, 2002).

In a similar vein, we test the market discipline hypothesis, that depositors require from riskier banks a higher premium for their deposits during a crisis, and in return riskier banks offer to pay higher deposit rates to stem deposit outflows during the COVID-19 pandemic. Theory suggests that higher capital improves banks' ability to absorb risk and hence their ability to create liquidity. Therefore, for riskier banks (i.e., weakly-capitalized banks) the relation between deposit rates and the equity-to-assets ratio should be negative. Building on this hypothesis, we suggest that the injection of liquidity from the Federal Reserve during the COVID-19 pandemic, indirectly recapitalized riskier banks through its positive impact on banks' liquidity and consequently it helped to avoid the exercise of market discipline.

2.2.2 The internal capital markets mechanism

Another way through which banks create and manage liquidity is the internal capital market. This mechanism is in work when banks increase deposit rates with the aim of boosting their deposits to fund new loans. Houston, James, and Markus (1997), Campello (2002) and Aschraft and Campello (2007) show that loans increase and decrease with the level of deposits providing empirical support for the importance role of the internal capital market in the creation and management of liquidity. Banks can respond to a funding shock by reallocating funds across locations through their internal capital markets. For the internal funding reallocation dynamics, Cetorelli and Goldberg (2012a), (2012b) provide direct evidence for the existence of a cross-border capital market where international banks transfer deposits across different regions to support new lending opportunities or to overcome liquidity shocks. A notable contribution in the literature is the work of Ben-David, Palvia, and Spatt (2017) which shows that deposit rates are mainly driven by banks' incentives for new loans rather than to stem deposits outflow.

Similarly, we test the internal capital markets theory hypothesis which suggests that banks determine deposit rates based on their funding needs. Precisely, banks' incentives to provide new loans drives deposit rates higher and by extension deposits grow. Then, the increase in deposits is used to fund new loans. Therefore, our second hypothesis suggests that the relationship between deposit growth, lending growth and deposit rates should be positive. Since, the results show that this mechanism was not in work during the pandemic, we test an additional hypothesis which suggests that the introduction of ample liquidity by the Federal Reserve during the COVID-19 pandemic helped banks to improve their liquidity levels. Therefore, banks achieved to increase their deposits, to provide new loans, while lowering their cost of capital -i.e., their deposit rates-.

2.2.3 Balance-sheet liquidity mechanism

Another important source through which banks create and manage their liquidity stems from exposure to undrawn loan commitments and exposure in wholesale funding. Unused loan commitments are the parts of credit lines that have not been drawn down, but banks are supposed to honor their obligation to fund these loans when requested by firms. Therefore, theory suggests that banks also create and manage their liquidity off the balance sheet through loan commitments (Diamond and Dybvig, 1983; Holstrom and Tirole, 1998; Kashyap, Rajan, and Stein, 2002). During periods of crisis, government interventions can help to prevent deposit outflows from banks, as showed in Gatev and Strahan (2006). However, another source of concern is that the higher the exposure to unused loan commitments the higher the liquidity risk and the liquidity needs for banks.

In addition, banks' exposure in wholesale funding represents short-term liquidity commitments. In line with Acharya and Mora (2015), and Acharya, Engle and Steffen (2021), we define liquidity demand risk as the ratio of banks' undrawn lending commitments and wholesale funding that exceed their deposits divided by banks' assets. The higher the exposure to unused credit commitments, the higher the liquidity risk for banks. In the empirical literature, Acharya and Mora (2015) report that during the 2007 financial crisis, deposit inflows into banks weakened and banks' loan-to-deposit shortfalls widened. As a result, banks with high exposure to unused credit commitments failed to meet their obligations. Also, the rest of the banks honored credit lines to firms because of the liquidity programs introduced by the government-sponsored agencies. Ivashina and Scharfstein (2010) study the 2007 crisis and show that more vulnerable banks with the higher credit line drawdowns adjusted their credit by cutting new lending. In a similar vein, Cornett, McNutt, Strahan, and Tehranian (2011) document that liquidity shocks led to a decline in credit supply during the financial crisis of 2007. Banks with strong capitalization continued to lend compared to relative poorly capitalized banks. However, banks with high off-balance-sheet liquidity risk significantly constrained new lending origination.

Holstrom and Tirole (1998) and Kashyap, Rajan, and Stein (2002) suggest that banks can also face liquidity risk through off-balance-sheet unused loan commitments. Acharya and Mora (2015) provide empirical evidence that during the 2007 crisis, banks with high exposure in undrawn lending commitments failed to meet their credit commitments.

We also test whether commitments-exposed banks experience high liquidity needs to honor their credit commitments, and therefore they offer to pay higher deposit rates to stem deposit outflows. Based on that hypothesis, banks with high liquidity risk adjust their credit lines by cutting new lending. Our fourth hypothesis suggests that banks with high liquidity risk increased their exposure to liquidity facilities offered from the Federal Reserve significantly more than banks with low commitments. This in turn, indirectly recapitalized banks, and helped banks to improve their liquidity, to honor their credit commitments, and to avoid an increase in their deposit rates.

2.3 Data and methodology

In this section we provide a brief description of the dataset and methodology used in this study. We use several sources of data from January 2016 till December 2020 in a quarterly frequency:

2.3.1 Data

- **Deposit rates**: We use deposit rates provided by RateWatch in branch level of US banks (money market deposits as well as Certificate of Deposits data). We use 3 kinds of deposit products across all U.S. branches: 12-month Certificates of Deposit with an account size up to $10,000; 12-month Certificates of Deposit (CDs) with an account size up to $100,000; and 12-month Certificates of Deposit (CDs) with an account size up to $500,000. Thedata is available in a monthly frequency.
- **Bank loans:** We collect detailed information on syndicated bank loans from Thomson Reuter's Dealscan. This source reports each loan as a deal, and contains information on the amount, the rate, the maturity, the lenders and the borrowers' names.
- **Banks' financial condition:** We use the Reports of Condition and Income (also known as Call Reports) to collect information to measure banks' capitalization, liquidity, commercial
- **COVID-19 Cases:** We collect detailed information for the number of cases per capita per state in the U.S. by using the rich dataset of CDC COVID Data Tracker.

2.3.2 Sample Selection Strategy

Regarding the sample selection strategy, we choose the sample period from 2016 January 2016 till December 2020, because the Federal funds effective rate goes beyond "zero lower bound" from 2016 January. The regressions are executed at quarterly frequency because the Call Report, which is one of the most important data source of this study is reported at quarterly frequency. Furthermore, we merge deposit rates and bank loans data by using "certificate number (CI)" as different banks have their own identical CI. Finally, The data in the range of 1%-99% were carefully checked and adjusted for any errors within these outliers.

The economic methods used in this study can be seen as an extension to Acharya and Mora (2015), who study how bank maintain their liquidity condition during the 2008 financial crisis. Acharya and Mora (2015) use key variables interacted with two crisis period dummies in their executions, while this study splits the sample into pre-pandemic and during the pandemic We include both state and bank fixed effects while Acharya and Mora (2015) only have bank fixed effects in their study.

2.3.2.3 Methodology

In this section we present the methodology used to test our hypotheses. We begin with the investigation of the market discipline mechanism and the precautionary savings hypothesis, followed by next we present the empirical model for the internal capital market hypothesis, and we conclude with the test for the effect of liquidity risk in the deposit rates, the flow of deposits, the supply of credit and on the use of Fed's liquidity facilities.

2.3.3.1 Market Discipline Theory and Precautionary Savings

If market discipline is exercised, then during distress conditions, depositors are concerned about their deposits and therefore they discipline riskier banks by demanding higher rates. In line with the literature, we employ the equity-to-assets ratio as a proxy to identify which banks are riskier (e.g., see Diamond and Rajan, 2000; Brown and Dinc, 2011; Ben- David, Palvia, and Spatt 2017 *inter alia*). The execution is similar to Ben- David, Palvia, and Spatt (2017), who use equity to assets ratio as a measurement of riskiness of banks. Berger, Bouwman, Kick, and Schaeck (2012) also use this measurement.

$$Deposit\_rate_{i,q} = \alpha + \beta_1 EA_{i,q-n} * I(q < 2020) + \beta_2 EA_{i,q-n} * I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}1)$$

where $Deposit\_rate_{i,q}$ is defined as the deposit rate of bank *i* at quarter *q*. $EA_{i,q-n}$ represents the lagged equity-to-assets ratio, with the number of lags being *n* = {1, 2}. $I(q < 2020)$ and $I(q \geq 2020)$ denote whether quarter *q* precedes 2020. $B_{i,q-1}$ is a set of bank-quarter control variables, including change in deposit to asset ratio with 1 lag, change in deposits with 1 lag, change in unused commitments to total loans ratio with 1 lag and change in liabilities to assets ratio. T_q represents a set of quarter fixed effects. All specifications are estimated with robust standard errors clustered by bank and quarter. We regress deposit rates of the same duration (12 months) but across different amounts of Certificates of Deposits ($10,000 and $500,000, and for $100,000 as a robustness test). If market discipline is exercised, the sign of the coefficient on the equity-to-assets ratio should be negative for weakly-capitalized banks.

Furthermore, to test for the precautionary savings theory we suggest that in counties with the higher COVID-19 cases banks' deposits grow faster and deposit rates decrease significantly more than in counties with low COVID-19 cases.

$$Deposit\_rate_{i,q} = \alpha + \beta_1 COVID-19CASES + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}2)$$

where $COVID-19CASES$ represents COVID-19 cases in state i at quarter q. And accordingly, for deposits:

$$Deposit\_rate_{i,q} = \alpha + \beta_1 COVID-19CASES + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}. \quad (2\text{-}3)$$

2.3.3.2 Internal Capital Markets

If the internal capital market mechanism is at work, banks' incentive to provide new loans lead to an increase in deposit rates, which in turn results to a rise in deposits. The increase in liquidity is used to fund the provision of new loans. Therefore, in Equation (2-4) below, if banks use their internal capital markets to create liquidity, there should be a positive coefficient on loan growth (i.e., β_2) and on the deposit rate (i.e., β_4).

$$Deposit\_Growth_{i,q} = \alpha + \beta_1 Loan\_Growth_{i,q-n} + \beta_2 Loan\_Growth_{i,q-n} * I(q \geq 2020) + \beta_3 Deposit\_Rate_{i,q-n} + \beta_4 Deposit\_Rate_{i,q-n} * I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q} \quad (2\text{-}4)$$

where $Deposit\_Growth_{i,q}$ represents the quarter-on-quarter net growth in total deposits for bank i. $Loan\_Growth_{i,q-n}$ is lagged quarter-on-quarter growth in Net Loans and Leases for bank i. The number of lags is $n = \{1, 2\}$. $Deposit\_Rate_{i,q-n}$ represents the lagged quarter-on- quarter deposit rate of bank i at quarter $q - n$. All specifications are estimated with robust standard errors clustered by bank and quarter. Similar to Equation (1), we regress deposit rates of the same duration (12 months) but across different amounts of Certificates of Deposits ($10,000 and $500,000).

Since the internal capital markets mechanism suggests that loan growth determines deposit rates, we also test the relation between the two instruments before and during the pandemic. If our hypothesis holds, then the coefficient of loan growth (i.e., β1 and β2) in Equation (5) should be positive.

$$Deposit\_Rate_{i,q} = \alpha + \beta_1 State\_Level\_Loan\_Growth_{i,q-n} \beta 2 State\_Level\_Loan\_Growth_{i,q-n} \times I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}5)$$

where $Deposit\_Rate_{i,q-1}$ represents the quarter-on-quarter deposit rate of 12-month maturity and $500,000 for bank i. Similar to Ben-David, Palvia, and Spatt (2017), to easy endogeneity concerns, we measure state-level loan growth to test its relationship with bank-level deposit rates. $State\_Level\_Loan\_Growth_{i,q-n}$ is lagged quarter-on-quarter growth across different categories of loans: Commercial & Industrial (C&I) and Net Loans and Leases for bank *i.* The number of lags is *n* = {1, 2}. All specifications are estimated with robust standard errors clustered by bank and quarter.

Furthermore, we assess the relation between deposit growth and loan growth, since our internal capital markets hypothesis suggests that banks' incentives to provide new loans leads to a haunt to increase their core deposits. To test the first part of the hypothesis we ask: Is deposit growth positively correlated with bank lending growth? Empirically, we follow the approach of Jayaratne and Morgan (2000).

$$Deposit\_Growth_{i,q} = a + \beta_1 Loan\_Growth_{i,q-n} + \beta_2 Loan\_Growth_{i,q-n} \times I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}6)$$

where $Deposit\_Growth_{i,q}$ represents the quarter-on-quarter change in deposits to total assets ratio for bank i. $Loan\_Growth_{i,q-n}$ is lagged quarter-on-quarter growth across two categories of loans: Syndicated loans and Net Loans and Leases for bank i. The number of lags is n ={1, 2}. All specifications are estimated with robust standard errors clustered by bank and quarter.

2.3.3.3 Liquidity Risk from Loan Commitments

Banks can also create liquidity off the balance sheet through unused credit commitments. These commitments are the parts of credit lines that have not been drawn down, but banks are supposed to honor their obligation to fund these loans when requested by firms. Therefore, the higher the exposure to unused credit commitments, the higher the liquidity needs and hence, the higher the liquidity risk. We follow Acharya, Engle and Steffen (2021) to measure liquidity risk, by adding wholesale funding exposure to unused credit commitments, and subtracting this with available cash in banks' balance sheets. The empirical literature suggests that during crisis episodes banks with high liquidity risk offer to pay higher deposit rates to attract more deposits. In turn these deposits will be used to honor their credit commitments. To test this hypothesis, we evaluate the relation between unused credit commitments with deposit rates, growth. If our hypothesis holds, then the sign of the coefficient on liquidity risk should be positive, and negative on deposit growth.

$$Liquidity\ Risk = (Unused\ Commitmetns + Wholesale\ Funding - Cash)/(Total\ Assets), \quad (2\text{-}7)$$

$$Deposit\_Rates_{i,q} = a + \beta_1 Liquidity\_Risk_{i,q-n} + \beta_2 Liquidity\_Risk_{i,q-n} \times I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}8)$$

$$Deposit\_Growth_{i,q} = a + \beta_1 Liquidity\_Risk_{i,q-n} + \beta_2 Liquidity\_Risk_{i,q-n} \times I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}9)$$

Furthermore, we assess whether banks with high liquidity risk adjust their credit by cutting new lending during the pandemic. To test this hypothesis, we use three different categories of lending: Syndicated loans, Commercial and Industrial Loans, and Net Loans and Leases:

$$Loan\_Growth_{i,q} = a + \beta_1 Liquidity\_Risk_{i,q-n} + \beta_2 Liquidity\_Risk_{i,q-n} \times I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}10)$$

Finally, we assess whether banks exposed to higher liquidity risk increased their exposure to liquidity facilities introduced by the Federal Reserve during the COVID-19 pandemic. Our hypothesis is that vulnerable banks with exposure to high liquidity risk increased their exposure to facilities offered by the Federal Reserve to improve their liquidity levels:

$$\text{Liquidity\_Risk}_{i,q} = a + \beta_1 \text{FED\_Liquidity}_{i,q-n} + \beta_2 \text{FED\_Liquidity}_{i,q-n} \times I(q \geq 2020) + \gamma B_{i,q-1} + \delta T_q + \varepsilon_{i,q}, \quad (2\text{-}11)$$

where $FED\_Liquidity_{i,q-n}$ is the lagged quarter-on-quarter change on the sum of Total Federal Funds sold to Commercial Banks, Reverse Repurchases, Vault Cash and Cash Items, and Balances due from Federal Reserve Banks for each bank i.[2]

2.4 Empirical results

In this section we present the results of the empirical tests for the effect of the pandemic and the effectiveness of the liquidity programs implemented by the Federal Reserve in banks' management of liquidity and credit commitments. Table 2.1 presents summary statistics for the main variables. We also conduct a t-test on the mean of the variables to see whether they are statistically significantly different. The results are shown in Table 2.5A in the appendix A. It is shown the mean of most variables are significantly different between the pre-pandemic period and during the pandemic. More precisely, Table 2.5A suggests the mean of deposit rates and syndicated loan amount are significantly lower during the pandemic compared to the pre-pandemic episode, while deposit amount and loan amount are significantly larger during the pandemic compared to the pre-pandemic episode.

-Please Insert Table 2.1 here-

In this chapter, the regressions are executed at bank level. Thus, we convert the raw deposit rate data, which is at branch level into bank level data by calculating the mean of deposit rates. In order to merge the bank data with state level variables, we use the headquarter of banks information provided by Call Report. As no manifest errors are found in all datasets used in this chapter, we do not specifically exclude any observation.

-Please Insert Table 2.2 here-

Table 2.2 presents the pairwise correlation matrix of the key variables in chapter 2. We can see that models estimated do not suffer from multicollinearity.

2.4.1 Precautionary Savings and Market Discipline

We start by investigating how the pandemic affected depositors' behavior. Table 2.3 shows that higher COVID-19 cases are associated with a significant decrease in deposit rates decrease and significant growth in deposit amounts. These results support the suggestion that households increase savings as a precaution against declines in future income. Next, we test whether depositors exercise market discipline during the pandemic-induced crisis by demanding a higher premium from risky banks. If weakly capitalized banks offer higher deposit rates to stem deposit outflow, the coefficient on the equity to assets ratio will be negative, and market discipline is exercised. On the other hand, if the injection of liquidity from the Federal Reserve is effective, then depositors will not request higher rates from weakly-capitalized banks, and hence, the coefficient on the equity to assets ratio will be positive. In Table 2.4 we present the results obtained from regressing deposit rates for different amounts ($10k and $500k Certificate of Deposits) on the equity to assets ratio. Deposits in the United States above $250k are not insured by the FDIC and therefore these deposits should, at least in theory, be more

[2] Total Federal Funds sold to Commercial Banks and Reverse Repurchases and Vault Cash and Cash Items and Balances due from Federal Reserve Banks are available from the Board of Governors of the Federal Reserve System, account H8 "Assets and Liabilities of Commercial Banks in the United States", and can be found here.

sensitive during crisis episodes. Panel A of Table 2.4 presents results for the period before and during the pandemic for the overall sample of banks. The results show that all coefficients are positive and statistically significant at 1% before and during the pandemic, indicating that market discipline was not exercised by depositors.

Next, we construct a subsample of weakly-capitalized banks to further investigate the market discipline hypothesis. Weakly capitalized banks are defined as the bottom 10% of capitalization within each quarter. If market discipline is exercised, the sign of the coefficient on capitalization should be negative for risky banks. Panel B shows that this coefficient is positive and statistically significant for deposits of $10k, while the coefficient for deposits of $500k is not significant. Therefore, we argue that risky banks do not offer higher deposit rates to stem deposit outflows. If market discipline was a salient factor, we should observe a significant negative relation between deposit rates and weakly-capitalized banks. Furthermore, these results support the findings presented in Panel A which show that market discipline was not exercised for the overall sample of banks. In contrast, the results indicate that the injection of liquidity from the Federal Reserve alleviated the concerns of liquidity stress and strengthened the liquidity condition of weakly capitalized banks. Since deposits are a critical source of funding for banks, this result also implies that banks lowered their cost of credit. In the robustness tests section, we provide additional robustness analyses which show the weak relationship between deposit rates and the capital ratio for deposits of different account size.

-Please Insert Table 2.3 here-

-Please Insert Table 2.4 here-

2.4.2 The Internal Capital Market Channel

In this section we test whether the pandemic affected the demand side for deposits, which is the internal capital market through which banks create liquidity. The market discipline hypothesis suggests that deposit rates mirror bank risk, since weakly capitalized banks should offer higher deposit rates. However, depositors might favor banks that offer lower deposit rates, due to differences in risk[3]. In contrast, the internal capital market hypothesis suggests that banks' intention to provide new loans leads to offer higher deposit rates to increase the flow of deposits and thus by extension to fund these loans. For this hypothesis to hold, deposit growth must be positively correlated with loan growth and with deposit rates.

2.4.2.1 The Relationship between Deposit Growth, Lending Growth, and Deposit Rates

In Table 2.5 we present the results from the regression estimated with standard errors clustered by bank and quarter (time). Loan growth is lagged, and it is measured by the quarterly change in net loans and leases, while deposit rates are measured through the Certificate of Deposits for accounts of $10k (Table 2.5). In Panel A of Table 2.5 we include all banks, and in columns (1) and (2) we first test the relation between loan growth and deposit growth. The results show that before the pandemic deposit growth has a significantly opposite direction of loan growth. However, this relationship changes during the pandemic, when deposit growth is very strongly correlated with loan growth. Further, the correlation increases during the COVID-19 pandemic crisis, and it is statistically significant at 1%. Precisely, column (1) in Table 2.5 reveals that a 1-standard-deviation change in net leases and loan growth is associated with a change of 0.5% in the same direction in deposit growth. Next, in columns (3) and (4), we include deposit rates on the right-hand side to examine the relation between lagged loan growth, lagged deposit rates and deposit growth. We find that deposit flows are positively correlated with growth in net loans and leases but *negatively* correlated with deposit rates during the pandemic. As a result, during the pandemic banks increase their deposit growth even though they offer lower deposit rates.

[3] We recognise that Z-score is also a popular way of measuring riskiness of banks, but here we follow Ben-David, Palvia and Spatt (2017), who use equity to assets ratio as the measurement.

In Table A1 in the Appendix, we test the same regression for accounts of £500k. When we use the alternative deposit account of $500k in Panel A of Table A1, the pattern continues to hold and the relation between deposit growth, lending growth and deposit rates is the same with the one observed in Table 2.5. Moreover, we breakdown the sample by bank capitalization to examine the same relation in Panels B (weakly capitalized) and C (well-capitalized) of Table 2.5. Weakly capitalized banks are defined as the bottom 10% of capitalization within each quarter, and well-capitalized banks as the top 10% of capitalization within each quarter. The results show that deposit growth is *negatively* correlated with deposit rates and with loan growth for weakly capitalized banks. When we test the same relationship with accounts of $500k, the results hold, indicating the robustness of our findings (Table A1). Notably, at the onset of the pandemic (quarter 1), the relation between deposit growth and lending growth was *positively* correlated. These results reflect the drawdown in credit lines from firms which resulted to an increase in bank lending during the first phase of the pandemic. However, weakly-capitalized banks adjusted their lending in the next quarters, by decreasing the provision of new loans. Finally, in Panel C of Table 2.5 we find that deposit growth is positively correlated with loan growth but *negatively* correlated with deposit rates for well-capitalized banks. The positive relation between deposit growth and lending growth implies that well-capitalized banks increased lending during the pandemic. Similar results are reported when we test for deposit accounts of $500k in Table A1 providing strong robustness for our findings.

-Please Insert Table 2.5 here-

Furthermore, we use Commercial and Industrial loans as an alternative measure of bank lending to examine the internal capital markets hypothesis. In Table 2.6 we present the results from the regression estimated with standard errors clustered by bank and quarter (time). Deposit rates are measured through the Certificate of Deposits for accounts of $10k. In Panel A of Table 2.6 we include all banks and in columns (1) and (2) we first test the relation between loan growth and deposit growth. For commercial and industrial loans, our results show a *positive* relationship in the first phase (Quarter 1) of the pandemic, and then it changes to negative afterwards. This result is consistent with the dramatic increase in involuntary lending that was caused when firms drawdown credit lines at the onset of the pandemic. In contrast, loan growth and deposit growth are always negatively correlated in the pre-pandemic period. A 1-standard-deviation change in loan growth is associated with a change of 13% in the same direction of deposit growth. Similar with the results in net loans and leases, we find that deposit growth is negatively correlated with deposit rate.

To ensure that our results are not driven by the regulatory protection that depositors enjoy for accounts less than $250k, we test the relation between deposit growth, lagged loan growth, and lagged deposit rates for Certificates of Deposits of $500k. In Table A2 in the Appendix, we report the results with the alternative deposit account of $500k., and we find that the same relations hold for both the pandemic and the pre-pandemic period. Since we do not find a positive relationship between deposit growth, deposit rates and loan growth for both loan categories, we conclude that banks improve their liquidity without the use of their internal capital market – the supply side of liquidity creation.

Further, we breakdown the sample by bank capitalization to examine the samerelation with weakly capitalized (Panel B) and well-capitalized (Panel C) banks in Table 2.6. For weakly capitalized banks, our results show that deposit growth is negatively correlated with loan growth, while we find weak significance for deposit rates during quarter 1 only. For well- capitalized banks the results show that there is positive relation between deposit growth and loan growth, while we do not find significance for deposit rates. These results indicate that in contrast with well-capitalized banks, less capitalized banks were forced to cut back in new credit origination as a response to the liquidity shock, while deposit rates do not play a significant role in the creation of liquidity to fund new loans. In Table A2, we test the same relationship with accounts of $500k hold, and we obtain similar results, indicating strong robustness for our findings.

-Please Insert Table 2.6 here-

2.4.2.2 The Relationship between Deposit Rates and Lending Growth

Next, we investigate the relationship between deposit rates and loan growth. In Table 6 we present the results from the regression estimated with standard errors clustered by bank and quarter (time). Loan growth is lagged, and it is measured by the quarterly change in net loans and leases. According to the internal capital market hypothesis, deposit rates should be positively correlated with loan growth. In Panel A of Table 2.7 we include all banks, while deposit rates are measured as Certificate of Deposits of $10k in columns (1) and (2), $100k in columns (3) and (4), and $500k in columns (5) and (6). We find that there is no strong relationship between deposit rates and loan growth, indicating that internal capital markets are not in work. We also breakdown the sample by bank capitalization in Panels B and C. For weakly-capitalized banks (Panel B) we find a negation relation for accounts of $10k., and 100k., however the significance is weak. Similarly, for well-capitalized banks (Panel C) the regression provides a meaningful positive coefficient between deposit rates and lending growth in quarter 3 for all account sizes in the pandemic crisis period only. This result indicates that well- capitalized banks have the ability to increase their lending by offering higher deposit rates. In contrast, for weakly-capitalized banks, deposit rates are not the dominant factor to grow their lending.

-Please Insert Table 2.7 here-

We examine further the relationship between deposit rates and lending growth by replacing net loans and leases with commercial and industrial loans in Table 2.8. To avoid any endogeneity concerns, we use banks' loan growth rate with loan growth per bank per state to examine the internal capital market across states. The results show that there is no strong significant coefficient in the relationship between deposit rates and loan growth. In addition, we breakdown banks by their capitalization in Panels B and C. For weakly-capitalized banks (Panel B) we find a strong negative relation which is significant at the 1% for accounts of $10k., and $100k. and only for quarter 3 of the pandemic. In contrast, for well-capitalized banks (Panel C) we do not find any significant results. These results indicate that deposit rates are not a dominant factor for banks' lending growth in commercial and industrial loans during the pandemic. Also, we use an alternative lending category: the quarter change in syndicated loans. The results reported in Table 2.3A in the Appendix, indicate that the internal capital market tool was not used during the pandemic, similar to our findings with new loans and leases and with commercial and industrial loans.[4]

-Please Insert Table 2.8 here-

2.4.2.3 The Relationship between Lending and Deposit Growth

Hitherto, we do not find a strong positive relation between deposit growth and deposit rates, and between deposit rates and loan growth during the COVID-19 pandemic. Since deposits and lending increased during the first phase of the pandemic, the decrease in deposit rates reflect that banks were not stressed on the deposit funding. This also implies that market discipline was not exercised and that the internal capital markets mechanism was not in work during the pandemic. Therefore, next we want to assess the relation between deposit growth and loan growth and whether this relation changed during the pandemic. The data on aggregate deposits suggest that the banking system was successful in strengthening their deposits in the first phase of the crisis. With the unprecedented credit line drawdowns and the subsequent increase in lending, we expect a positive relation between deposit growth and loan growth. The results in Panel A of Table 2.9 show that bank lending growth increased in line

[4] In Table 2.4A in the Appendix, we also test the relationship based on bank size, measured as total assets. The results provide small statistical significance, and provide evidence that capitalization represents a bank characteristic which contains more information for banks' liquidity condition.

with deposits. Before the pandemic, the results show a negative coefficient, which implies that lending growth moved in the opposite direction of deposit growth. From Panel B and C, we find that well- capitalized and large banks have greater ability to fund their lending with their deposits relative to weakly capitalized and small banks.

-Please Insert Table 2.9 here-

Next, we use quarter-on-quarter change of commercial and industrial loans to assess the relation between growth in lending and deposit growth. The results in Table 2.10 show that an increase in deposit growth is associated with a strong increase in lending growth during the second phase of the pandemic. Notably, the relationship between these two, was negative before the pandemic, indicating that growth in lending was not funded by deposits. The results from Table 2.10 also reveal that banks with the higher exposure in Fed's liquidity facilities expand their lending in line with the growth in their deposits. In contrast, banks with low exposure in Fed's liquidity facilities expand their lending only after the first phase of the pandemic.

-Please Insert Table 2.10 here-

2.4.3 The Balance-Sheet Mechanism

In this section we investigate how liquidity-exposed banks adjust their lending, deposit rates and their exposure to the Federal Reserve liquidity facilities in reaction to the liquidity shock during the pandemic.

2.4.3.1 The Relation between Deposit Rates and Liquidity Risk

Banks' liquidity risk is measured through their unused credit commitments, and their wholesale funding minus available cash. We start by assessing the relation between liquidity risk and deposit rates. To improve their liquidity condition, banks with high unused credit commitments are expected to offer higher deposit rates to increase their deposit flows. We use Certificates of Deposits (CDs) of $10k. accounts of deposit rates in columns (1) and (2) of Table 2.11 and CDs of $500k. in columns (3) and (4). The results show a strong negative coefficient between liquidity risk and deposit rates, which is significant at 1%. These findings imply that liquidity risk and deposit rates move in the opposite direction. This pattern continues when we test the relation for banks with the higher liquidity risk in Panel B of Table 2.11, indicating that banks exposed to high liquidity risk did not increase deposit rates to stem deposits outflow. One explanation for this is the surge in precautionary savings during the first phase of the pandemic and a second explanation is that these banks used the liquidity facilities offered by the Fed in order to increase their liquidity levels. We test for the latter in the following sub-sections.

-Please Insert Table 2.11 here-

2.4.3.2 The Relation between Deposit Growth and Liquidity Risk

In Table 2.12 we present results for the relation between deposit growth and liquidity risk. The dataset on aggregate deposits suggest that the banking system was successful in attracting deposits during the pandemic. The results show a strong negative relationship between deposit growth and liquidity risk which is significant at 1%. In columns (5) and (6) the results also show that banks with the higher exposure to liquidity risk experience the higher decline in their deposits. These results indicate that banks with high liquidity risk are more vulnerable to deposit outflows, since the higher the exposure to liquidity risk, the higher the decline in deposits.

-Please Insert Table 2.12 here-

2.4.3.3 The Relation between Lending and Liquidity Risk

We also test how liquidity risk-exposed banks adjust lending in reaction to the liquidity shock. Liquidity risk is measured through i) off-balance unused credit commitments which are converted into loans and add pressure to banks' liquidity condition; and ii) wholesale loan commitments which are loan commitments the interbank market. We use three categories of loans to measure growth in lending: Commercial and Industrial Loans, Net Loans and Leases, and Syndicated Loans. The results in Table 2.13 show a positive relationship between Liquidity Risk and growth in Commercial and Industrial Loans. This result is consistent with the dramatic increase in involuntary lending that was caused when firms drawdown credit lines and therefore, off-balance-sheet commitments were converted to loans. In contrast, when we use net loans and leases to test the relationship with liquidity risk in Panel B, we find a strong negative relationship between banks with high exposure to liquidity risk and growth in lending. These results imply that banks with high exposure to liquidity risk respond to liquidity shock by cutting back new lending. Similarly, the findings in Panel C reveal that increased exposure to liquidity risk is associated with a drop in the provision of syndicated loans.

-Please Insert Table 2.13 here-

2.4.4 The Relation between Fed's Liquidity Injection and Liquidity Risk

Finally, we assess the relationship between liquidity risk and banks' exposure to the Fed's liquidity facilities. We measure banks' exposure in these liquidity facilities through the quarter-on-quarter change on the sum of Total Federal Funds sold to Commercial Banks and Reverse Repurchases and Vault Cash and Cash Items and Balances due from Federal Reserve Banks. The results in Table 2.14 show a strong positive relationship between liquidity risk and banks' exposure to Fed's facilities. Precisely, we find that banks with high exposure to liquidity risk increase their exposure to the liquidity facilities offered by the Fed significantly more than low- liquidity risk exposed bank.

-Please Insert Table 2.14 here-

2.5 Robustness Check

We present sensitivity tests in Tables 2.15, and 2.16. In addition, many sensitivity tests are also presented in the Appendix. In Table 2.15 we provide robustness test for the supply-side of banks' liquidity creation: the market discipline channel. Precisely, we use a different account of deposit rates, the Certificate of Deposits for $100k. The results show that the relationship between deposit rates and weakly-capitalized banks is positive again. This result supports our initial findings that market discipline was not the dominant factor for deposit rates during the pandemic. Next, we provide sensitivity tests for the demand channel of banks' liquidity creation. We assess the relation between deposit growth, loan growth and deposit rates on the county level for each bank. Deposit rates are measured based on the rate provided in Certificate of Deposits for accounts of $10k. (Panel A) and of $500k. (Panel B), while lending growth is measured through the quarter-on-quarter change of Commercial and Industrial Loans for each bank. From Panel A in Table 2.16 we find that, the relationship between deposit growth and lending growth is strongly positive, while the relationship with deposit rates is negative. The same pattern continues in Panel B: the relationship between deposit growth and lending growth is strongly positive, while the relationship with deposit rates is negative. All coefficients are significant at 1%. These results indicate that banks' deposit rates move in the opposite direction of deposit and lending growth, and hence the internal capital market mechanism is not in work during the pandemic.

-Please Insert Table 2.15 here-

-Please Insert Table 2.16 here-

Lastly, several binned scatterplots graph 2.6A are shown in the Appendix A in order to present the relationships among key variables.

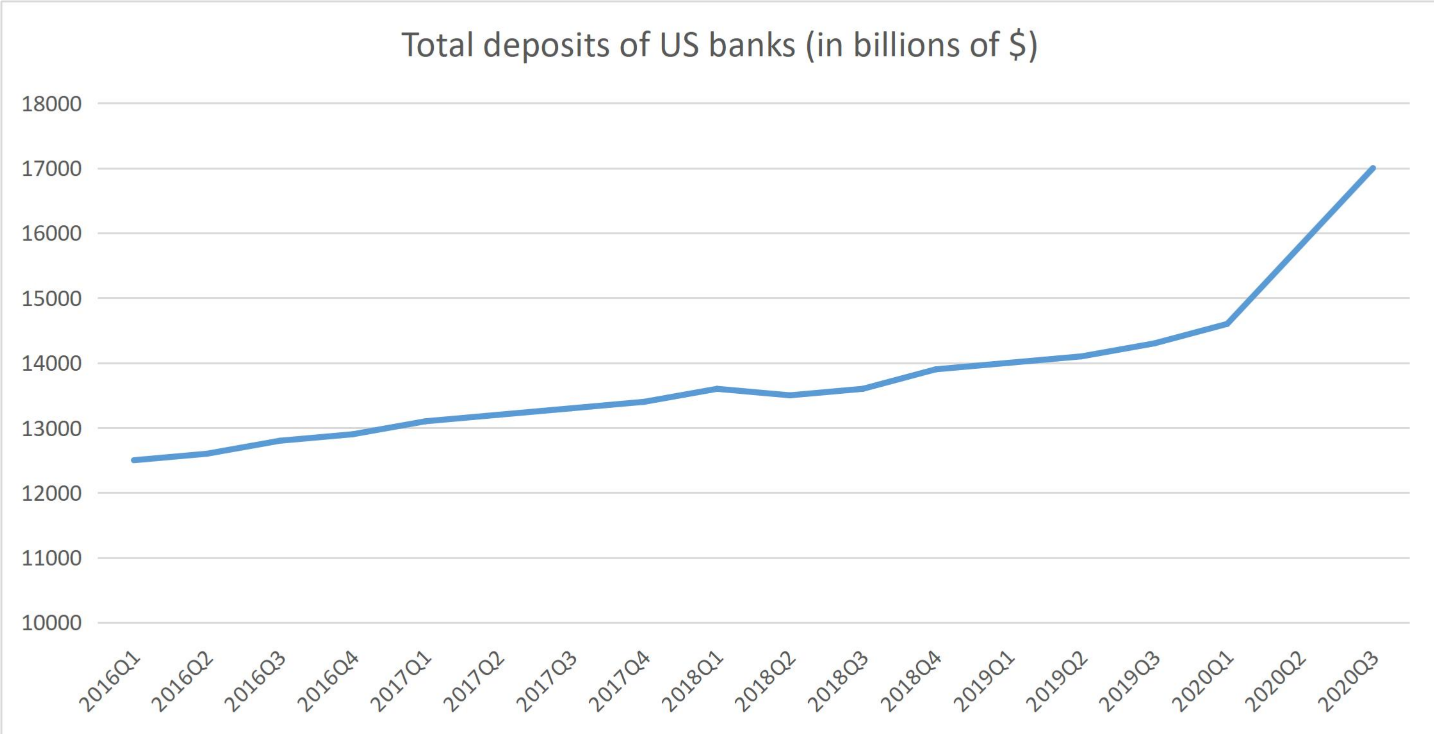
2.6 Conclusion

The COVID-19 pandemic-induced recession brought aggregate shocks to the United States banking system, with liquidity pressure and significant financial disruptions especially across the funding markets. From the onset of the pandemic, households increased their bank savings and the Federal Reserve injected liquidity to stabilize the financial system. This study shows how this expansion of liquidity was distributed across the banking system. In our first set of tests, we find that households increase savings as a precautionary action against future declines in income, while also we find no evidence for the exercise of market discipline by depositors. More precisely, depositors should discipline risky (weakly-capitalized) banks, however deposit rates are not negatively correlated with banks' capitalization, contradicting the market discipline theory for the COVID-19 pandemic period. This implies that during the pandemic weakly capitalized banks were not forced to offer higher deposit rates to stem deposits outflow, and hence achieved to keep their cost-of-capital in sustainable levels.

Furthermore, we provide strong evidence that deposit growth is positively correlated with lending growth, but negatively correlated with lagged deposit rates. This result indicates that banks' internal capital market was not in work during the pandemic. Next, we assess how liquidity risk in the form of undrawn and wholesale loan commitments affected bank lending activities. In the beginning of the COVID-19 pandemic, undrawn loan commitments materialized as borrowers drew on preexisting commitments to improve their liquidity. Weakly-capitalized banks with high liquidity risk, increased their exposure to the liquidity facilities introduced by the Federal Reserve, more than low-commitments banks. As a result, banks honored their credit commitments, however these takedowns displaced lending capacity since weakly capitalized banks adjusted their lending by reducing the origination of new loans. In contrast, well-capitalized banks increased lending in line with the increase in their deposits. Finally, we find that banks with high exposure to Federal Reserve's liquidity facilities originated significantly more loans than banks with lower exposure. In aggregate, our results provide strong evidence that most of the decline in bank lending creation during the height of the pandemic can be explained by the degree of their exposure in liquidity risk and in the Federal Reserve's liquidity facilities.

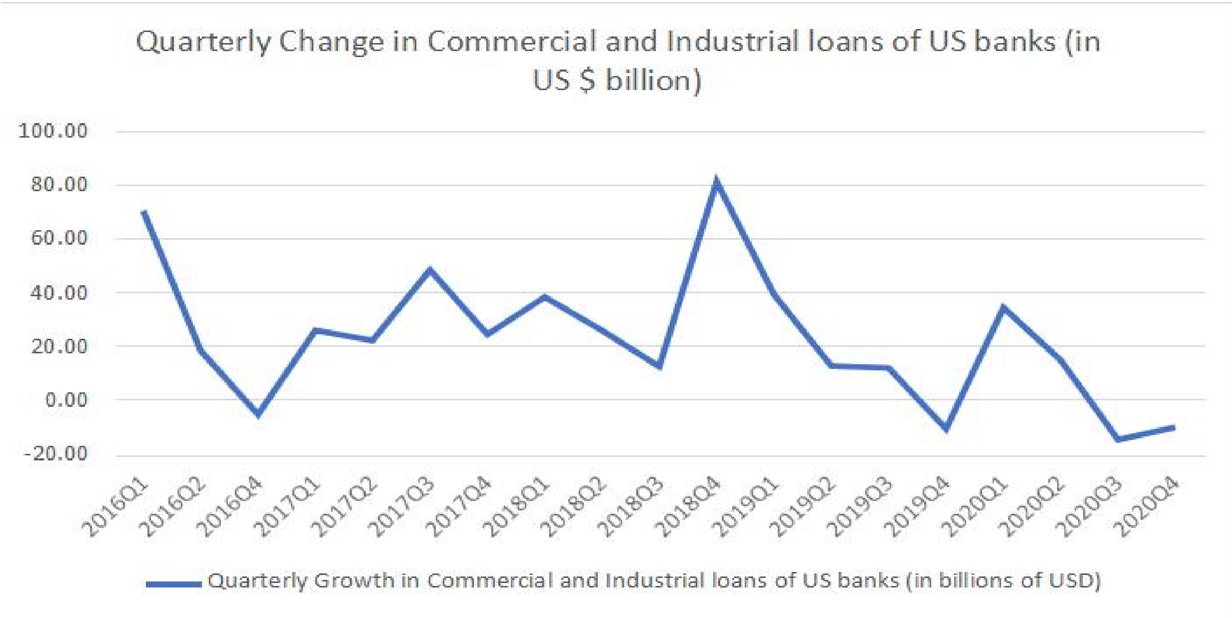
Our findings are especially relevant for macroprudential and monetary policy makers. Since banks with greater risk to credit line drawdowns reduced their lending more than other banks, monetary policy makers can respond by designing liquidity tools that target the characteristics of these banks in future crises. Accordingly, macroprudential policy makers might wish to use banks' exposure in liquidity risk as a signal for tightening (or loosening) the time-varying loan-to-value ratios, and the counter-cyclical capital buffers. Furthermore, the absence of market discipline from depositors implies that the new deposit insurance framework introduced by the Dodd-Frank act in 2010 enhances financial stability, while also that deposit rates are not reflecting bank riskiness, but rather reveal frictions in access to new funding.

Figure A1. Aggregate deposits. This figure shows the quarterly aggregate deposits from 2016 till 2020.



Source: Call Report, analysed by the author.

Figure A2. Unused credit commitments to total assets. This figure shows the quarterly ratio of unused credit commitments (Liquidity Risk) to total assets 2016 till 2020.



Source: Call Report, analysed by the author.

Table 2.1. Summary Statistics

Panel A. Summary Statistics of Main Sample (bank-quarter observations) amounts in US$ millions.

	N	Mean	Std.Dev	P5	P25	P50	P75	P95
Total Assets	10,5632	3,252.2	51,600.0	36.7	102.5	218.7	525.5	3740.4
Total Deposits	10,5642	2,512.6	39,000.0	29.6	85.5	183.6	437.8	2963.1
Total Equity	10,5471	359.7	5,354.0	4.4	11.9	24.8	59.2	411.0
Commercial and Industrial loans	10,5642	387.8	5,988.6	0.2	1.3	14.1	43.2	393.8
Net Loans and Leases	10,5632	1,768.0	24,100.0	16.5	59.4	140.7	359.0	2563.7
Total Unused Commitments	10,5642	1,388.8	24,500.0	0.7	6.3	19.6	62.5	602.5
Total Federal Reserve Repurchase	10,5632	91.7	3,605.6	0.0	0.0	0.0	1.6	14.6
Cash	10,5632	358.5	7,527.5	2.2	6.9	15.1	36.3	209.0
Syndicated loans	5,206	9,280.0	22,300.0	0.0	81.3	652.0	6,490.0	54100.0

Panel B. Summary Statistics of ratios in Main Sample (bank-quarter observations)

	N	Mean	Std.Dev	P5	P25	P50	P75	P95
Total Equity to Assets ratio	10,5471	0.123	0.069	0.081	0.096	0.110	0.130	0.188
Total Deposits to Assets ratio	10,5642	0.829	0.092	0.705	0.804	0.848	0.879	0.907
Total Liabilities to Total Assets ratio	10,5642	0.878	0.070	0.812	0.870	0.890	0.904	0.920
Unused Commitments ratio	10,4995	0.137	0.090	0.025	0.084	0.128	0.174	0.259

Panel C. Summary Statistics of Deposit Rates (bank-quarter observations)

	N	Mean	Std.Dev	P5	P25	P50	P75	P95
12-month CD rate, $10k accounts (12MCD10K rate)	83,565	0.658	0.486	0.150	0.300	0.500	0.900	1.730
12-month CD rate, $100k accounts (12MCD100K rate)	80,787	0.686	0.496	0.150	0.341	0.500	0.950	1.750
12-month CD rate, $500k accounts (12MCD500K rate)	71,679	0.708	0.507	0.150	0.350	0.520	1.000	1.760

Notes: This table presents summary statistics for the variables used in the analysis. The sample period is from 2016Q1-2020Q4. Panel A and Panel B show summary statistics for the analysis for the main sample. Panel C shows summary statistics for the sample with deposit rates for a variety of account sizes per bank per branch.

Table 2.2. Pairwise correlation matrix

	12mcd10k deposit rate	12mcd100k deposit rate	12mcd500k deposit rate	Deposit to total asset	Tier 1 capital to total asset	Unused commitments to total loans	Cash plus Repo amount	Other borrowed funds	Total assets	Net loans and leases	Total liabilities	Total deposits	Syndicated loans amount
12mcd10k deposit rate	1												
12mcd100k deposit rate	0.9369	1											
12mcd500k deposit rate	0.9365	0.9573	1										
Deposit to total asset	-0.0687	-0.0677	-0.0708	1									
Tier 1 capital to total asset	0.1091	0.1092	0.1112	-0.7231	1								
Unused commitments to total loans	0.0055	0.0094	0.017	-0.0252	0.0014	1							
Cash plus Repo amount	-0.0279	-0.0267	-0.0255	-0.0344	-0.0154	0.0002	1						
Other borrowed funds	-0.0271	-0.0245	-0.0202	-0.0748	-0.0183	-0.0002	0.8446	1					
Total assets	-0.0369	-0.0353	-0.0311	-0.0412	-0.0218	-0.0001	0.9148	0.9063	1				
Net loans and leases	-0.0372	-0.0353	-0.0295	-0.0477	-0.0228	-0.0002	0.8156	0.8922	0.9747	1			
Total liabilities	-0.0369	-0.0352	-0.0312	-0.0403	-0.0222	-0.0001	0.9185	0.9067	0.9999	0.9727	1		
Total deposits	-0.0377	-0.036	-0.0316	-0.0362	-0.0231	-0.0002	0.8958	0.884	0.9973	0.9794	0.997	1	
Syndicated loans amount	0.0046	0.0046	0.0145	-0.0993	0.011	0.3291	0.7307	0.7419	0.7216	0.6869	0.722	0.7045	1

Notes: This table reports the the pairwise correlation matrix for key variables used in this chapter.

Table 2.3. Deposit Rates, Deposit growth and COVID-19 cases

Panel A. Deposit rates and COVID-19 cases	12-Month CD $10k account rate		12-Month CD $500k account rate	
	(1)	(2)	(1)	(2)
	i=1	i=2	i=1	i=2
COVID-19 cases per capita (t-i)	-2.000***	-2.000***	-0.976	-2.812
	(37.17)	(37.16)	(0.27)	(0.65)
State Fixed effects	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.0913	0.0913	0.0741	0.0741
No. of obs.	41,491	41,484	4,097	4,097

Panel B. Deposit growth and COVID-19 cases	Deposit growth (in thousands of $)		Deposit to total assets growth (in %)	
	(1)	(2)	(1)	(2)
	i=1	i=2	i=1	i=2
COVID-19 cases per capita (t-i)	2,388.1*	2,423.7*	0.009	0.011
	(1.73)	(1.65)	(0.87)	(0.97)
State Fixed effects	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.0133	0.0133	0.0155	0.0155
No. of obs.	15,222	15,222	15,222	15,222

Notes: This table presents regressions of deposit rates, deposit growth and COVID-19 cases per capita. Panel A presents the regression results that estimate the effect of COVID-19 on deposit rates. Panel B presents the regression results that estimate the effect of COVID-19 in the growth of deposits. In columns (1) and (3) the independent variables are lagged by 1 quarter (i=1) and therefore for the pandemic period it reflects results for Q3 2020.In columns (2) and (4) the independent variables are lagged by 2 quarters (i=2) and therefore for the pandemic period it reflects results for Q2 2020. The sample is from March 2020 till December 2020 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Standard errors are clustered by bank and quarter. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.4. Deposit Rates and Bank Tier 1 Ratio

Panel A. Whole sample — Dependent Variables:	12-Month CD $10k account rate		12-Month CD $500k account rate	
	(1)	(2)	(1)	(2)
	i=1	i=2	i=1	i=2
Equity to assets (t-i) × I *(q<2020Q1)*	0.005***	0.006***	0.005***	0.006***
	(7.40)	(8.61)	(6.25)	(7.48)
Equity to assets (*t-i*) × I (*q≥2020Q1)*	0.002***	0.003***	0.004***	0.004***
	(2.95)	(3.84)	(3.19)	(3.72)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.703	0.703	0.724	0.724
F-test (Pre-pandemic - Pandemic = 0)	1.94*	2.30**	0.27	0.74
No. of obs.	83,565	83,565	71,679	71,679

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% lower-capitalized banks)	Dependent Variables: 12-Month CD $10k account rate		12-Month CD $500k account rate	
	(1)	(2)	(1)	(2)
	i=1	i=2	i=1	i=2
Equity to assets (t-i) × I (q<2020Q1)	0.006	0.013**	0.016**	0.019***
	(1.02)	(2.01)	(2.35)	(2.71)
Equity to assets (*t-i*) × I (*q≥2020Q1)*	0.020**	0.029***	0.028*	0.023
	(2.03)	(2.78)	(1.84)	(1.48)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-square	0.740	0.739	0.770	0.765
F-test (Pre-pandemic - Pandemic = 0)	-1.43	-0.75	-1.18	-1.04
No. of obs.	8,062	8,072	6,861	6,875

Notes: This table presents regressions of 12-month Certificate of Deposits (CD) rates on lagged Tier 1 Capital to Risk-Weighted-Assets Ratio. In Panel A the whole sample of banks is used. Panel B splits the sample by bank capitalization using the bottom 10% decile. In columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.5. Deposit Growth, Net Loans and Leases Growth, and Deposit Rates of Small Accounts

Panel A. Deposit Growth, Loan Growth and Deposit Rates

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $10k account rate *(t-i)* × I (q<2020Q1)			17.866	-7.624
			(0.85)	(0.33)
12-Month CD $10k account rate *(t-i)* × I (*q≥2020Q1)*			-309.194***	-319.647***
			(8.55)	(10.17)
Net loans and Leases Growth *(t-i)* × I (q<2020Q1)	-0.384***	-0.119***	-0.385***	-0.132***
	(39.73)	(11.73)	(37.16)	(12.04)
Net loans and Leases Growth *(t-i)* × I (q≥2020Q1)	0.587***	0.121***	0.601***	0.1076***
	(85.77)	(14.65)	(83.74)	(12.40)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.289	0.227	0.318	0.248
No. of obs.	105,581	105,552	83,520	83,451

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $10k account rate *(t-i)* × I (q<2020Q1)			12.479	2.003
			(0.67)	(0.10)
12-Month CD $10k account rate *(t-i)* × I (*q≥2020Q1)*			-63.529**	-46.218*
			(2.02)	(1.73)
Net loans and Leases Growth *(t-i)* × I (q<2020Q1)	-1.551***	-0.571***	-0.818***	0.254***
	(11.84)	(3.92)	(15.48)	(4.20)
Net loans and Leases Growth *(t-i)* × I (q≥2020Q1)	-0.802***	1.138***	-0.354***	0.109**
	(10.39)	(10.97)	(10.78)	(2.30)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.289	0.135	0.261	0.182
No. of obs.	10,536	10,533	8,054	8,044

Panel C. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% highly capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $10k account rate *(t-i)* × I (q<2020Q1)			-33.341	-25.561
			(1.55)	(1.07)
12-Month CD $10k account rate *(t-i)* × I (*q≥2020Q1)*			-50.141	-67.307**
			(1.33)	(1.99)
Net loans and Leases Growth *(t-i)* × I (q<2020Q1)	-0.248***	0.441***	-0.089***	-0.010
	(11.35)	(19.68)	(3.27)	(0.35)
Net loans and Leases Growth *(t-i)* × I (q≥2020Q1)	0.216***	0.374***	0.129***	0.337***
	(4.31)	(6.62)	(3.11)	(6.97)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.114	0.184	0.178	0.252
No. of obs.	10,680	10,677	6,905	6,912

Notes: This table presents regressions of quarter-on-quarter deposits growth on lagged quarter-on-quarter loan growth and 12-month Certificate of Deposit (CD) rate, and lagged quarter-on- quarter loan growth. The CD rates are for accounts of $10k. Loan growth is defined as quarterly change in net loans and leases. In Panel A the whole sample of banks is used. Panel B splits the sample by bank capitalization using the bottom 10% decile. Panel C splits the sample by bank capitalization using the top 10% decile. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1). In columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.6. Deposit growth, Commercial and Industrial Loans Growth, and Deposit Rates of Small Accounts

Panel A. Deposit Growth, Loan Growth and Deposit Rates

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $10k account rate *(t-i)* * I (q<2020Q1)			13.774	-3.761
			(0.67)	(0.16)
12-Month CD $10k account rate *(t-i)* * I (*q≥2020Q1)*			-298.991***	-341.083***
			(8.41)	(10.87)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	-1.033***	-0.441***	-1.050***	-0.430***
	(39.67)	(16.25)	(38.52)	(14.95)
Commercial and Industrial Loans *(t-i)* * I (q≥2020Q1)	-0.299***	1.299***	-0.307***	1.312***
	(19.61)	(101.88)	(19.17)	(98.70)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.229	0.310	0.250	0.341
No. of obs.	105,581	105,552	83,520	83,451

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $10k account rate *(t-i)* * I (q<2020Q1)			11.539	3.158
			(0.61)	(0.16)
12-Month CD $10k account rate *(t-i)* * I (*q≥2020Q1)*			-46.136	-51.278*
			(1.45)	(1.92)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	-3.398***	-2.628***	-0.738***	0.404**
	(9.12)	(6.89)	(4.84)	(2.53)
Commercial and Industrial Loans *(t-i)* * I (q≥2020Q1)	-0.476***	-0.260	-0.344***	-0.510***
	(3.19)	(0.84)	(6.38)	(3.98)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.281	0.123	0.238	0.182
No. of obs.	10,536	10,533	8,054	8,044

Panel C. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $10k account rate *(t-i)* * I (q<2020Q1)			-30.407	-25.385
			(1.49)	(1.07)
12-Month CD $10k account rate *(t-i)* * I (*q≥2020Q1)*			-46.110	-63.929*
			(1.29)	(1.90)
Quarter change in commercial and industrial loans *(t-i)* * I (q<2020Q1)	1.564***	-0.416***	1.921***	-0.672***
	(17.48)	(4.53)	(25.13)	(8.11)
Quarter change in commercial and industrial loans *(t-i)* * I (q≥2020Q1)	0.736***	0.798***	0.681***	0.813***
	(6.42)	(5.59)	(7.51)	(6.92)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.131	0.152	0.257	0.259
No. of obs.	10,680	10,677	6,905	6,912

Notes: This table presents regressions of quarter-on-quarter deposits growth on lagged quarter-on-quarter loan growth and 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter loan growth. The CD rates are for accounts of $10k. Loan growth is defined as quarterly change in net loans and leases. In Panel A the whole sample of banks is used. Panel B splits the sample by bank capitalization using the bottom 10% decile. Panel C splits the sample by bank capitalization using the top 10% decile. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1). In columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.7. Deposit rates and Net Loans and Leases Growth

Panel A. Whole sample	Dependent Variables:					
	12-Month CD $10k rate		12-Month CD $100k rate		12-Month CD $500k rate	
	i=1	i=2	i=1	i=2	i=1	i=2
Loan Growth (t-i) * I (q<2020Q1)	-0.0015	0.0003	-0.0009	0.0033*	-0.0020	0.0003
	(0.91)	(0.16)	(0.49)	(1.73)	(1.03)	(0.16)
Loan Growth (t-i) * I (q≥2020Q1)	0.0001	0.0025*	0.0002	0.0022	0.0001	0.0006
	(0.08)	(1.66)	(0.15)	(1.47)	(0.05)	(0.36)
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.7031	0.7031	0.7064	0.7064	0.7239	0.7239
No. of obs.	83,554	83,545	80,813	80,804	71,674	71,666

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)	Dependent Variables:					
	12-Month CD $10k rate		12-Month CD $100k rate		12-Month CD $500k rate	
	i=1	i=2	i=1	i=2	i=1	i=2
Loan Growth (t-i) * I (q<2020Q1)	0.0201	0.0808**	-0.0184	-0.0185	-0.1190**	-0.0388
	(0.56)	(2.00)	(0.51)	(0.45)	(2.35)	(0.76)
Loan Growth (t-i) * I (q≥2020Q1)	-0.0445**	0.0565*	-0.0490**	-0.0254	-0.1230	-0.0155
	(2.01)	(1.81)	(2.19)	(0.80)	(1.60)	(0.23)

Table 2.7 (Continued). Deposit rates and Net Loans and Leases Growth

Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.7404	0.7390	0.7460	0.7459	0.7700	0.7651
No. of obs.	8,062	8,072	7,798	7,810	6,861	6,875

Panel C. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)	Dependent Variables:					
	12-Month CD $10k rate		12-Month CD $100k rate		12-Month CD $500k rate	
	i=1	i=2	i=1	i=2	i=1	i=2
Loan Growth (t-i) * I (q<2020Q1)	0.0010	0.0208*	0.0187	0.0215*	0.0126	0.0141
	(0.85)	(1.81)	(1.59)	(1.84)	(1.08)	(1.18)
Loan Growth (t-i) * I (q>=2020Q1)	0.0600**	0.0136	0.0538**	0.0203	0.0691**	-0.0243
	(2.56)	(0.51)	(2.26)	(0.75)	(2.27)	(0.79)
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.7429	0.7460	0.7471	0.7506	0.7706	0.7747
No. of obs.	10,982	11,019	10,537	10,578	9,364	9,397

Notes: This table presents regressions of 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter loan growth. The CD rates are for accounts of $10k., 100k., and $500k. Loan growth is defined as quarterly change in net loans and leases. In Panel A the whole sample of banks is used. Panel B splits the sample by bank capitalization using the bottom 10% decile. Panel C splits the sample by bank capitalization using the top 10% decile. Independent variables are lagged by 1 quarter (i=1). Also, independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.8. Deposit Growth, Commercial and Industrial Loans Growth, and Deposit Rates of Large Accounts

Panel A. Deposit Growth, Loan Growth and Deposit Rates

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			-7.972	31.865
			(0.38)	(1.38)
12-Month CD $500k account rate *(t-i)* * I *(q≥2020Q1)*			-263.759***	-242.399***
			(7.15)	(7.71)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	-1.033***	-0.441***	-0.930***	-0.444***
	(39.67)	(16.25)	(33.69)	(15.34)
Commercial and Industrial Loans *(t-i)* * I (q>=2020Q1)	1.299***	-0.299***	1.550***	-0.383***
	(101.88)	(19.61)	(108.68)	(22.73)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.310	0.229	0.359	0.253
No. of obs.	105,581	105,552	75,691	78,532

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			37.043**	15.877
			(2.10)	(0.85)
12-Month CD $500k account rate *(t-i)* * I *(q≥2020Q1)*			41.619	-4.487

Table 2.8 (Continued). Deposit Growth, Commercial and Industrial Loans Growth, and Deposit Rates of Large Accounts

			(1.37)	(0.18)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	-3.398***	-2.628***	-0.443***	0.308**
	(9.12)	(6.89)	(3.25)	(2.12)
Commercial and Industrial Loans *(t-i)* * I (q≥2020Q1)	-0.476***	-0.260	-2.082***	-0.603***
	(3.19)	(0.84)	(18.20)	(5.19)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.281	0.123	0.368	0.226
No. of obs.	10,536	10,533	7,254	7,538

Panel C. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			-40.998*	-15.793
			(1.88)	(0.64)
12-Month CD $500k account rate *(t-i)* * I *(q≥2020Q1)*			-54.863	-48.174
			(1.40)	(1.36)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	1.564***	-0.416***	1.929***	-0.644***
	(17.48)	(4.53)	(24.28)	(7.48)
Commercial and Industrial Loans *(t-i)* * I (q≥2020Q1)	0.736***	0.798***	1.120***	0.778***
	(6.42)	(5.59)	(10.57)	(6.40)
Bank Fixed effects	Yes	Yes	Yes	Yes

Table 2.8 (Continued). Deposit Growth, Commercial and Industrial Loans Growth, and Deposit Rates of Large Accounts

Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.131	0.152	0.278	0.257
No. of obs.	10,680	10,677	6,175	6,413

Notes: This table presents regressions of quarter-on-quarter deposits growth on lagged quarter-on-quarter loan growth and 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter loan growth. The CD rates are for accounts of $500k. Loan growth is defined as quarterly change in net loans and leases. In Panel A the whole sample of banks is used. Panel B splits the sample by bank capitalization using the bottom 10% decile. Panel C splits the sample by bank capitalization using the top 10% decile. In columns (1) and (2) independent variables are lagged by 1 quarter (i=1) and in columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Standard errors are double-clustered by bank and quarter. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.9. Loan Growth and Deposit Growth

Panel A. Whole sample	Dependent Variables: Quarter-on-quarter Loans Growth			
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
Deposits growth (t-i) * I (q<2020Q1)	-0.3842***	-0.1193***	-0.0301*	0.0335**
	(39.73)	(11.73)	(1.95)	(2.17)
Deposits growth (t-i) * I (q≥2020Q1)	0.5871***	0.1205***	0.0259**	0.0389***
	(85.77)	(14.65)	(2.37)	(3.11)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.2892	0.2275	0.0634	0.0562
No. of obs.	105,581	105,552	105,581	105,552

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)	Dependent Variables: Quarter-on-quarter Loans Growth			
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
Deposits growth (t-i) * I (q<2020Q1)	-1.5514***	-0.5714***	0.3110	-0.0266
	(11.84)	(3.92)	(1.13)	(0.88)
Deposits growth (t-i) * I (q≥2020Q1)	-0.8024***	1.1375***	-0.0434	0.0392
	(10.39)	(10.97)	(0.27)	(0.17)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes

Table 2.9 (Continued). Loan Growth and Deposit Growth

R-squared	0.2895	0.1356	0.1711	0.1378
No. of obs.	10,536	10,533	10,536	10,533

Panel C. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)	Dependent Variables: Quarter-on-quarter Loans Growth			
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
Deposits growth (t-i) * I (q<2020Q1)	-0.2478***	0.4409***	-0.2910**	0.0843
	(11.35)	(19.68)	(2.19)	(0.62)
Deposits growth (t-i) * I (q≥2020Q1)	0.2161***	0.3742***	0.5260*	0.9020***
	(4.31)	(6.62)	(1.72)	(2.64)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.1142	0.1840	0.2468	0.1367
No. of obs.	10,680	10,677	10,680	10,677

Notes: This table presents regressions of quarter-on-quarter loan growth on lagged quarter-on-quarter deposits growth. In columns (1) and (2) the dependent variable is net loans and leases growth and the independent is deposits growth. In columns (3) and (4) the dependent variable is net loans and leases to total assets growth and the independent is deposits to total assets growth. In Panel A the whole sample of banks is used. Panel B separates the sample by bank capitalization using the bottom 10% decile. Panel C separates the sample by bank capitalization using the top 10% decile. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1) and in columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Standard errors are double-clustered by bank and quarter. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.10. Loan Growth, Federal Reserve Liquidity and Deposit Growth

Panel A. Whole Sample	Dependent Variable: Δ Commercial and Industrial Loans to Total Assets			
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
Deposits to total assets growth (t-i) × I (<2020)	-0.006***	-0.001		
	(3.67)	(0.85)		
Deposits to total assets growth (t-i) × I (≥2020)			0.129***	0.0142
			(12.34)	(1.03)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.0683	0.0667	0.5084	0.5009
No. of obs.	90,351	90,331	15,230	15,221

	Dependent Variable: Δ Commercial and Industrial Loans to Total Assets			
Panel B. Pandemic Period	Lower 10% with exposure to Fed's Liquidity		Higher 10% with exposure to Fed's Liquidity	
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
Deposits to total assets growth (t-i) × I (≥2020) × FL	0.146***	-0.071*	0.061**	0.086**
	(3.79)	(1.73)	(2.11)	(2.16)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.6447	0.5490	0.4914	0.4916
No. of obs.	1,522	1,521	1,523	1,523

Notes: This table presents regressions of quarter-on-quarter loan to total assets growth on lagged quarter-on-quarter deposits to total assets growth. In Panel A columns (1) and (2) the dependent variable is commercial and industrial loans growth and the independent is deposits to total assets growth before the pandemic. In columns (3) and (4) the dependent variable is commercial and industrial loans to total assets growth and the independent is deposits to total assets growth during the pandemic. In Panel A the whole sample of banks is used. Panel B separates the sample by banks' exposure to Federal Reserve Liquidity Facilities (denoted as FL) using the bottom and top 10% deciles. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1) and in columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.11. Deposit rates and Liquidity Risk

	Dependent Variables:			
Panel A. Whole sample	12-Month CD $10k rate		12-Month CD $500k rate	
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
Liquidity Risk (t-i) * I (q<2020Q1)	-0.1641***	-0.1523***	-0.1906***	-0.1943***
	(4.03)	(3.72)	(4.13)	(4.21)
Liquidity Risk (t-i) * I (q≥2020Q1)	-0.3021***	-0.3053***	-0.3345***	-0.3670***
	(6.11)	(6.25)	(5.04)	(5.50)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.7033	0.7033	0.7240	0.7240
No. of obs.	83,565	83,565	71,679	71,679

	Dependent Variables:			
Panel B. Banks with higher Liquidity Risk (top 10%)	12-Month CD $10k rate		12-Month CD $500k rate	
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
Liquidity Risk (t-i) * I (q<2020Q1)	-0.4710***	-0.4278***	-0.4273***	-0.3170**
	(4.36)	(3.74)	(3.17)	(2.27)
Liquidity Risk (t-i) * I (q≥2020Q1)	-0.7390***	-0.7191***	-0.5374***	-0.4195**
	(5.83)	(5.63)	(2.93)	(2.28)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.7468	0.7438	0.7658	0.7646
No. of obs.	7,969	7,995	6,628	6,644

Notes: This table presents regressions of 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter liquidity risk. The CD rates are for accounts of $10k., and $500k. Liquidity risk is defined as quarterly change in Unused Credit Commitments and Wholesale Funding. In Panel A the whole sample of banks is used. Panel B presents results for banks with the higher (top 10%) exposure to liquidity risk. Independent variables are lagged by 1 quarter (i=1) and therefore for the pandemic period it reflects results after Q1 2020. Also, independent variables are lagged by 3 quarters (i=3) and therefore for the pandemic period it reflects results for Q1 2020 only. The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.12. Deposit Growth and Liquidity Risk

	Dependent Variable: Deposits to total assets growth					
	Whole sample of Banks		Lower 10% of Liquidity Risk Banks		Higher 10% of Liquidity Risk Banks	
	(i=1)	(i=2)	(i=1)	(i=2)	(i=1)	(i=2)
Liquidity Risk (t-i) * I (q<2020Q1)	-4.2251***	-2.2994***	-5.2655	-1.3958	-6.2469***	-6.8107***
	(14.84)	(8.13)	(1.33)	(0.88)	(6.79)	(7.46)
Liquidity Risk (t-i) * I (q≥2020Q1)	-3.6686***	-1.9597***	-9.5066	-5.1037	-5.8180***	-6.2368***
	(10.75)	(5.83)	(1.63)	(1.21)	(5.75)	(6.21)
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.0768	0.0754	0.2278	0.2279	0.1886	0.1799
No. of obs.	105,611	105,611	10,487	10,436	11,129	11,154

Notes: This table presents regressions of quarter-on-quarter deposits to total assets growth on lagged quarter-on-quarter liquidity risk. In columns (1) and (2) the whole sample of banks is included. In columns (3) and (4) the sample is separated to banks with lower (bottom 10%) exposure to liquidity risk. In columns (5) and (6) the sample includes banks with higher (top 10%) exposure to liquidity risk. In columns (1), (3) and (5) independent variables are lagged by 1 quarter (i=1) and in columns (2), (4), and (6) independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.13. Commercial and Industrial Loans Growth and Liquidity Risk

	Dependent Variable: Δ Commercial and Industrial Loans			
	Higher 10% of Liquidity Risk Banks		Lower 10% of Liquidity Risk Banks	
	(i=1)	(i=2)	(i=1)	(i=2)
Liquidity Risk (t-i) * I (q<2020Q1)	89.066*	103.071**	-26.175	-1.236
	(1.73)	(2.02)	(0.81)	(0.10)
Liquidity Risk (t-i) * I (q≥2020Q1)	202.036***	223.717***	4.344	145.474***
	(3.27)	(3.69)	(0.09)	(4.25)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.0443	0.0444	0.1193	0.1162
No. of obs.	11,129	11,154	10,487	10,436

Notes: This table presents regressions of quarter-on-quarter lending growth on lagged quarter-on-quarter liquidity risk. In columns (1) and (2) the sample includes banks with higher (top 10%) exposure to liquidity risk. In columns (3) and (4) the sample includes banks with lower (bottom 10%) exposure to liquidity risk. In columns (1), and (3) independent variables are lagged by 1 quarter (i=1) and in columns (2), and (4) independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.14. Liquidity Risk and Federal Reserve Liquidity Facilities

	Dependent Variable: Δ Liquidity Risk			
	Higher 10% Liquidity Risk Banks		Lower 10% Liquidity Risk Banks	
	(i=1)	(i=2)	(i=1)	(i=2)
Δ Fed Liquidity (t-i) × I (q<2020Q1)	0.0026	0.0289***	0.0371***	-0.0060
	(0.29)	(3.07)	(8.31)	(1.29)
Δ Fed Liquidity (t-i) × I (q≥2020Q1)	0.0601***	0.0408*	-0.0039	-0.0146
	(3.13)	(1.85)	(0.44)	(1.28)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.9542	0.9502	0.6113	0.6107
No. of obs.	10,488	10,488	10,472	10,418

Notes: This table presents regressions of quarter-on-quarter change in liquidity risk on lagged change in Fed's liquidity facilities. In columns (1) and (2) the sample includes banks with higher (top 10%) exposure to liquidity risk. In columns (3) and (4) the sample includes banks with lower (bottom 10%) exposure to liquidity risk. In columns (1), and (3) independent variables are lagged by 1 quarter (i=1) and therefore for the pandemic period it reflects results after Q1 2020. In columns (2), and (4) independent variables are lagged by 2 quarters (i=2) and therefore for the pandemic period it reflects results for Q1 2020 only. The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.15. Deposit Rate and Bank Tier 1 Ratio

	Dependent variable: 12-Month CD $100k rate					
	Whole Sample		Lower 10% by Capitalization		Higher 10% by Capitalization	
	(1)	(2)	(3)	(4)	(5)	(6)
	(i=1)	(i=2)	(i=1)	(i=2)	(i=1)	(i=2)
Equity to Assets ratio *(t-i)* × *I (<2020)*	0.0024***	0.0025***	0.0642***	0.0681***	0.0013*	0.0012
	(6.00)	(6.14)	(9.00)	(9.55)	(1.80)	(1.57)
Equity to Assets ratio *(t-i)* × I *(≥2020)*	0.0004	0.0007	0.0153**	0.0298***	-0.0019	-0.0021
	(0.65)	(1.03)	(2.02)	(3.82)	(1.46)	(1.56)
Bank Fixed Effects	Y	Y	Y	Y	Y	Y
Quarter Fixed Effects	Y	Y	Y	Y	Y	Y
R-squared	0.7045	0.7064	0.7592	0.7582	0.7545	0.756
Observations	122,538	117,877	12,241	11,774	12,241	11,774

Notes: This table presents regressions of 12-month Certificate of Deposits (CD) rates on lagged Tier 1 Capital to Risk-Weighted-Assets Ratio. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1) and in columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.16. Deposit Growth, Loan Growth and Deposit Rates

Panel A. Deposit Growth, Loan Growth and 12-Month CD $10k rates

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
12MCD10K rate *(t-i)* × I (q<2020Q1)			137.182	-28.770
			(0.82)	(0.16)
12MCD10K rate *(t-i)* × I *(q≥2020Q1)*			-1757.555***	-1864.103***
			(5.59)	(6.96)
Net Loans and Leases Growth *(t-i)* × I (q<2020Q1)	-0.377***	-0.108***	-0.377***	-0.119***
	(12.26)	(3.35)	(11.65)	(3.47)
Net Loans and Leases Growth *(t-i)* × I (q≥2020Q1)	0.570***	0.107***	0.578***	0.084
	(26.22)	(4.08)	(25.78)	(3.11)
Bank Fixed effects	Y	Y	Y	Y
Quarter Fixed Effects	Y	Y	Y	Y
R-squared	0.2907	0.2321	0.3220	0.2561
No. of obs.	10,552	10,548	8,621	8,616

Panel B. Deposit Growth, Loan Growth and 12-Month CD $500k rates

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	(i=1)	(i=2)	(i=1)	(i=2)
12MCD500K rate *(t-i)* × I (q<2020Q1)			-20.795	30.749

Table 2.16 (Continued). Deposit Growth, Loan Growth and Deposit Rates

			(0.12)	(0.17)
12MCD500K rate *(t-i)* × I (*q≥2020Q1)*			-1705.219***	-1474.226***
			(5.03)	(5.50)
Net Loans and Leases Growth (t-i) × I (q<2020Q1)	-0.377***	-0.108***	-0.342***	-0.096***
	(12.26)	(3.35)	(10.28)	(2.88)
Net Loans and Leases Growth *(t-i)* × I (q≥2020Q1)	0.570***	0.107***	0.636***	0.066**
	(26.22)	(4.08)	(26.46)	(2.50)
Bank Fixed effects	Y	Y	Y	Y
Quarter Fixed Effects	Y	Y	Y	Y
R-squared	0.2907	0.2321	0.3250	0.2502
No. of obs.	10,552	10,548	7,703	8,519

Notes: This table presents regressions of quarter-on-quarter deposits growth on lagged quarter-on-quarter loan growth and 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter loan growth. In Panel A, the CD rates are for accounts of $10k and in Panel B for accounts of $500k. Loan growth is defined as quarterly change in net loans and leases. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1) and in columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Chapter 3: US repo market, dealer risk and liquidity

Abstract

US banks are heavily reliant on the repo market. This chapter examines the functioning of the US tri-party repo market, investigating the role of dealer's riskiness on repo volumes and rates during the post-crisis period (2010:Q2-2019:Q4) and the starting quarter of the COVID-19 pandemic (2020:Q1). It is found that the market perception of dealer risk adversely impact repo volumes undertaken by dealers. Furthermore, the contribution of bank liquidity conditions to bank repo volumes and rates is examined in this study through the Liquidity Mismatch Index (LMI). The findings in this chapter suggest the LMI explains well the repo volumes and repo rates of banks during the post-crisis period. As indicated by our study, policymakers should be aware that the amount repo dealers take on in repo transactions is moderated by the market's perception of riskiness and liquidity conditions.

3.1 Introduction

Repurchase agreements (Repos), short-term agreements to sell collaterals, supported by a contract to repurchase the collateral at a higher price. The repo market fulfils a significant function in the US financial system as a stable source of short-term funding. In addition, banks also rely on the repo market to meet their short-term liquidity needs. In addition, it serves an instrumental part in the price discovery system of liquidity assets and other derivatives. The repo market has always been seen as a potential source of financial instability, especially in times of liquidity stressed (Copeland, Martin and Walker, 2014). During the recent financial crisis in 2008, the US repo market experienced great fluctuations, leading to intense debates on the relationship among dealer risk profile, liquidity profile and repo (Copeland, Duffie, Martin and McLaughlin, 2012).

This chapter aims to analyse the functioning the US tri-party repo market during the post-crisis period and the starting quarter of the COVID-19 pandemic. To put it more precisely, an investigation into whether dealer risk can influence the volume and rate at which dealers undertake repo is first conducted in this study. Our empirical analysis reveals an increase in the market perception of risk of dealers is associated with a decrease in the reverse repo amount during the post-crisis period (2010:Q2-2019:Q4). In addition, it is shown that in the starting quarter of the pandemic (2020:Q1), dealers with higher market perception of risk tend to borrow more funds through repo transactions. Secondly, this chapter examines the relationship between the liquidity mismatch index (LMI) and the volume and the rate of repo undertaken by banks. The empirical results of this study indicate that the LMI provides sound explanatory power for banks' repo volumes and repo rates.

The tri-party repo in the US is the highlight of this chapter. In contrast to bilateral repo market, the tri-party repo market involves a third party (Bank of New York Mellon, BNYM or JP Morgan Chase and JPMC) acting as a custodian and agent for the buyer and seller, providing settlements and collateral management services to the parties to the transaction and settling repo transactions on their own balance sheets. In addition, the clearing banks are responsible for the daily revaluation of assets and the daily re-margining of collateral (Copeland, Duffie, Martin and McLaughlin, 2012). Another difference lies in that the bilateral repo market imposes restrictions on the type of collateral that can be used in the transaction in comparison to tri-party repo market. Most research on the US repo market has focused on tri-party repo market rather than bilateral repos, because data for bilateral repo transactions are hard to obtain, as mentioned by Krishnamurthy, Nagel and Orlov (2014).

As repo is a major contributor to the funding of US financial institutions and it has experienced fluctuations during the liquidity stressed periods in the past, this study begins by examining how the repo market operates using transaction level data from the US tri-party repo market. To be more precise, the chapter investigates the role of market perception's riskiness of dealers (CDS spreads) on the repo market's trading volume and rate of primary dealers during the post-crisis period (2010:Q2-2019:Q4) and starting quarter of the pandemic (2020:Q1), which is a potential period of liquidity strain period. Secondly, this chapter runs regressions based on the entire sample, which is then split into two types: bank dealers and non-bank dealers, to examine whether the market perception's of dealers' riskiness have a heterogenous impact on repo rates for these two categories of dealers. Finally, as banks rely heavily on the repo market for their short-term liquidity needs, this research investigates whether liquidity shocks to bank affect repo volumes and repo rates at the bank level by using a unique liquidity measurement called Liquidity Mismatch Index, raised by Bai, Krishnamurthy and Weymuller (2017).

In the post-crisis period, the Federal Reserve conducted reverse repos (draining liquidity from the banking system) on a daily basis, but rarely repo (injecting liquidity into the banking system). Consistent with Krishnamurthy, Nagel, and Orlov (2014) and Copeland, Martin and Walker (2014), the findings of this study show that repo volume and rates appear to be stable. However, market perceptions of riskiness have strong explanatory power for both repo volume and rates. When the sample is split into bank dealers and non-bank dealers, the repo volume and rate can be found to be more sensitive to changes in market perceptions of riskiness than non-bank dealers. In addition, this chapter also finds that banks with deteriorating liquidity condition (decrease in LMI), tend to participate less in the reverse repos to avoid liquidity loss.

Turning to the starting quarter of the COVID-19 pandemic (2020:Q1), this study finds a reversion in the coefficient of the relationship between dealers' riskiness and repo volumes (and rate). This is mainly due to the huge repo volume ($175 billion overnight + $500 billion term) conducted by the Federal Reserve to inject liquidity. When splitting the sample, this study identifies that only non-bank dealers, which the market perceives as riskier, borrow more through the repo market. The findings reinforce Giese and Haldane (2020) who suggest that banks play as the role of "shock-absorbers" as capital and liquidity conditions had improved prior to the pandemic, while the non-bank dealers rely heavily on the repo market during the pandemic. On the other hand, it can be indicated in our study that, the non-bank dealers call for a greater focus on non-bank dealers in the pandemic starting quarter. In the spring of 2020, the US non-bank financial sector experienced an adverse liquidity shock induced by the COVID-19 pandemic shock, posing a 'cash rush' issue for non-bank dealers. This was attributed to the non-bank investors' choice to "flight to safety" by pulling out their investment, and these "runs" cause liquidity shortage on non-bank dealers (Falato, Goldstein and Hortacsu, 2021 and Breckenfelder and Hoerova, 2022).

The outline of the chapter is presented below..In Section 3.2, the review of related literature will be presented. Section 3.3 introduces the research questions and hypotheses of this study. In Section 3.4 there is a presentation of the data and summary statistics. In Section 3.5, the empirical investigation is given. Finally, Section 3.6 draws the conclusion.

3.2. Literature Review, Research Question and Hypotheses

This section is a review of the literature focusing on the evolution of repo markets, bank liquidity measurement and liquidity condition and repo market behavior during the COVID-19 pandemic, with the aim of identifying trends and gaps in existing research.

Following the relevant literature, the research questions and hypotheses formulated for the purpose of this chapter will be presented.

3.2.1 Evolution of the repo market

Sub-section 2.1 presents the literature review on the repo market. Firstly, the literature review about the emerge of repo transactions is represented in 3.2.1.1. Secondly, 3.2.1.2 shows the literature on the rise of tri-party repo market in the US. Thirdly, 3.2.1.3 presents the review of literature on the current structure of US repo market.

3.2.1.1 The emerge of repo

Repurchase agreements (repo) are short-term agreements to sell collaterals and enter the contracts simultaneously to repurchase them at higher prices later. The modern term "repurchase agreements" first appeared in the 19th century, but only in the legal and judicial spheres of the United States and UK. For instance, In I.F.R (1869) mentions about "the right (privilege) for the lender to redeem the collateral used with a price negotiated before". Thereafter, the use of repurchase agreements to raise short-term funds in commerce was widely discussed and debated (Richardson, 1928), suggesting the embryo stage of bilateral repurchase agreement market appeared. These transactions in this stage can be demonstrated by the figure shown below:

[Please insert Figure B1 here]

The Federal Reserve started to recognize bankers' acceptances and government securities as collaterals and to engage in repo transactions from the 1920s. However, according to statistics provided by Hearings (1931), the volume of repo transactions by Federal Reserve was quite small, which was as little as $100 million to $200 million from 1924 to the end of the year 1935[5], according to the statistics provided by Hearings (1931). As a result, repo attracted little attention in the discussion of monetary policy until the late 1930s. During the Second World War, the Federal Reserve System developed a special repo transaction to encourage banks and other dealers to hold Treasury bills for wartime fundraising purposes. This arrangement came into effect a few months after the attack on Pearl Harbor and expired in August 1947 (Simmons, 1947). Under this arrangement, "a bank, a business firm or might sell his holdings to a Federal Reserve Bank under option to repurchase a like amount of bills of the same maturity at any time prior to maturity"[6]. And repo transactions were made at a special rate at 3/8 of 1%, which according to Simmons (1954), Capie (2011) and Mullin (2020), also made the transactions beneficial to the Treasury bill holders. Moreover, the Federal Reserve starts to use repo transactions as a regular monetary policy tool after 1951.

3.2.1.2 The rise of tri-party repo market

Although the volume of repo transactions grew steadily from the 1950s to the 1980s, the structure of the repo market did not change significantly during this period. However, one critical event – the collapse of Drysdale Government Securities[7], a midsized dealer, accelerated a new form of repo market structure – the tri-party repo, in May 1982 (Garbade, 2006). This event indicates that although the repo (bilateral) is normally considered short-term collateral loans, participants should take take into account

[5] repo fell into disuse during the Great Depression, see Garbade (2006).

[6] See Federal Reserve Bank of New York Circular no. 2476 (August 8, 1942), Circular No. 3230 (July 3, 1947).

[7] In May 1982, Drysdale had a $4 billion short position and a $2.5 billion long position in Treasury securities in the repo market (Garbade, 2006). However, it failed in the speculative transactions, making it impossible to repurchase the securities from the counterparties. The counterparties of Drysdale suffer from losses of $300 million in total in this event (Welles, 1982). A few dealers collapsed after 1982 including Lion, E.S.M, and Bevill, Bresler also demonstrate the need of a new form repo transactions mechanism (Sollinger, 1994).

credit risk as they will suffer significant losses, especially in periods of uncertainty, should their counterparties refuse or fail to repurchase the collateral on the repurchase date. Moreover, another major drawback of the bilateral repo market is that transactions are conducted over the counter (OTC), making the delivering repo securities cost and financing cost high.

Fortunately, several large banks have started to develop tri-party repos to reduce the cost of financing and the credit risk borne by dealers. The structure of tri-party repo can be illustrated in the diagram below.

[Please insert Figure B2 here]

In a tri-party repurchase agreement, an intermediary acting as clearing house stands between the borrower and the dealer. On the date of the transaction, the cash borrower is obliged to deliver collaterals and the lender is obliged to deliver cash to the clearing house. The clearing house will then verify the acceptability of the securities and ensure that the market value of the collateral exceeds the required margin before handing over the cash to the borrower At the repurchase date, the cash borrower will return cash to the bank while the lender will return the collaterals to the bank (Garbade, 2006 and Copeland, Duffie, Martin and McLaughlin, 2012).

It is worth mentioning that there are three advantages under this arrangement. First, the tri-party repos protect the lenders from the credit risk by requiring borrowers to provide margin. Once the borrowers fail to meet the margin requirement, the clearing house will sell the securities (mostly treasury bills) in the secondary market and repay the lenders. Second, as the securities remain with the clearing house for the duration of the repo transactions, the borrowers can recover the securities at a higher price before the repurchase date. Third, the costs of delivering securities reduce largely compared to the original bilateral repo transactions. Next, I will present a review of the literature on the repo market structure in the 21st century.

3.2.1.3 The repo market structure in the 21st century

Currently, the US repo market consists of two segments: the bilateral repo segment and the tri-party repo segment. The majority of dealers involved in bilateral repo transactions are hedge funds and the securities used as collaterals in these transactions are often exceptional, according to Copeland, Duffie, Martin and McLaughlin (2012). Moreover, the Federal Reserve is now responsible for delivering both securities and cash between two parties. Since bilateral repo transactions are OTC, it is difficult to know exactly the size of US bilateral repo market (Krishnamurthy, Nagel and Orlov, 2014).

However, Copeland, Martin, and Walker (2014) estimate the size of bilateral repo segment to be approximately $1 trillion as of May 2012.

When it comes to the tri-party repo segment, there are two banks that are acting as clearing houses in the US tri-party repo market., namely the Bank of New York Mellon (BNYM) and the JP Morgan Chase (JPMC), according to the information provided by the Federal Reserve Bank of New York. As of April 2022, the size of tri-party repo segment is $3.81 trillion and 90% of the collaterals used in these transactions are US Treasury securities and government agency obligations including mortgage-backed securities [MBS], debentures, and collateralized mortgage obligations[8].

The tri-party repo market is considered to be the most stable and essential source of short-term funding for banks due to the ease with which dealers can access large-scale short-term funding through it. Short-term debt is always considered to be a critical factor in the financial crisis (Diamond and Dybvig, 1983, He and Xiong, 2012 and Krishnamurthy, Nagel and Orlov, 2014), and there has been intense debate in the literature about what role the repo market played during the 2008 financial crisis. For instance, Gorton and Metrick (2010, 2012) document the tri-party repo market might play a central in the 2008 financial crisis by showing there is a rise in margin requirements in the repo market which leads to "borrowers run". They assume that non-depository financial institutions packaged long-term and illiquid assets, including residential mortgages, auto loans, and credit card loans, as collateral to private-label asset-backed securities (ABS) so that they could use these assets as collaterals to borrow from the repo market. As a result, when the market condition became risky in 2007, lenders in the repo market ran away and the market collapsed.

However, Copeland, Martin and Walker (2014) examine tri-party repo dataset of confidential data, including both repo volume and margins and they find that margin remain stable in the tri-party repo market remain stable, with the exception of Lehman Brothers, signaling the absence of a widespread "repo runs" during the recent financial crisis. Krishnamurthy, Nagel, and Orlov (2014) study the tri-party repo market by using SEC filing data money market mutual funds and securities lenders and find that margins appear mostly stable in the tri-party repo market during the financial crisis, but they stopped accepting private ABS as collateral during periods of stress. In summary, there is no general consensus on whether the repo market act as a significant contributor in accelerating the 2008 financial crisis, and whether repo market is a source of financial instability during the liquidity stressed period

[8] The statistics is from the Tri-party Repo Infrastructure Reform Task Force of Federal Reserve.

remains a puzzle.

The repo market allows banks to use their securities to fund liquidity demand and to smooth liquidity shock with low costs. Liquidity is therefore a key driver for banks to participate in repo market.

According to Copeland, Walker and Martin (2014), when clients withdraw their assets from dealers, dealers are exposed to liquidity stress, which triggers increased perception of the dealer's riskiness[9]. And the dealers will sell collaterals in the repo market with the aim to raise short-term liquidity. As a result, we should expect an increase in market perception of riskiness to be associated with an increase (decrease) in repo (reverse repo) volumes. Moreover, dealers with an increase in the market's perception of riskiness should also associate with a decrease (increase) in the repo (reverse repo) rate in the repo transactions. Because repo rate represents the cost of short-term funding in these transactions, dealers with higher levels of liquidity concerns will be less likely to participate in repo transactions or will participate but with a higher reverse repo rate, and vice-versa.

Repo rates, rather than repo spreads, are selected as major topic in this research out of considerations in three aspects. Firstly, spread data in the US are kept as a confidential dataset and are not available to the public. Secondly, the only collateral types used in repo transactions are government securities, including Treasury Bills, agency MBS and other agency securities. Spreads on these collateral types are quite stable during the post-crisis period. Thirdly, the large increase in the spread at dealer level seldom appeared until few days before its collapsed. For instance, the repo spread for Lehman Brother does not increase until 5 trading days before its collapsed, according to Copeland, Walker and Martin (2014).

To examine the effects of dealer's riskiness on both repo volumes and repo rates, this research follows Copeland, Walker and Martin (2014)'s methodology of examining the effects of perception of a dealer's riskiness, which is measured by dealers' credit default swaps (CDS), as the following equation (1) and (2) shows.

$$log\left(Volume_{d,i,t}\right) = c + \alpha_1 \, log\left(CDS_{i,t-1,}\right) + \alpha_2 \, log\left(CDS_{i,t-1,}\right)^2 + \sum_{k=1}^{h} I_{k=}Colltype_{i,t}\gamma_k + Bank\ control\ variables + Quarter\ fixed\ effects + Dealer\ fixed\ effects; \quad (3\text{-}1)$$

[9] As described in Duffie (2011), Lehman Brothers lost clients, which makes Lehman could no longer use these securities as collaterals in the repo transactions before its collapsed. In order to remedy this situation, Lehman sold collaterals in the repo market to raise short-term liquidity.

$$\log\left(Rate_{d,i,t}\right) = c + \alpha_3 \log\left(CDS_{i,t-1,}\right) + \alpha_4 \log\left(CDS_{i,t-1,}\right)^2 + \sum_{k=1}^{h} I_{k=}Colltype_{i,t}\gamma_k + Bank\ control\ variables + Quarter\ fixed\ effects + Dealer\ fixed\ effects. \quad (3\text{-}2)$$

The dependent variable is the repo volume or the repo rate of collateral d for dealer i at day *t*, $CDS_{i,t-1,}$ denotes the credit default swap spread for dealer *i* at day *t-1*. While $I_{k=}Colltype_{i,t}\gamma_k$ are the dummies of collateral type including Treasury Bills, agency MBS and other agency securities. In addition, bank control variables are included in each regression, including total assets in log, equity to assets, return on equity and liquidity ratio. Quarter fixed effects and dealer fixed effects are also included.

The dataset used in this chapter is a transaction-level dataset of repo transactions provided by the Federal Reserve Bank of New York, in which the Fed is always a party and the primary dealers are the counterparties. During the post crisis period (2010:Q2-2019Q4), the Fed conducted reserve repo transactions[10], that is, transactions that drain liquidity from dealers. And the transaction was under a bid-ask mechanism.

This research begins with the hypothesis that market's perception of dealer's riskiness negatively affect reverse repo trading volumes, as measured by the credit default swap spreads (CDS spreads) of dealers. This is because when the market's perception of a dealer's risk will increase when the dealer is exposed to an "asset pull" or other liquidity event from a customer. Therefore, to preserve their short-term liquidity, dealers should reduce their participation in reverse repo transactions, which is reflected in the reduced volume of reverse repo transactions in the post-crisis period, as illustrated in Hypothesis I below.

Hypothesis I: *Dealers with higher risk perception participate less in the repo transaction (*$\alpha_1 < 0$*), during the post-crisis period.*

Furthermore, this chapter also assumes that market perceptions of dealers' riskiness will positively affect reverse repo trading rates, as measured by the dealer's credit default swap spread (CDS spread). This is because in the post-crisis period, dealers with higher degree of riskiness should only accept reverse repo transactions with a higher return, which is reflected in an increase in repo rates, as shown in Hypothesis II below.

Hypothesis II: *Dealers with higher risk perception participate in repo transaction with higher*

[10] In the reverse repo transactions conducted by the Fed, Fed sells collaterals to dealers thus draining liquidity from the dealers.

rate $\alpha_3 < 0$*, during the post-crisis period.*

During the starting quarter of the COVID-19 pandemic (2020:Q1), as a response to growing concerns about liquidity conditions, the Federal Reserve announced a series of increases in the size of its repo operations. Federal Reserve offered term repo at $500 billion and overnight repo for $175 billion, according to Carlson, Saravay and Tian (2021)[11]. As the repo transaction provides liquidity to dealers, this research hypothesizes that when the study splits the sample by running regressions in the starting quarter of the COVID-19 pandemic, an increase in the market's riskiness to dealers will have a positive impact on repo trading volumes. This is because dealers with higher levels of riskiness is expected to borrow more funds through the repo market. Alternatively, the repo rate can be viewed as a cost of borrowing, and therefore riskier dealers are also expected to borrow at a higher repo rate, as shown in Hypothesis III below.

Hypothesis III: *An increase in the market's perception of dealer's riskiness has a* ***positive*** *impact on the repo transaction volume (*$\alpha_{1-pandemic} > 0$*), and a positive impact on the repo transaction rate (*$\alpha_{3-pandemic} < 0$*), in the pandemic starting quarter.*

In the next section, the literature discussing bank liquidity and its measurement is presented.

3.2.2 Bank Liquidity and its measurement

It has been suggested by theory that bank liquidity makes significant difference in financial crises. The classical theoretical model raised by Diamond and Dybvig (1983) suggests the mismatch between assets illiquidity and the liability liquidity makes banks vulnerable to the "depositors run" in a panic and will lead to disruption of monetary policy system and a reduction in production. As a result, regulators conduct different policies with the aim to improve the bank liquidity condition, in order to preventing the occurrence of crisis or to mitigate the effects of crisis.

One of the most important frameworks of bank liquidity management is BASEL III, which requires banks to implement minimum liquidity standards for commercial banks, including the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR), according to BIS (2013 and 2014). Moreover, in the US, the Federal Reserve conducts annual liquidity stress tests - Comprehensive Liquidity Assessment and Review (CLAR) on large banks to prevent future crisis (Fed, 2019). In

[11] Federal Reserve starts to conduct repos as the funding markets experienced significant pressures in 2019 Sept, and the volume growing significantly during the pandemic.

addition to regulatory tools, during the 2008 financial crisis, when banks encountered extreme liquidity stress, the Federal Reserve conducted unprecedented liquidity provision of up to $1.5 trillion by implementing open market operations, large-scale asset purchase programs and Term Auction Facility (TAF), according to Fleming (2012).

The existing literature has mainly studied and evaluated these policies by developing a theoretical framework based on Diamond and Dybvig (1983) bank model (Brunnermeier 2009, Perotti and Suarez, 2011 and Caballero and Krishnamurthy, 2014).

A novel liquidity measurement methodology, Liquidity Mismatch Index (LMI), is proposed by Bai, Krishnamurthy and Weymuller (2018). The LMI is built on the earlier theoretical framework by Brunnermeier, Gorton, and Krishnamurthy (2012), and aims to capture the mismatch between market liquidity of assets and funding liquidity of liabilities of banks. LMI assumes the depositors will act adversely and extract cash as much as possible (liability side liquidity) and banks will raise liquidity by selling their assets (asset side liquidity). The LMI is the difference between these two amounts. Bai, Krishnamurthy and Weymuller (2017) calculate the bank-level LMI from 2002 to 2014 by using bank Consolidated Reports of Condition and Income (Call Report). This index successfully captures the period of tight bank liquidity in 2008 when aggregate LMI fell from $4 trillion to -$6 trillion. They found that this index has strong explanatory power for bank lending decisions and future risk of bank crash.

LMI has been widely adopted. For instance, Silva (2019) studies whether banks consider their competitors' liquidity mismatch policies when making decisions, by using LMI of a bank to predict the decisions of its competitors. Marozva (2020) investigates the impact of bank liquidity risk, as measured by LMI, on credit risk in the South African banking system. While Kapoor and Peia (2021) use LMI as an indicator to assess the effectiveness of three rounds quantitative easing (QE) from 2008-2014. Unfortunately, no studies investigating the relationship between bank liquidity risk and the repo market have been identified. As described in the previous sub-sections, the repo market is one of the most stable sources of short-term liquidity for banks and therefore this research question is critical and needs to be answered.

3.2.3 Liquidity condition and repo market behavior during the COVID-19 pandemic

The COVID-19 pandemic inflicts a server downturn of uncertain duration in the US. To contain the pandemic, the US government enacted numerous strategies including social distancing, national quarantines, and shutdown of non-essential businesses. Banks faced with unprecedented scale liquidity demand as firms and households drew funds from bank credit lines[12] (Li, Strahan and Zhang, 2020 and Gounopoulos, Luo, Nicolae and Paltalidis, 2021).

In the March 2020, the Federal Reserve increased the size of its repo operations in response to the tight liquidity conditions, more details of which can be found in Figure B3, where the outstanding amount of repo on the part of the Fed is shown. A notable change during the COVID-19 pandemic is Federal Reserve conducts more term repos rather than overnight repos, compared to normal period.

[Please insert Figure B3 here]

Several studies have investigated how repo market functioned during the COVID-19 pandemic and have assessed the effects of the policy conducted by the Fed. For example, Roberts-Sklar and Baines (2020) find that during the first phase of the COVID-19 pandemic, non-bank dealers experienced increased demand for short-term funding and borrowed more cash through the repo market. Giese and Haldane (2020) argue that bank became shock absorbers during the pandemic because the liquidity condition improved before before the 2019:Q4 crisis occurred. An important finding among these papers is during the pandemic, non-bank dealers relied more on and lent more from the repo market, compared to the bank dealers.

In addition, Huser, Lepore and Veraart (2021) find that banks borrow more via the tri-party repo market than bilaterally given that the tri-party market is more attractive because it is less capital-intensive. Eren, Schrimpf and Sushko (2020) also uncover evidence to support that the clearing market is preferred by dealers in the US dollar funding market during the COVID-19 pandemic.

These studies successfully capture the dynamics of repo market during the COVID-19 pandemic. However, given the scarcity of repo market data (Gorton et al., 2020), these studies have failed to evaluate the impact of the repo operations conducted by the Federal Reserve by constructing the relationship among the riskiness of dealers, liquidity condition of banks and dealer-level repo volumes and repo rate.

As noted earlier, LMI measures the mismatch between the market liquidity of banks' assets and the funding liquidity of their liabilities, and this index has been used widely in policy evaluation and

[12] Evidence can be found in the increase in credit card loan, Commercial and Industrial loan (C&I loan) and unused commitments from Call Reports.

bank behavior prediction. However, the relationship between bank's LMI and its behavior in repo market remains unanswered and there is no empirical study to investigate the relationship between bank liquidity risk and the repo market. This chapter therefore explore how bank liquidity shocks, as measured by LMI, will affect banks' repo volumes and interest rates.

With the goal to answer this question, this research runs the following two regressions:

$$\log\left(Volume_{d,i,t}\right) = constant + \alpha_5 \log\left(LMI_{i,q-1,}\right) + \sum_{k=1}^{h} I_{k=}Colltype_{i,t}\gamma_k + Bank\ control\ variables + Quarter\ fixed\ effects + Dealer\ fixed\ effects; \quad (3\text{-}3)$$

$$\log\left(Rate_{d,i,t}\right) = constant + \alpha_6 \log\left(LMI_{i,q-1,}\right) + \sum_{k=1}^{h} I_{k=}Colltype_{i,t}\gamma_k + Bank\ control\ variables + Quarter\ fixed\ effects + Dealer\ fixed\ effects. \quad (3\text{-}4)$$

where the $LMI_{i,q-1,}$ is the Liquidity Mismatch Index at quarter *q-1* for bank *i*. The reason for the quarterly frequency here is that the index is constructed by using Call Report, which is a quarterly data source. According to Bai, Krishnamurthy and Weymuller (2018), a decrease (increase) in LMI indicates a worse (better) liquidity condition of the bank. As a result, this chapter hypothesizes a positive relationship between LMI and the reverse repo volume for bank dealers during the post-crisis period. This applies because banks with negative liquidity shocks (decreasing LMI) should participate less in reverse repos conducted by the Federal Reserve, as the following Hypothesis IV shows:

Hypothesis IV: *Banks with higher Liquidity mismatch index participate more in repo transactions (*$\alpha_5 < 0$*), during the post-crisis period.*

Similarly, this study hypothesizes a negative correlation between LMI and reverse repo rate for bank dealers during the post-crisis period. Such correlation is made due to the fact that banks with deteriorating liquidity conditions (lower LMI) are expected to participate in reverse repo transactions at higher returns (repo rates), as shown in Hypothesis V below.

Hypothesis V: *Banks with higher Liquidity mismatch index participate in the repo transaction with lower rates (*$\alpha_6 < 0$*), during the post-crisis period.*

In the starting quarter of the COVID-19 pandemic (2020:Q1), the Federal Reserve conducted a large number of repo instead of reverse repo transactions, as described earlier. The study hypothesizes a negative correlation between LMI, and the volume of repo transactions in which banks participate, because as banks with worsening liquidity conditions are expected to borrow more through the repo market. In addition, banks tend to borrow at a higher cost (repo rate), as suggested by Hypothesis VI:

Hypothesis IV: *Banks with higher Liquidity mismatch index participate less in the repo* *transactions* ($\alpha_{5-pandemic} < 0$)*, and with high rates* ($\alpha_{6-pandemic} < 0$)*, in the starting quarter of the pandemic.*

3.3 Data

Data (including data sources) and summary statistics used in the study are presented in Section 3.

3.3.1 Data description

Tri-party Repos transaction level data: Data at the triparty repo transaction level, including volumes and rates, are collected from the Federal Reserve of New York Bank and include both repos and reverse repos transaction from 2010:Q3 to 2020:Q1 with a daily frequency.

In these transactions, the Federal Reserve acts as one party, a third party (the tri-party bank) acts as a custodian and 78 primary dealers act as counterparties. Three types of collateral are used, including: Treasury Bill, agency MBO and other agency collaterals. It is also worth mentioning that this dataset is reported with a 2-year lag.

Credit Default Swap data: Credit Default Swap (CDS) spreads data is from Markit, a financial information service company. The data is collected from 2010:Q3 to 2020:Q1 at daily frequency. Different maturities of CDS spreads including 6-month, 1-year, 3-year, 5-year and 10-year are used in this chapter.

Call Report data: Call Report from Financial Institutions Examination Council's (FFIEC) is used in this research. The sample period is 2010:Q3 to 2020Q1, with quarterly frequency. This chapter collects bank control variables, namely total assets, equity to assets, return on equity and liquidity ratio identifies whether a dealer is a bank dealer or non-bank dealer and constructs Liquidity Mismatch Index (LMI) to measure the liquidity condition of banks by using the information from Call Report data. Appendix III provides details on constructing LMI.

3.3.2 Sample selection Strategy

Regarding the sample selection strategy, we choose the sample period from 2010:Q3 to 2020:Q1 because this is the maximum length of sample period that we can obtain from the Federal Reserve

Bank of New York, which is the unique transaction level data source of US repo market until now. Although the data is provided at daily frequency, only large dealers are included. Then, we merge the tri-party transaction level data with the Credit Default Swap data provided by the Markit. Both data frequencies are in daily. Then we calculate the LMI for 28 bank dealers and merge with tri-party repo market data. We also examine. Finally, the data in the range of 1%-99% were carefully checked and adjusted for any errors within these outliers.

Following Copeland, Martin and Walker (2014), we construct our economic model in this chapter. Two significant differences are: i) we are studying the post-crisis period and the starting quarter of the pandemic while they are studying the 2008 financial crisis period; ii) besides controling for collateral types and dealer fixed effects, our model also takes time fixed effects into account.

3.3.3 Summary Statistics

[Please insert Table 3.1 here]

Table 1 presents the summary statistics used in this study. The CDS spread, repo amounts and repo rates are reported under the "daily frequency variables". Bank-level financial variables are reported under the "quarterly frequency variables". In this chapter, we manually merge the CDS dataset from Markit and the Tri-party repo market dataset from the Federal Reserve of New York Bank. Observations for which CDS data are not available are excluded from this study.

[Please insert Table 3.2 here]

Table 3.2 presents the pairwise correlation matrix of the key variables in Chapter 2. It can see that the estimated model does not show multicollinearity. A t-test is also carried out on the means of the variables to see if they are statistically significantly different. The results are shown in Table 3.4B in the Appendix B. It is shown the mean of most variables are significantly different between the pre-pandemic period and during the pandemic. More precisely, the means of repo rate, repo amount, 6-month, 1-year, 3-year CDS spreads are significantly higher during the pandemic, while the 10-year CDS spread is lower during the pandemic.

3.4. Empirical Investigation and Results

With the goal to answer the research questions and to test the hypotheses introduced in Section 3.3, empirical investigations are executed, and the results are provided in this section.

3.4.1 Repos volume and dealer's riskiness – post-crisis episode

Can changes in the market perception of dealer's riskiness explain the changes in repo volumes? This chapter begins with a regression with all dealers during the post-crisis period (2010:Q2-2019:Q4) based on Eq. (3-1) as discussed in Section 3.4, the results of which are presented in Table 3.3.

[Please insert Table 3.3 here]

As can be seen in Table 3.3, market perceptions of dealer riskiness has strong explanatory power for repo volumes. The estimated coefficients on the log of the CDS spreads are all statistically negative ($\alpha_1 < 0$), suggesting that an increase in the perception of risk for dealers explains the decrease in the volume of reverse repos they traded during the post-crisis period, which is consistent with our expectation. In addition, the coefficients of bank dealer dummy are significantly negative (in the regressions without dealer fixed effects), indicating this effect is stronger for bank dealers, who are more sensitive to changes in market perceptions of riskiness. For instance, every 1% increase in the log of the 6-month CDS spread predicts a 1.66% decrease in the repo amount transactions undertook by the dealers[13].

To ensure the change in market perceptions of dealer riskiness has a heterogenous effect on bank dealers and non-bank dealers, this chapter combines the sample by splitting it into bank and non-bank dealers using information from Call Report and separate regressions are also conducted. Table 3.4 shows the results for non-bank dealers, while Table 3.5 shows the results for bank dealers.

[Please insert Table 3.4 here]

[Please insert Table 3.5 here]

As can be seen in Table 3.4 and Table 3.5, the estimated coefficients on the log of the CDS spreads for the non-bank dealers are still negative but insignificant ($\alpha_{1\,non-bank\,dealers} < 0$, for example, a 1% increase in 6-month CDS spreads for non-bank dealers is associated with a 1.10% decrease in repo transactions. In contrast, the coefficients for bank-dealers remain negative and significant ($\alpha_{1\,bank\,dealers} < 0$), 1% increase in the 6-month CDS spread is associated with 9.12% decrease in the repo transaction amount . These results suggest Hypothesis I holds by confirming the change in

[13] The effects are calculated by (1.01^coefficient-1) *100 as both dependent and independent variables after log transformation.

market's perception of dealer's riskiness plays a role in the change in reverse repo volume the dealer participate in.

However, in the absence of better data, we cannot precisely examine the reasons why dealer riskiness has a different impact on reverse repo volumes for bank dealers and non-bank dealers. One possible answer is that the non-bank dealers in this tri-party repo market are large mutual funds such as Dreyfus and Fidelity. These non-bank dealers have higher risk tolerance compared to bank dealers, according to Gorton and Metrick (2012).

3.4.2 Repos rate and dealer's riskiness– post-crisis episode

Turning to the relationship between the market perception of dealer's riskiness and the repo rate, this chapter estimates equation (2) as discussed in Section 3.3. And the results are shown in Table 3.6.

[Please insert Table 3.6 here]

The results in Table 3.6 indicate that positive significant coefficients are found when using shorter maturity CDS spreads (1-year and 3-year) as independent variables ($\alpha_{3\ shorter\ maturity\ CDS\ spreads} > 0$), however, the coefficients are negative significant when using longer maturity CDS spreads (5-year and 10-year) as independent variables ($\alpha_{3\ longer\ maturity\ CDS\ spreads} < 0$). For example, a 1% increase in the 6-month CDS spread can only predict a negligible 0.003% increase in the reverse repo rate. However, a 1% increase in the 3-year CDS spread only predict a 2.206% increase in the reverse repo rate, which is relatively large and significant. These results implicitly suggest that short term CDS has a much more prominent effect in determining the reverse repo rate conducted by dealers.

Again, the sample is divided into two subsamples, namely bank dealers and non-bank dealers, and regressed separately.

[Please insert Table 3.7 here]

[Please insert Table 3.8 here]

Table 3.7 and Table 3.8 show the results. The coefficients are negative significant for non-bank dealers ($\alpha_{3\ non-bank\ dealers} < 0$), but positive significant for bank dealers ($\alpha_{3\ bank\ dealers} > 0$) for all maturities except the 10-year CDS spread. These results suggest that Hypothesis II holds, but only for bank dealers. For instance, a 1% increase in 5-year CDS spread is associated with an 8.206% decrease in repo rates for non-bank dealers. However, for bank-dealers, the effect is positive, which is 3.325%.

These results reinforce the claim in Section 5.1 that market perceptions of dealer riskiness have a heterogeneous effect on both banks and non-dealers in terms of volume and interest rates.

Combined with the results in 3.5.2, this study finds that changes in market perceptions of dealer riskiness have strong explanatory power for both reverse repo volume and rate, and have a greater impact on bank dealers. Some studies have shown that non-bank dealers (mainly hedge funds) will not increase their reliance on the repo market for their short-term liquidity needs until 2019 ((Roberts-Sklar and Baines, 2019) or until the COVID-19 pandemic (BOE, 2020), possibly hinting at why the sign of the coefficient α_3 differs between for non-bank and bank dealers.

3.4.3 Repo market and Liquidity Mismatch Index (Bank dealers) – post-crisis episode

Can liquidity condition explain the volume of collateral and rates of bank dealers involve in tri-party repo market? To answer this question, the following equation is run specifically in this study, which has been discussed in Section 3.3 already:

[Please insert Table 3.9 here]

The results in Table 3.9 suggest bank liquidity condition have a positive effect on the volume of repos ($\alpha_5 > 0$). It is found that a 1% increase in the LMI (an improvement in the liquidity condition) can explain a 0.025% increase in the reverse repo volume dealers transact with the Fed, with quarter fixed effects only (or a 1.018% increase in the reverse repo volume with bank-year fixed effects). The results suggest Hypothesis IV holds.

Notably, only bank traders are included in the LMI regressions according to Bai, Krishnamurthy and Weymuller (2018), this index is intended to measure the exposure of banks' exposure to liquidity stress events. And these results re-emphasize the view that US banks are using repo market as a key source of short term financing market (Gorten and Metrick, 2012), showing that banks adjust their reverse repo transaction volume sensitively according to their liquidity condition (LMI), as both estimated coefficients are significant at the 1% level. In addition, these results also support the view that banks tend to maintain liquidity in the face of adverse liquidity shocks for precautionary reasons (Afonso, Kovner and Schoar, 2011).

Furthermore, a regression of Eq. (3-4) is run to investigate the relationship between repo rates and

Liquidity Mismatch Index (LMI):

[Please insert Table 3.10 here]

As can be seen from the results in Table 3.10, the coefficients of Liquidity Mismatch Index (LMI) are insignificant and small, indicating that bank liquidity condition, as measured by the LMI, has little explanatory power on the repo rates. The effect is insignificant and close to zero, and these results suggest that Hypothesis V does not hold during the post-crisis period. Combined with the results in Table 3.9, this chapter finds banks are more concerned with repo volumes rather than rates during the post-crisis period.

3.4.4 Repos volume and dealer's riskiness – COVID-19 pandemic episode

The COVID-19 pandemic brought about a server downturn and an uncertain prospect in the economy. Banks in the US faced the shock head-on, which caused a sharp increase in loan, and their liquidity came under pressure in the first phase of the pandemic. In this sub-section, we investigate the relationship between Repos volume and dealer's riskiness at transaction level in the first quarter of 2020, which is the starting quarter of COVID-19 pandemic, to examine how the changes in the market's perception of dealer's riskiness can affect the changes in repo volume. This research re-estimates equation (1), but only with the observations in first quarter of year 2020.

[Please insert Table 3.11 here]

Table 3.11 demonstrates the results. It can be find that, contrary to the results in table 3.2, the estimated coefficients on the log of the CDS spreads are statistically positive and is associated with dealer and month fixed effects, suggesting that an increase in market perceptions of dealer riskiness has a positive impact on the repo transaction volume $(\alpha_{1-pandemic} > 0)$. For instance, a 1% increase in the 6-month CDS spread can forecast a 3.177% increase in the repo transaction amount, an effect that is much higheras compared to the post-crisis period. Compared to the results in Table 3.3, the sign of coefficients reverts. The sign reversion is explained by the fact that the Federal Reserve conducted a large number of repo transactions, up to $675 billion, in 2020:Q1, injecting liquidity into the banking system. As for the coefficients on bank dealer dummies, they are all negative significant, suggesting that bank dealers are less sensitive to non-bank dealers.

Furthermore, the sample is split into non-bank traders and bank traders again and then regressed separately.

[Please insert Table 3.12 here]

[Please insert Table 3.13 here]

Table 3.12 and Table 3.13 present the results. The estimated coefficients are significantly positive for non-bank dealers ($\alpha_{1-pandemic\, non-bank} > 0$) however negative significant for bank dealers ($\alpha_{1-pandemic\, bank} < 0$). Indeed, Giese & Haldane (2020) claim that US banks are acting as shock absorbers at the first phase of the pandemic, given that both of their capital and liquidity conditions improved prior to the pandemic (2019:Q4). And the large increase in deposit growth prior to the pandemic (Gounopoulos, Luo, Nicolae and Paltalidis, 2021) could also explain why there is no positive correlation between bank dealers' CDS spreads and repo volumes.

Turning to non-bank dealers, the positive coefficients indicate non-bank dealers with higher market perception of riskiness tend to borrow more through the repo market in the starting quarter of the pandemic. For example, a 1% increase in 6-month CDS spreads for non-bank dealers leads to a 6.620% increase in repo volume for non-bank dealers. It is worth of noting that the non-bank dealers are faced with server liquidity pressure ("dash for cash") as investors chose to "flight to safety" in the first phase of the pandemic as the degree of uncertainty increased, according to Falato, Goldstein and Hortacsu (2021)[14] and Breckenfelder and Hoerova (2022).

3.4.5 Repos rates and dealer's riskiness – COVID-19 pandemic episode

In addition, a regression of Eq. (3-2) is applied to investigate the relationship between repo rates and dealer riskiness, but only for the 2020:Q1 observations.

[Please insert Table 3.14 here]

The findings are presented in Table 3.14. The negative coefficient ($\alpha_3 < 0$) between repo rates and CDS indicates that the market perceived riskier dealers to borrow from the repo market at a lower cost in the starting quarter of the pandemic (2020:Q1). This result reflects the effectiveness of the

[14] Investment funds on US corporate bond market experienced cumulative outflows of about 10% of net asset value in the 2020:Q1, compared to a 2.2% on average, according to Falato, Goldstein and Hortacsu (2021).

Federal Reserve's repo operations to avoid a liquidity crunch. Again, the entire sample is split into two subsamples, namely non-bank dealers and bank dealers, and we re-estimate the coefficients from the previous regressions.

[Please insert Table 3.15 here]

[Please insert Table 3.16 here]

Table 3.15 and Table 3.16 demonstrate the results. It is observed that the estimated coefficients of CDS spreads are positive significant for non-bank dealers ($\alpha_{3-pandemic\,non-bank} > 0$) but negative significant for bank dealers ($\alpha_{3-pandemic\,bank} < 0$), suggesting that non-bank dealers with higher degree of riskiness pay higher costs for borrowing but bank dealers do not. These results strengthen the findings in Sub-section 5.4 that bank dealers function as shock absorbers during the first phase of the COVID-19 pandemic as they accumulate strong liquidity and capital conditions prior to the pandemic. Non-bank dealers, on the other hand, rely more on the repo market during the pandemic. As a result, it is suggested that Hypothesis III holds for the non-bank dealers only.

3.4.6 Repos market and bank's Liquidity Mismatch Index (LMI) – COVID-19 pandemic episode

Lastly, this chapter investigates whether the Liquidity Mismatch Index (LMI) contributed to banks' repo volumes and rates during the COVID-19 pandemic episode. Further details are provided in Eq. (3-3) and Eq. (3-4):

[Please insert Table 3.17 here]

[Please insert Table 3.18 here]

Table 3.17 finds a negative relationship ($\alpha_{5-pandemic} < 0$) between LMI and the repo volume, suggesting that banks subject to adverse liquidity shock (decrease in LMI) tend to borrow more through the repo market. However, with bank and month fixed effects, this effect is significant only at the 10% level. For the relationship between LMI and repo rate, Table 3.18 suggests that changes in LMI in the starting quarter of the pandemic (2020:Q1) do not significantly affect bank dealers' repo rates. Therefore, Hypothesis VI does not hold.

3.4.7 Robustness check without second order polynomial CDS variables

In Copeland, Martin and Walker (2014), the regressions include both the first-order lag of credit default swap (CDS) and the second-order lag polynomial of CDS. This study follows the identification method of Copeland, Martin and Walker (2014). However, it is found that the relationship between repo variables and credit default swap is linear (neither convex nor concave). A few tables are provided from Table 3.5B to Table 3.8B from the Appendix B to show that the conclusion will not change excluding the second order polynomial CDS variables. Several hierarchical scatter plots have also been generated for the main variables used in this chapter, as can be seen in Table 3.9B in the appendix.

3.5. Conclusion

Finally, this chapter examines how US repo market operates during the post-crisis and the starting quarter of the COVID-19 pandemic. Firstly, the Federal Reserve conducts reverse repos (draining liquidity) on a daily basis during the post-crisis period, but conducted a large number of repos (injecting liquidity) during the COVID-19 pandemic. Secondly, empirical results during the post-crisis period reveal that bank dealers with a higher perception of riskiness in the market (as measured by CDS spreads) reduce reverse repo volumes or only accept transactions with higher interest rates in order to maintain liquidity. However, non-bank dealers do not submit to this effect. With respect to the starting quarter of the pandemic, that the liquidity position and capital position of bank dealers improve prior to the pandemic, our results suggest the non-bank dealers rely more on the repo market to fund their liquidity demand, as compared to bank dealers. Thirdly, this chapter investigates whether a new measure of banks' liquidity position, the Liquidity Mismatch Index (LMI), can explain banks' repo volume and rate. The findings in this study demonstrate that LMI has good explanatory power during the post-crisis period, however, it has little explanatory power in the start quarter of the pandemic, particularly for repo rates.

Copeland, Martin and Walker (2014) study the US repo market operation by using the confidential data. They conclude that, prior to the collapse of Lehman Brothers, dealer risk had little impact on repo margins and interest rates. The contribution of this chapter is to demonstrate that the market perception of dealer's risk makes a significant difference in determining the repo amount the dealer undertakes. Moreover, an LMI as proposed by Bai, Krishnamurthy and Weymuller (2018) is used in this study for the first time to investigate whether bank liquidity condition can affect bank's decisions on repo market.

Future research could, for instance, investigate the bilateral repo market as the Office of Financial Research (OFR) is currently conducting data collecting pilot project for bilateral repo market[15]. The US bilateral repo market accounts for half of the overall market and is more vulnerable to runs and fire sales than the tri-party repo market. Thus, studying the bilateral repo market with the data provided by the pilot project might provide a more complete picture of the repo market. In addition, the data set adopted in this study is the tri-party repo market disclosed to the public and includes only government securities as collateral. However, the confidential tri-party dataset[16] includes repo transactions by using a broader set of collaterals such as corporate bonds, equities and municipal debt. A study of the confidential data set will also yield a better understanding of how US repo market operates.

[15] More information on the bilateral repo market data collection pilot project can be found: https://www.financialresearch.gov/data/repo-data/

[16] The confidential tri-party repo dataset is held by Bank of New York Mellon (BNYM) and JP Morgan Chase (JPMC).

Figure B1 (Bilateral) repo transactions mechanism (Source: Created by the author based on the information provided by Federal Reserve Bank of New York)

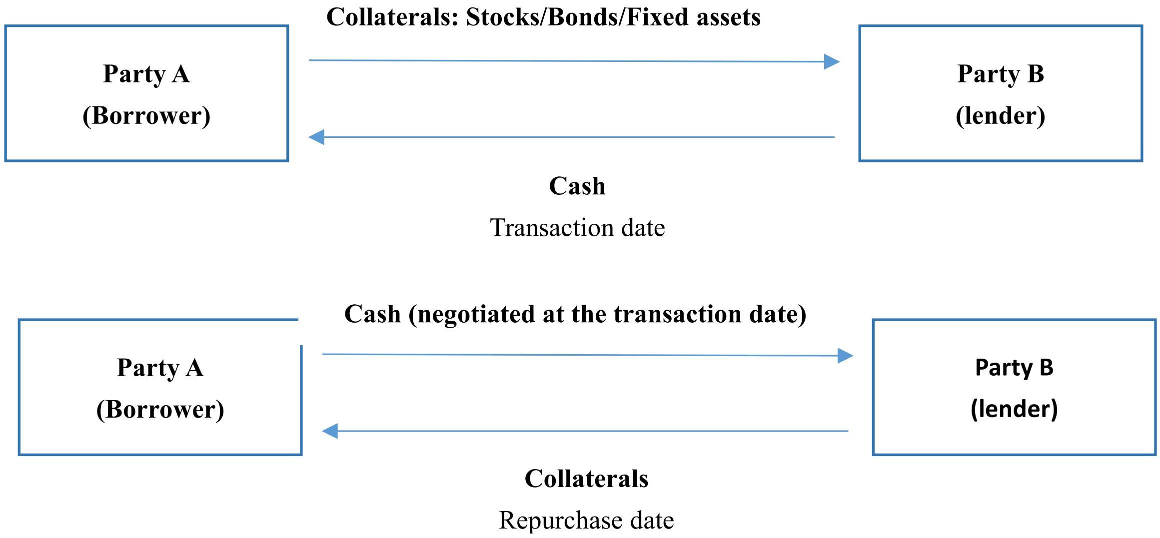


Figure B2. Tri-party repo transactions mechanism (Source: Created by the author based on the information provided by Federal Reserve Bank of New York)

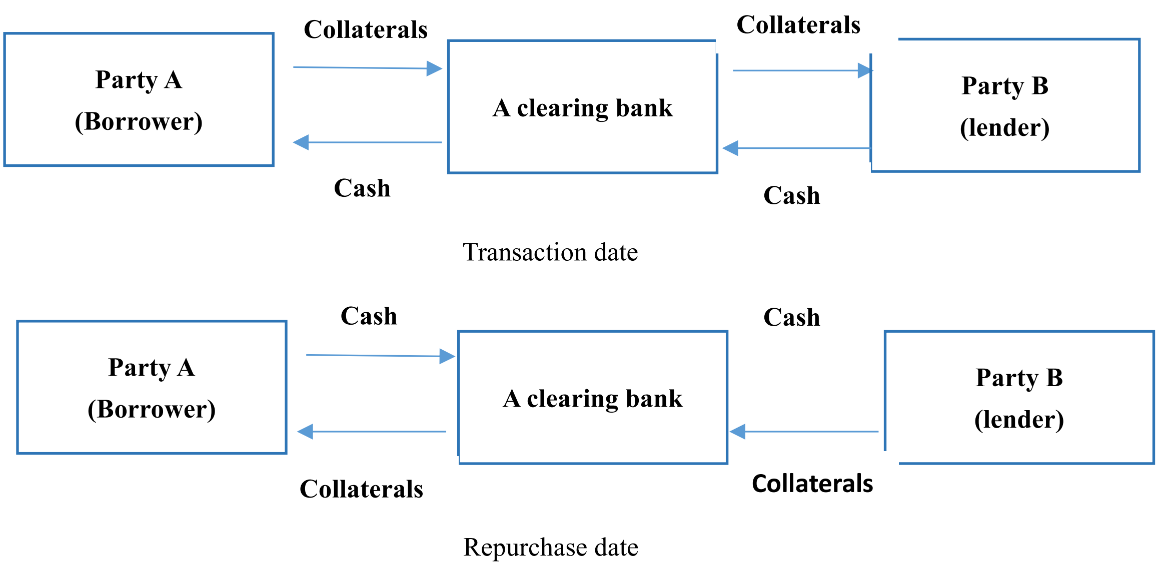
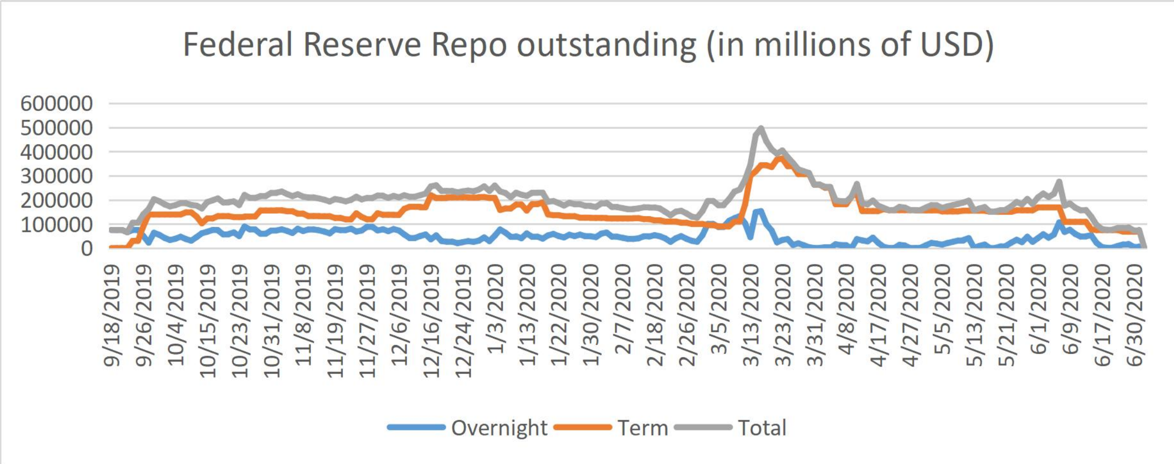
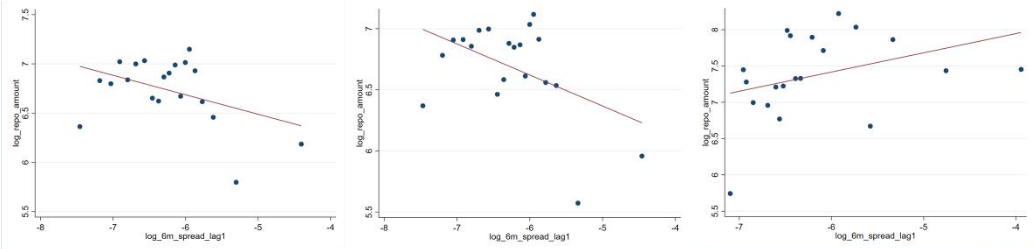


Figure B3. Federal Reserve Repo outstanding (Source: Federal Reserve bank of New York Mellon)

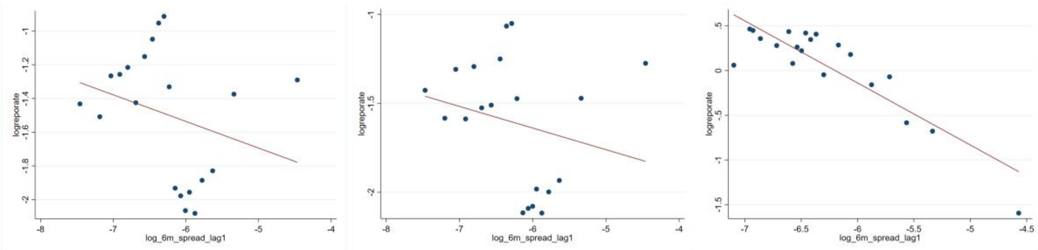


Graph 3.4. Binned scatterplots for key variables

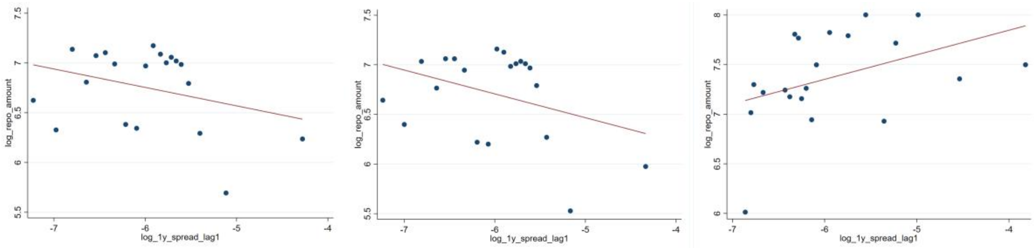
Panel A. Repo amount in log and 6-month CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



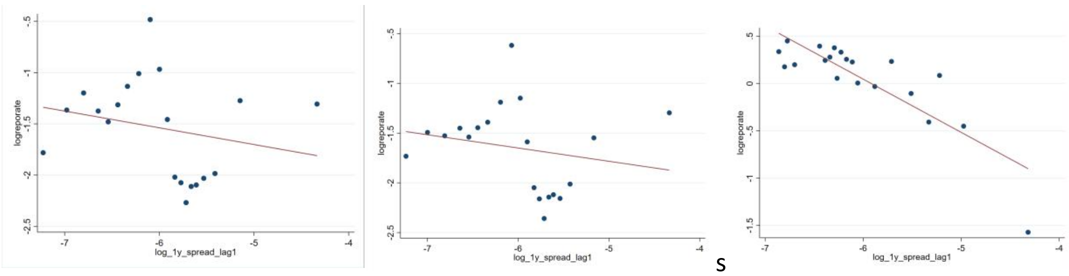
Panel B. Repo rate in log and 6-month CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



Panel C. Repo amount in log and 1-year CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)

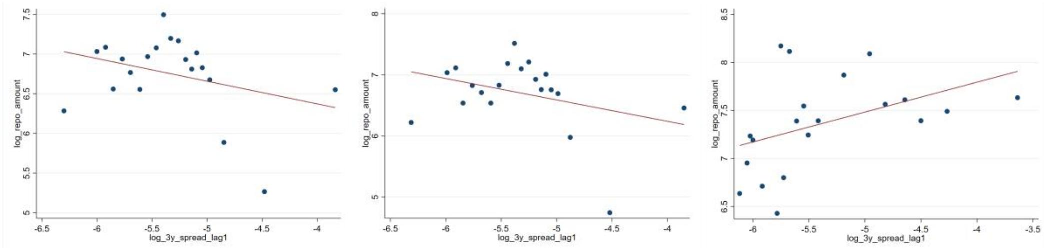


Panel D. Repo rate in log and 1-year CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)

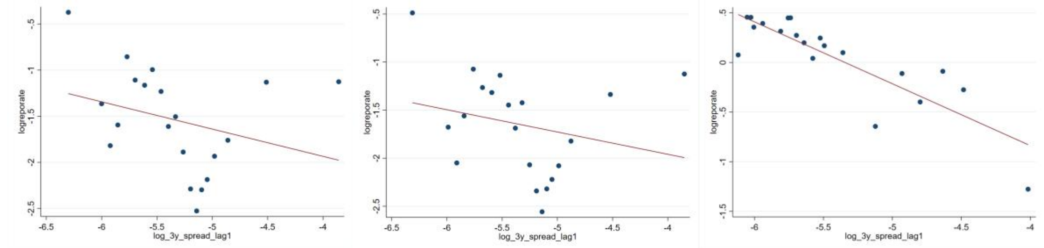


s

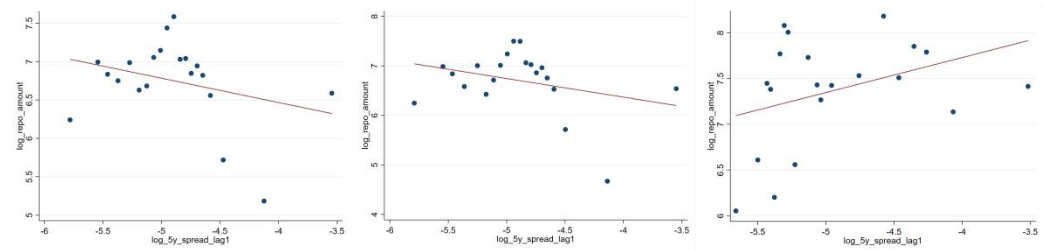
Panel E. Repo amount in log and 3-year CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



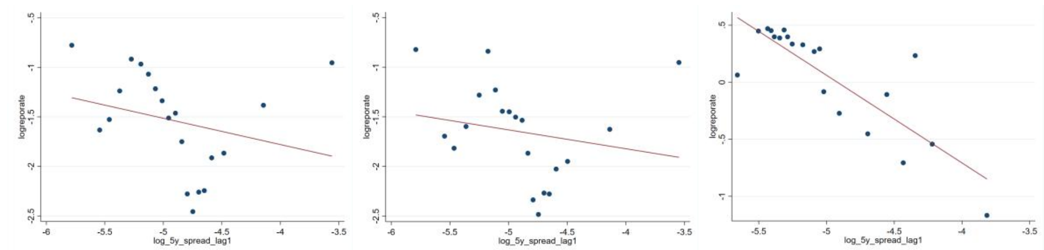
Panel F. Repo rate in log and 3-year CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



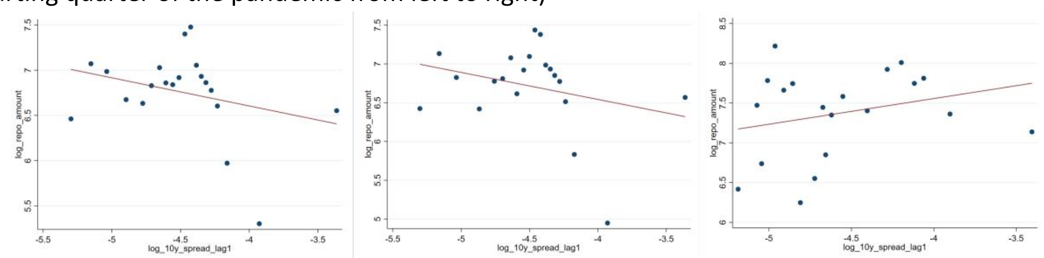
Panel G. Repo amount in log and 5-year CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



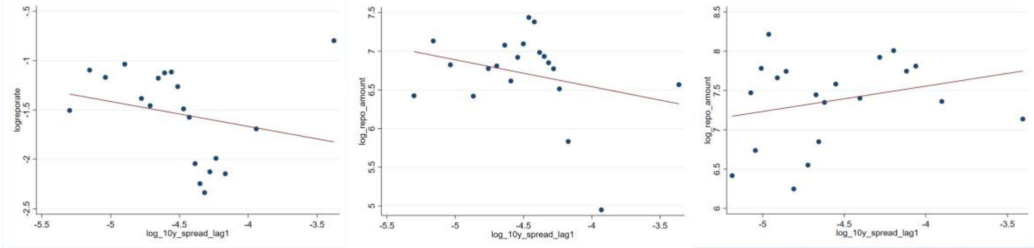
Panel H. Repo rate in log and 5-year CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



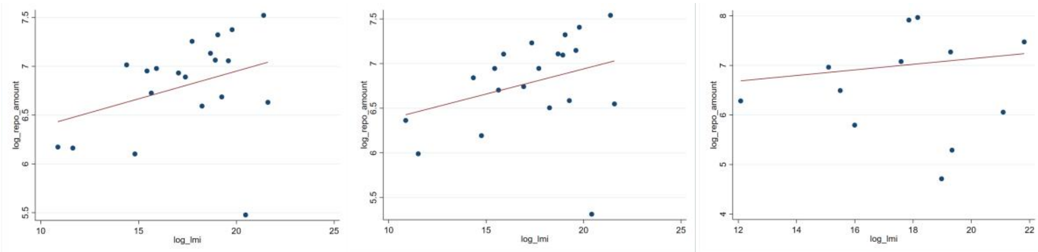
Panel I. Repo amount in log and 10-year CDS spread in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



Panel J. Repo rate in log and 10-year CDS spread in log (whole sample, pre-pandemic andthe starting quarter of the pandemic from left to right)



Panel K. Repo amount in log and LMI in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)



Panel L. Repo rate in log and LMI in log (whole sample, pre-pandemic and the starting quarter of the pandemic from left to right)

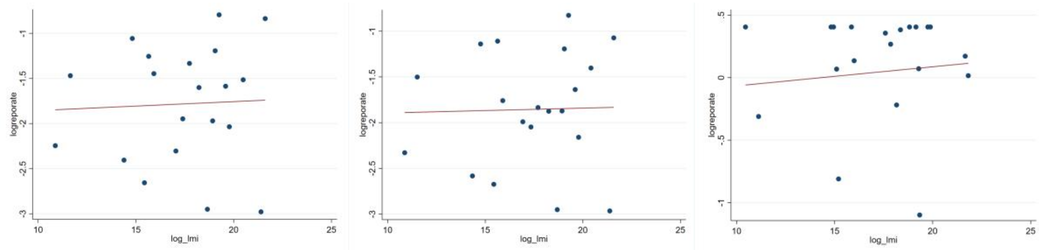


Table 3.1. Summary Statistics

	Summary Statistics of the dataset from 2012 - 2020				
Daily frequency variables	**Numbers of observations**	**Mean**	**Std. Dev**	**Min**	**Max**
Repo Rate (Include both repo and reverse repo, in %)	25419	0.49	0.59	0.00	2.25
Repo Volume (in millions of $)	25419	1,100	2874.02	1	30,000
6-month CDS spread	9274	0.0026	0.0034	0.0003	0.0671
1-year CDS spread	9574	0.0032	0.0036	0.0004	0.0706
3-year CDS spread	9589	0.0047	0.0046	0.0008	0.0714
5-year CDS spread	9588	0.0086	0.0059	0.0015	0.0749
10-year CDS spread	9564	0.0122	0.0066	0.0027	0.0766
Quarterly frequency variables	**Numbers of observations**	**Mean**	**Std. Dev**	**Min**	**Max**
Total assets (in billions of $)	1006	255.66	519.06	0.0345	2,367
Return on assets ratio	1006	0.1020	0.0617	-0.1044	0.4509
Equity to assets ratio	1006	0.1423	0.1420	0.0488	0.9232
Liquidity ratio	1006	0.1990	0.2050	0.0002	0.9854
Liquidity Mismatch Index (LMI, in billions of $)	1006	305.00	596.34	0.03	2982.12

Notes: This table reports the number of observations, mean, standard deviation, minimum and maximum value for key variables used in this chapter.

Table 3.2. Pairwise correlation matrix

	Repo amount in log	Repo rate in log	Total asset in log	Liquidity ratio in log	Equity to total asset	Return on asset	6-Month CDS spread	1-Year CDS spread	3-Year CDS spread	5-Year CDS spread	10-Year CDS spread	LMI
Repo amount in log	1											
Repo rate in log	-0.1939	1										
Total asset in log	0.0783	0.0067	1									
Liquidity ratio in log	0.1236	0.0215	0.2018	1								
Equity to total asset	-0.0893	0.1865	0.0389	0.2459	1							
Return on asset	-0.0305	0.0712	0.119	-0.4647	-0.1052	1						
6-Month CDS spread	-0.0543	-0.022	-0.0419	0.401	0.2695	-0.2196	1					
1-Year CDS spread	-0.0596	-0.0262	-0.0408	0.4511	0.3032	-0.2547	0.9913	1				
3-Year CDS spread	-0.0753	-0.0158	-0.0824	0.5148	0.3583	-0.292	0.8865	0.9172	1			
5-Year CDS spread	-0.0753	-0.0012	-0.0913	0.558	0.4063	-0.3149	0.763	0.8039	0.9707	1		
10-Year CDS spread	-0.0628	-0.0031	-0.1025	0.5977	0.4331	-0.3613	0.6682	0.7174	0.9197	0.9815	1	
LMI	0.0048	-0.0101	0.6299	0.0751	-0.0694	-0.0304	-0.0645	-0.013	-0.0491	-0.0395	0.0311	1

Notes: This table reports the the pairwise correlation matrix for key variables used in this chapter.

Table 3.3. Repo Transaction volume and Credit default swap – all dealers during the post crisis period

	Repo Volume (Dependent variable: Collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-1.135***	-1.681***	-1.430***	-2.182***	-2.580***	-4.641***	-3.381***	-6.032***	-5.332***	-7.384***
	(3.31)	(5.30)	(3.94)	(6.63)	(5.22)	(10.66)	(5.25)	(12.72)	(5.49)	(12.66)
log (CDS Squared, day t-1)	-0.114***	-0.139***	-0.141***	-0.187***	-0.301***	-0.449***	-0.422***	-0.637***	-0.695***	-0.837***
	(3.97)	(5.33)	(4.50)	(6.78)	(6.42)	(10.67)	(6.49)	(12.76)	(6.66)	(12.68)
Bank dealer dummy	2.769***	-0.564***	2.741***	-0.562***	2.653***	-0.657***	2.679***	-0.722***	2.650***	-0.785***
	(5.61)	(10.21)	(5.69)	(10.51)	(5.55)	(12.13)	(5.61)	(13.31)	(5.56)	(13.82)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Quarter Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.4859	0.3387	0.5001	0.3468	0.5004	0.3526	0.5056	0.3561	0.5060	0.3539
Observations	8609	8609	8909	8909	8924	8924	8923	8923	8899	8899
Number of dealers	25	25	25	25	25	25	25	25	25	25

Notes: This table presents the regression of Repo volume on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is from 2010:Q2 to 2019:Q4, all bank dealers and non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.4. Repo Transaction volume and Credit default swap – non-bank dealers during the post crisis period

	Repo Volume (Dependent variable: Reverse Repo collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-1.112	0.0569	-1.011	1.299	-1.979**	1.482	-2.559**	0.256	-3.249**	-0.972
	(1.56)	(0.63)	(1.39)	(1.38)	(2.23)	(1.46)	(2.44)	(0.23)	(2.21)	(0.81)
log (CDS Squared, day t-1)	-0.125**	0.0924	-0.119*	0.161**	-0.268***	0.195*	-0.368***	0.0754	-0.481***	-0.0659
	(2.18)	(1.25)	(1.96)	(1.99)	(3.27)	(1.92)	(3.39)	(0.62)	(3.02)	(0.46)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Quarter Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.7363	0.4996	0.7353	0.4996	0.7422	0.4942	0.7444	0.4889	0.7449	0.4840
Observations	1534	1534	1569	1569	1572	1572	1572	1572	1569	1569
Number of dealers	9	9	9	9	9	9	9	9	9	9

Notes: This table presents the regression of Repo volume on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is from 2010:Q2 to 2019:Q4, only non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.5. Repo Transaction volume and Credit default swap – bank dealers during the post crisis period

	Repo Volume (Dependent variable: Reverse Repo collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-1.004***	-1.722***	-1.225***	-1.893***	-2.134***	-4.215***	-3.127***	-6.321***	-4.882***	-10.951***
	(2.64)	(5.24)	(3.03)	(5.49)	(3.72)	(8.14)	(4.12)	(9.25)	(4.12)	(10.48)
log (CDS Squared, day t-1)	-0.0943***	-0.155***	-0.117***	-0.176***	-0.231***	-0.419***	-0.354***	-0.658***	-0.577***	-1.202***
	(2.93)	(5.75)	(3.31)	(6.15)	(4.22)	(8.58)	(4.60)	(9.64)	(4.49)	(10.77)
log (total assets, t-1)	-0.465***	0.035***	-0.488***	0.0341***	-0.458***	0.0334***	-0.469***	0.0335***	-0.514***	0.0314***
	(4.28)	(5.23)	(4.62)	(5.16)	(4.34)	(5.01)	(4.45)	(4.99)	(4.87)	(4.70)
Bank liquidity ratio (t-1)	-0.916*	1.607***	-0.978**	1.338***	-1.166**	1.323***	-1.182**	1.356***	-1.199**	1.628***
	(1.86)	(7.79)	(2.03)	(6.66)	(2.40)	(6.51)	(2.42)	(6.66)	(2.45)	(8.02)
Equity to assets (t-1)	-3.922**	-1.174*	-3.840**	-1.135*	-3.754**	-0.469	-3.711***	-0.302	-3.727**	-0.425
	(2.25)	(1.67)	(2.24)	(1.65)	(2.20)	(0.68)	(2.17)	(0.43)	(0.29)	(0.60)
Return on equity (t-1)	-0.039***	0.0319***	-0.038***	0.0287***	-0.0377***	0.0236***	-0.0378***	0.0208***	-0.0382***	0.0206***
	(5.55)	(7.17)	(5.55)	(6.63)	(5.50)	(5.48)	(5.50)	(4.81)	(5.56)	(4.75)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Quarter Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.4902	0.3965	0.4928	0.3996	0.4943	0.4020	0.4945	0.4036	0.4925	0.4036
Observations	7075	7075	7340	7340	7352	7252	7351	7351	7330	7330
Number of dealers	16	16	16	16	16	16	16	16	16	16

Notes: This table presents the regression of Repo volume on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is from 2010:Q2 to 2019:Q4, only bank dealers are included. Furthermore, as this table only presents the regressions for bank dealers, bank liquidity ratio, equity to assets ratio and return on equity ratio with one quarter lag are used as additional control variables. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.6. Repo rates and Credit default swap – all dealers during the post crisis period

	Repo rates (Dependent variable: Reverse Repo rates in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	0.00285	0.278	0.0462	0.624**	-0.0839	2.193***	-0.211***	0.747*	-0.353***	-5.784***
	(0.07)	(1.16)	(1.00)	(2.45)	(1.32)	(6.54)	(2.55)	(1.72)	(2.82)	(8.91)
log (CDS Squared, day t-1)	0.0296***	0.0532***	0.0791**	0.0992***	-0.00186	0.311***	-0.0134	0.206***	-0.0294**	-0.489***
	(0.83)	(2.64)	(1.97)	(4.46)	(0.31)	(9.65)	(1.61)	(4.63)	(2.19)	(6.89)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.9799	0.2855	0.9795	0.3044	0.9795	0.3415	0.9796	0.3401	0.9795	0.3241
Observations	8609	8609	8909	8909	8924	8924	8923	8923	8899	8899
Number of dealers	25	25	25	25	25	25	25	25	25	25

Notes: This table presents the regression of Repo rate on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is from 2010:Q2 to 2019:Q4, all bank dealers and non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.7. Repo rates and Credit default swap – non-bank dealers during the post crisis period

	Repo rates (Dependent variable: Reverse Repo rates in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	0.126	-3.399***	0.248**	-3.277***	0.112	-5.443***	0.132	-8.408***	0.297	-12.161***
	(1.45)	(6.80)	(2.28)	(6.29)	(0.87)	(9.34)	(0.82)	(12.19)	(1.32)	(13.38)
log (CDS Squared, day t-1)	0.0122*	-0.237***	0.0263***	-0.230***	0.0161	-0.473***	0.0209	-0.839***	0.0409*	-1.325***
	(1.75)	(5.81)	(2.83)	(5.10)	(1.30)	(8.39)	(1.26)	(11.77)	(1.68)	(13.45)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.9892	0.4750	0.9839	0.4797	0.9838	0.4776	0.9838	0.4833	0.9839	0.4905
Observations	1534	1534	1569	1569	1572	1572	1572	1572	1569	1569
Number of dealers	9	9	9	9	9	9	9	9	9	9

Notes: This table presents the regression of Repo rate on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is from 2010:Q2 to 2019:Q4, only non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.8. Repo rates and Credit default swap – bank dealers during the post crisis period

	Repo rates (Dependent variable: Reverse Repo rates in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-0.005	1.299***	0.030	1.422***	-0.094	3.596***	-0.266***	3.287***	-0.479***	-0.644
	(0.10)	(5.32)	(0.57)	(5.51)	(1.27)	(10.13)	(2.70)	(7.02)	(3.11)	(0.87)
log (CDS Squared, day t-1)	0.003	0.133***	0.0071	0.157***	-0.0004	0.428***	-0.0151	0.457***	-0.0365**	0.0975
	(0.73)	(6.42)	(1.55)	(6.96)	(0.06)	(12.25)	(1.51)	(9.52)	(2.19)	(1.20)
log (total assets, t-1)	0.026*	1.645***	0.0172	1.700***	0.0102	1.518***	0.0100	1.517***	0.0126	1.599***
	(1.83)	(23.63)	(1.26)	(25.26)	(0.75)	(22.93)	(0.73)	(23.03)	(0.92)	(24.16)
Bank liquidity ratio (t-1)	0.081	-4.591***	0.0670	-4.401***	0.106*	-3.612***	0.126**	-3.407***	0.121*	-3.587***
	(1.27)	(16.32)	(1.07)	(15.95)	(1.68)	(13.30)	(2.00)	(12.55)	(1.90)	(13.12)
Equity to assets (t-1)	0.069	25.715***	0.0748	25.425***	0.0106	23.145***	-0.0145	22.358***	0.0271	22.662***
	(0.31)	(24.26)	(0.34)	(24.48)	(0.05)	(22.75)	(0.07)	(22.01)	(0.12)	(22.13)
Return on equity (t-1)	0.001	0.096***	0.0004	0.096***	0.0003	0.092***	0.0005	0.095***	0.0005	0.0977***
	(0.99)	(22.41)	(0.42)	(22.92)	(0.39)	(22.74)	(0.51)	(23.42)	(0.55)	(23.87)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
R-squared	0.9766	0.3438	0.9769	0.3658	0.9770	0.3979	0.9770	0.4030	0.9770	0.3932
Observations	7075	7075	7340	7340	7352	7352	7351	7351	7330	7330
Number of dealers	16	16	16	16	16	16	16	16	16	16

Notes: This table presents the regression of Repo rate on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is from 2010:Q2 to 2019:Q4, only bank dealers are included. Furthermore, as this table only presents the regressions for bank dealers, bank liquidity ratio, equity to assets ratio and return on equity ratio with one quarter lag are used as additional control variables. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.9. Repo Transaction volume and Liquidity Mismatch Index – post-crisis period

Repo Volume (Dependent variable: Repo collateral value in log)		
	(1)	(2)
Log (liquidity mismatch index, t-1)	0.025***	1.018***
	(4.68)	(4.68)
Bank liquidity ratio (t-1)	1.899***	5.597**
	(16.06)	(2.37)
Equity to assets (t-1)	-2.568***	-512.485***
	(6.69)	(3.40)
Return on equity (t-1)	0.021***	0.637***
	(6.28)	(3.21)
Collateral type control	Yes	Yes
Bank Fixed effects	No	No
Quarter Fixed effects	Yes	No
Bank-year fixed effects	No	Yes
R-squared	0.4107	0.6742
Observations	11877	11877
Number of dealers	27	27

Notes: This table presents the regression of Repo volume on 1 quarter lagged of liquidity mismatch index (LMI) in log. In column (1) collateral type control and quarter fixed effects are included, while in collateral type control and bank-year fixed effects are included. Bank liquidity ratio, equity to assets and return on equity are included in the regressions. The sample period is from 2010:Q2 to 2019:Q4. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.10. Repo rates and Liquidity Mismatch Index - post-crisis period

Repo rates (Dependent variable: Repo Rates in log)		
	(1)	(2)
Log (liquidity mismatch index, t-1)	-0.0003	0.002
	(0.48)	(0.02)
Bank liquidity ratio (t-1)	0.005	-10.423*
	(0.34)	(1.79)
Equity to assets (t-1)	0.017	316.53*
	(0.58)	(1.92)
Return on equity (t-1)	0.0002	-0.371***
	(0.58)	(4.97)
Collateral type control	Yes	Yes
Bank Fixed effects	Yes	No
Quarter Fixed effects	Yes	No
Bank-year fixed effects	No	Yes
R-squared	0.9754	0.9769
Observations	11877	11877
Number of dealers	27	27

Notes: This table presents the regression of Repo volume on 1 quarter lagged of liquidity mismatch index (LMI) in log. In column (1) collateral type control and quarter fixed effects are included, while in collateral type control and bank-year fixed effects are included. Bank liquidity ratio, equity to assets and return on equity are included in the regressions. The sample period is from 2010:Q2 to 2019:Q4. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.11. Repo Transaction volume and Credit default swap – all dealers 2020 1st quarter

	Repo Volume (Dependent variable: Reverse Repo collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	3.143***	1.905*	2.708**	1.670	2.909**	2.237	3.289*	2.807	7.453***	6.283**
	(3.02)	(1.91)	(2.44)	(1.55)	(1.98)	(1.54)	(1.72)	(1.46)	(2.64)	(2.22)
log (CDS Squared, day t-1)	0.271***	0.124	0.236**	0.101	0.265*	0.155	0.317	0.212	0.833**	0.595*
	(2.78)	(1.37)	(2.18)	(1.00)	(1.75)	(1.06)	(1.53)	(1.04)	(2.51)	(1.83)
Bank dealer dummy	-2.071***	-2.165***	-2.107***	-2.242***	-2.059***	-2.162***	-2.039***	-2.132***	-1.875***	-2.200***
	(6.18)	(6.38)	(5.78)	(6.47)	(6.10)	(6.36)	(6.05)	(6.30)	(5.12)	(6.21)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
R-squared	0.3891	0.3658	0.3865	0.3659	0.3842	0.3654	0.3827	0.3648	0.3853	0.3646
Observations	664	664	664	664	664	664	664	664	664	664
Number of dealers	17	17	17	17	17	17	17	17	17	17

Notes: This table presents the regression of Repo volume on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is 2020:Q1, all bank dealers and non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.12. Repo Transaction volume and Credit default swap – non-bank dealers 2020 1st quarter

	Repo Volume (Dependent variable: Reverse Repo collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	6.442***	5.782***	7.340***	6.675***	12.098***	11.468***	16.702***	16.181***	22.754***	22.344***
	(5.93)	(5.46)	(6.45)	(5.93)	(7.54)	(7.17)	(7.68)	(7.38)	(7.84)	(7.56)
log (CDS Squared, day t-1)	0.530***	0.430***	0.624***	0.516***	1.149***	1.018***	1.726***	1.586***	2.518***	2.364***
	(4.85)	(4.22)	(5.38)	(4.69)	(6.72)	(6.22)	(7.19)	(6.74)	(7.61)	(7.13)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.4737	0.4494	0.4798	0.4543	0.4953	0.4714	0.4910	0.4659	0.4911	0.4624
Observations	275	275	275	275	275	275	275	275	275	275
Number of dealers	5	5	5	5	5	5	5	5	5	5

Notes: This table presents the regression of Repo volume on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year.The sample period is 2020:Q1, only non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.13. Repo Transaction volume and Credit default swap – bank dealers 2020 1st quarter

	Repo Volume (Dependent variable: Reverse Repo collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-2.229	-4.145**	-3.980**	-5.230***	-6.373***	-6.989***	-8.215***	-8.756***	-13.646***	-15.427***
	(1.20)	(2.52)	(2.10)	(2.99)	(2.87)	(3.21)	(2.97)	(3.16)	(2.83)	(3.24)
log (CDS Squared, day t-1)	-0.202	-0.407***	-0.385**	-0.533***	-0.659***	-0.756***	-0.897***	-1.005***	-1.614***	-1.910***
	(1.16)	(2.76)	(2.08)	(3.25)	(2.88)	(3.47)	(2.99)	(3.41)	(2.81)	(3.45)
log (total assets, t-1)	-0.012	0.075	0.061	0.151*	0.0163	0.062	0.028	0.083	0.112	0.219**
	(0.13)	(0.96)	(0.61)	(1.78)	(0.21)	(0.82)	(0.34)	(1.08)	(1.04)	(2.39)
Bank liquidity ratio (t-1)	-8.180***	-8.029***	-7.311***	-7.109***	-7.319***	-7.548***	-7.756***	-8.095***	-6.490***	-6.239***
	(3.82)	(3.77)	(3.33)	(3.29)	(3.44)	(3.56)	(3.71)	(3.86)	(2.89)	(2.83)
Equity to assets (t-1)	70.306***	71.059***	64.588***	63.370***	73.814***	78.025***	75.563***	80.232***	72.668***	76.069***
	(3.95)	(3.98)	(3.58)	(3.54)	(4.20)	(4.41)	(4.29)	(4.53)	(4.13)	(4.30)
Return on equity (t-1)	0.147***	-0.160***	-0.143***	-0.153***	-0.152***	-0.167***	-0.159***	-0.176***	-0.158***	-0.176***
	(4.08)	(4.43)	(4.00)	(4.26)	(4.26)	(4.65)	(4.41)	(4.88)	(4.36)	(4.87)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.4089	0.3936	0.4134	0.4000	0.4194	0.4044	0.4204	0.4057	0.3923	0.4041
Observations	389	389	389	389	389	389	389	389	389	389
Number of dealers	12	12	12	12	12	12	12	12	12	12

Notes: This table presents the regression of Repo volume on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is 2020:Q1, only bank dealers are included. Furthermore, as this table only presents the regressions for bank dealers, bank liquidity ratio, equity to assets ratio and return on equity ratio with one quarter lag are used as additional control variables. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.14. Repo Transaction rates and Credit default swap – all dealers 2020 1st quarter

	Repo rates (Dependent variable: Repo rate in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-0.642	-3.825***	-0.317	-3.037***	-0.798	-2.890***	-2.151**	-3.315***	1.938	-2.381**
	(1.08)	(7.88)	(0.54)	(6.23)	(1.16	(4.43)	(2.45)	(3.87)	(1.63)	(2.19)
log (CDS Squared, day t-1)	0.043	-0.289***	0.085	-0.236***	0.075	-0.246***	-0.035	-0.306***	0.570***	-0.214*
	(0.80)	(7.04)	(1.52)	(5.51)	(1.08)	(3.89)	(0.37)	(3.41)	(4.12)	(1.75)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.6200	0.5200	0.6218	0.4928	0.6498	0.4740	0.6440	0.4669	0.7008	0.4559
Observations	625	625	625	625	625	625	625	625	625	625
Number of dealers	17	17	17	17	17	17	17	17	17	17

Notes: This table presents the regression of Repo rate on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is 2020:Q1, all bank dealers and non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.15. Repo Transaction rates and Credit default swap – non-bank dealers 2020 1st quarter

	Repo rates (Dependent variable: Repo rates in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	6.478***	-2.377	8.019***	0.135	7.526***	1.845	7.121***	5.213***	5.916***	4.972***
	(2.81)	(1.36)	(4.14)	(0.09)	(5.72)	(1.59)	(4.32)	(3.73)	(2.92)	(3.33)
log (CDS Squared, day t-1)	0.695***	-0.141	0.854***	0.054	0.985***	0.236**	1.061***	0.653***	1.018	0.671***
	(3.68)	(1.02)	(5.24)	(0.45)	(7.80)	(2.17)	(6.20)	(4.45)	(1.18)	(4.00)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.6615	0.5121	0.6789	0.5018	0.7601	0.5251	0.7756	0.5765	0.7671	0.5666
Observations	268	268	268	268	268	268	268	268	268	268
Number of dealers	5	5	5	5	5	5	5	5	5	5

Notes: This table presents the regression of Repo rate on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year. The sample period is 2020:Q1, only non-bank dealers are included. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.16. Repo Transaction rates and Credit default swap – bank dealers 2020 1st quarter

	Repo rates (Dependent variable: Reverse Repo rates in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-1.395**	-4.894***	-2.149***	-5.216***	-3.833***	-6.853***	-5.642***	-8.788***	-3.128**	-12.962***
	(2.45)	(9.80)	(3.83)	(10.08)	(5.89)	(9.84)	(6.52)	(9.42)	(2.07)	(8.89)
log (CDS Squared, day t-1)	0.002	-0.356***	-0.056	-0.395***	-0.202***	-0.571***	-0.375***	-0.803***	0.036	-1.317***
	(0.04)	(8.17)	(1.03)	(8.46)	(3.03)	(8.35)	(4.02)	(8.32)	(0.20)	(8.22)
log (total assets, t-1)	-0.109***	-0.006	-0.141***	0.002	-0.064***	-0.004	-0.076***	0.001	-0.251***	0.003
	(-3.98)	(0.51)	(4.74)	(0.15)	(2.67)	(0.32)	(2.93)	(0.05)	(7.36)	(0.25)
Bank liquidity ratio (t-1)	-0.983	1.968***	-1.229*	2.361***	-0.612	2.767***	-0.217	2.651***	-1.983***	2.589***
	(0.16)	(5.81)	(1.84)	(6.85)	(0.97)	(7.84)	(0.33)	(7.11)	(2.78)	(6.46)
Equity to assets (t-1)	-1.114	1.466	2.633	-1.274	-9.700	-0.259	-11.56	-0.279	-9.956	-1.021
	(0.16)	(1.36)	(0.38)	(1.17)	(1.43)	(0.24)	(1.59)	(0.24)	(1.36)	(0.86)
Return on equity (t-1)	0.004	0.016***	-0.002	0.017***	0.009	0.018***	0.0153	0.016***	0.025*	0.014**
	(0.28)	(3.04)	(0.13)	(3.35)	(0.73)	(3.52)	(1.11)	(2.99)	(1.78)	(2.46)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.7454	0.6517	0.7548	0.6521	0.7679	0.6536	0.7363	0.6163	0.7307	0.5721
Observations	357	357	357	357	357	357	357	357	357	357
Number of dealers	12	12	12	12	12	12	12	12	12	12

Notes: This table presents the regression of Repo rate on 1 day lagged of credit default swap spreads of the bank. In column (1) and (2), 6-month CDS spreads are used as variables. And column (1) include collateral type, dealer and quarter fixed effects as control variables, while column (2) only includes collateral type and quarter fixed effects as control. From column (3) to column (10) are using CDS spreads with different maturities, including 1-year, 3-year, 5-year and 10-year.The sample period is 2020:Q1, only bank dealers are included. Furthermore, as this table only presents the regressions for bank dealers, bank liquidity ratio, equity to assets ratio and return on equity ratio with one quarter lag are used as additional control variables. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.17. Repo Transaction volume and Liquidity Mismatch Index (LMI) – bank dealers 2020 1st quarter

Repo Volume (Dependent variable: Repo collateral value in log)		
	(1)	(2)
Log (liquidity mismatch index, t-1)	-1.447*	0.069
	(1.89)	(0.21)
log (total assets, t-1)	1.371*	-0.016
	(1.81)	(0.05)
Bank liquidity ratio (t-1)	-4.431	3.646***
	(1.37)	(5.72)
Equity to assets (t-1)	33.691	-4.465**
	(1.42)	(2.60)
Return on equity (t-1)	-0.073	0.012
	(1.53)	(0.87)
Collateral type control	Yes	Yes
Bank Fixed effects	Yes	No
Month Fixed effects	Yes	Yes
Bank-month fixed effects	No	No
R-squared	0.4043	0.1502
Observations	540	540
Number of dealers	21	21

Notes: This table presents the regression of Repo volume on 1 quarter lagged of liquidity mismatch index (LMI) in log. In column (1) collateral type control and quarter fixed effects are included, while in collateral type control and bank-year fixed effects are included. Bank liquidity ratio, equity to assets and return on equity are included in the regressions. The sample period is 2020:Q1. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.18. Repo Transaction rate and Liquidity Mismatch Index (LMI) – bank dealers 2020 1st quarter

Repo Rate (Dependent variable: Repo Rate in log)		
	(1)	(2)
Log (liquidity mismatch index, t-1)	-0.515	-1.217
	(0.858)	(1.14)
log (total assets, t-1)	0.825	3.003
	(0.37)	(1.08)
Bank liquidity ratio (t-1)	1.504	2.721
	(0.60)	(0.87)
Equity to assets (t-1)	16.578	67.651
	(0.33)	(1.07)
Return on equity (t-1)	0.073	0.244
	(0.13)	(1.56)
Collateral type control	Yes	Yes
Bank Fixed effects	Yes	No
Month Fixed effects	Yes	Yes
R-squared	0.4396	0.1312
Observations	469	469
Number of dealers	19	19

Notes: This table presents the regression of Repo rate on 1 quarter lagged of liquidity mismatch index (LMI) in log. In column (1) collateral type control and quarter fixed effects are included, while in collateral type control and bank-year fixed effects are included. Bank liquidity ratio, equity to assets and return on equity are included in the regressions. The sample period is 2020:Q1. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Chapter 4: The Deposits Channel, Financial Stability, and Households

Abstract

This chapter first investigates the role of heterogeneity in deposit rates in predicting the severity of crisis, output and credit conditions. Moreover, it is shown that increased heterogeneity in deposit rates, combined with fragile financial conditions, can lead to more severe crises. Secondly, using US household survey data, this chapter finds that increases in the deposit rates negatively affect households' consumption and salary. In addition, by grouping households into three different cohorts according to their balance sheet positions, the chapter finds that increases in interest rate and deposit rate have the most significant impact on consumption and salary for households with mortgage.

4.1. Introduction

The 2002 Dot-com recession and the Great Recession in 2008 led to a significant decline in US GDP growth rate and household's consumption expenditure. During the Great Recession, US GDP fell sharply by 4.3%, making it as the most severe recession since the Great Depression of 1929. Also, according to data provided by the Federal Reserve Bank of St. Louis, household consumption expenditure fell by 4.07% in the second quarter of 2009 as compared to the previous peak. This chapter investigates the role of deposits and credit condition on economic output and households in the US by using the data from 2001:Q1-2019:Q4.

An extensive literature review suggests that money and banking have profound influences on macroeconomy, credit condition and the household sector during crisis periods, as can be observed, for example, in Bernanke (1983), Jorda, Schularick and Taylor (2013) and Berger, Irresberger and Roman (2020). This literature focuses on the role of bank lending on the real economy, while the role of deposits is neglected. Bank deposits are the primary and the most stable funding source for banks (Diamond and Dybvig, 1983 and Hanson et al., 2015). However, few studies have investigated the role of deposits on the real economy. Drechsler et al. (2017) present a new monetary policy transmission channel, the deposits channel, showing that an increase in the Federal Funds rate can lead to a contraction in bank lending and a downturn in the economy through outflows of bank deposits. Notably, the deposits channel implies that banks adjust the deposit rates heterogeneously in the face of monetary policy shock. The deposits channel highlights the importance of deposit rate heterogeneity to the real economy. However, to date, no studies have investigated the direct impact of deposit rate heterogeneity on macroeconomic conditions, including output and household conditions.

Figure C1 reveals the standard deviation of four deposit rates, which is the key measurement of deposit rate heterogeneity in this chapter. As can be seen, there was a significant increase in deposit rate heterogeneity prior to both crises. An intuitive fact is that the heterogeneity in deposit rates increase significantly before two crises and in late 2019.

【Insert Figure C1 here】

Motivated by this fact, this chapter firstly investigates the role of heterogeneity in deposit rates in predicting the severity of the economic downturns. It is shown that heterogeneity in deposit rate predicts well the peak-to-trough GDP growth rate at state level. Moreover, the literature provides evidence that abrupt change in credit spreads, coupled with a fragile financial stability condition, are a good signal regarding future output growth (see, for example, Gertler and Lown (1999), Schularik and Zakrajšek (2012) and Krishnamurthy and Muir (2017)). Moreover, this chapter contributes to the existing literature by providing empirical evidence on that increased heterogeneity in deposit rates, coupled with a fragile financial condition, can lead to more severe economic downturn, which is documented as "FD" model in the chapter. In addition, this chapter also finds an increase in heterogeneity is associated with a negative change in S&P municipal bond index, which is a measurement for credit condition.

Secondly, the chapter investigates the role of deposits on household's consumption and salary (nominal). Deposits are one of possible forms of wealth and the highest liquidity asset for households (Pitoňáková, 2017). However, no studies have investigated how changes in deposit rates affect the households. A study of Cloyne, Ferreria and Surico (2020) suggests that an increase in deposit rates is associated with a decrease in household's consumption and salary. Moreover, this chapter finds the deposit rate shock has the greatest impact on mortgage cohort, when splitting the households into three "cohorts" based on their balance sheet positions.

This chapter contributes to the existing literature from three main aspects. Firstly, in line with Drechsler et al. (2017)'s findings, by finding that heterogeneity in deposit rates predicts future output well, this chapter presents a good picture of heterogeneity in deposit rates. Also, this chapter complements the findings ofo Schularik and Zakrajšek (2012) and Krishnamurthy and Muir (2017) by providing novel evidence that increased deposit rate heterogeneity combined with increased financial vulnerability (measured by loan growth) will lead to a more severe economic downturn. Moreover, it is found that changes in deposit rates and interest rates have significant impact on households, and the effects are determined by the households' balance sheet conditions.

These findings suggest additional cautionary measures should be taken by policymakers when observing increased heterogeneity in deposit rates, as these are signals of potential future crises, particularly in periods of rapid credit growth. Futhermore, they should also be aware of the fact the effects on households' consumption from interest rate changes are heterogenous among households based on the balance sheet conditions.

The following sections are arranged as the follows. Section 4.2 presents a literature review to reveal the research gap. Section 4.3 presents a summary of statistics and information of data source.

Section 4.4 introduces the methodology used and hypotheses to be investigated in this chapter. Empirical evidence and discussions are provided in Section 4.5. The conclusions are drawn in section 4.6.

4.2 Literature Review

In this section, literature related to the topic of heterogeneity in bank rates setting, deposit rates and financial stability, and consumer expenditure is provided and discussed.

4.2.1 Heterogeneity in bank deposit rates setting

As indicated by the available literature, heterogeneous responses to interest rate shocks have a major contribution to the transmission of monetary policy. According to Gambacorta and Iannotti (2007), heterogeneity in the response of bank interest rates to market rates helps helps explain how monetary policy decisions are transmitted through the economy, rather than the consequences for bank lending.

In a more recent work, Drechsler, Savov and Schnabl (2017) document a novel channel for the transmission of monetary policy, namely the deposits channel. The study that when the Fed fund rate rises, banks will widen the spreads they charge on deposits, thus leading to an outflow of deposits from the banking system. This outflow further leads to a reduction in bank lending, output and employment rate. There is an implicit relationship between the deposit channel and the heterogeneity of deposit rates.. This is because banks respond heterogeneously to the interest rate shocks as the degree of market concentration varies across regions. Repullo (2020) constructs an alternative model based on Drechsler, Savov and Schnabl (2017) and find the effects on output and consumption are in the same camp.

Moreover, Holton and Rodriguez (2018) study the financial crisis in the euro area and claim that banks' responses to monetary policy shocks are heterogeneous due to changes in the structure of their balance sheets.

However, there is no study investigating the role of heterogeneity in bank rates setting on the macro-economy and financial stability. The analysis of heterogeneous behavior in banks' interest setting has been largely neglected by the existing literature, according to Gambacorta and Iannotti (2007).

4.2.2 Credit, financial stability, banks, and crises

There is a large body of evidence in the existing literature as to the evolution of credit and the fact that it has significant impact on economic downturns and financial crises. For example, Gerlter and Lown (1999) reveal that the high yield spread exerts considerable significant explanatory power on the business cycle. Also, this explanatory power can be magnified by financial accelerator. Moreover, by using U.S. data from 1929 to 2015, Schularik and Zakrajšek (2012) show the elevated credit market sentiment can forecast 2 to 3 year decline in economic activity.

Also, we cannot deny fact that banks are central to credit creation (Bernanke and Blinder, 1988) and credit has a profound impact on business cycle and the occurrence of crisis. For instance, Bernanke (1983) shows that the unrestricted expansion in bank credit is instrumental in shaping the crisis. While Jorda, Schularick and Taylor (2013) discover that bank credit growth offers excellent explanatory power in predicting financial crises in 14 developed countries between 1870-2008, while Gilchrist and Zakrajsek (2012) investigate the role of credit spreads in determining consumption, investment, output and price level by using US corporate bond credit spread index. Their findings suggest the corporate bond index is a robust predictor of future economic patterns.

The financial crisis of 2008 highlights the importance of banking sector in financial stability. A major factor behind this is the "bank lending channel", which suggests that tight monetary policy drains deposits out of the banking system and bank lending consequently declines (Bernanke and Blinder, 1982 and Gambacorta and Marques-Ibanez, 2011). According to Bernanke and Gertler (1990) and more recently to the empirical evidence of Eggertsson and Krugman (2012), credit alsohas a significant part to play in shaping the business cycle. This is because increased leverage increases the vulnerability of the economy to shocks, the effect of financial accelerators becomes stronger when balance sheets are larger.

More recently, Salido, Stein and Zakrajšek (2017) reveal that an increase in the credit market sentiment is associated with an economic downturn afterwards. Also, Mian, Sufi and Verner (2017) find that an increase in the household debt to GDP ratio can predict lower GDP growth and higher unemployment rate by using an unbalanced panel data of 30 countries from 1960-2012. A paper of great relevance to the work undertaken in this chapter by Krishnamurthy and Muir (2017), which shows that "there was unusually high credit growth and unusually narrow credit spreads prior to the crisis", is documented as "FZ" model. This chapter contributes to the "FZ" model by showing that the recession was preceded by high heterogeneity in deposit rates and high credit growth. Moreover, this chapter is the first to provide empirical evidence at state level showing that the deposit rates are on average higher from 1 to 5 quarters before the crises compared to the other quarters.

Moreover, fluctuations in asset prices has been identified as an essential source of financial instability. He and Krishnamurthy (2013) have shown that a sudden and dramatic increase of risk premia in asset prices leads to the recent financial crisis. It is suggested in their theoretical framework that the crisis is triggered by an increase in the household's exposure to the risky asset caused by the asset purchasing policy. The severity of future crisis can be estimated by the size of asset price fluctuations (Schulmeister, 2010).

4.2.3 Interest rate, saving and consumption

The relationship between consumption growth and the interest rate has attracted great interest. Although Keynes's consumption theory suggests that the short-term fluctuations in interest rate should have little impact on consumption, there is a large empirical literature showing the interest rate has a significant impact on consumption (e.g., Attanasio and Weber, 1993, Elmendorf, 1996, Kaplan and Violante 2014 and Jappelli and Scognamiglio, 2018).

The consensus behind why interest rate can affect consumption are the rational expectations and permanent income hypothesis (Friedman, 1957), which suggests the effects of real interest rate affect consumption through substitution and income effects. The substitution effect suggests consumers can benefit from an increase in the interest rate if they save more for today, while the income effects suggest that consumers can benefit from an increase in interest rates if they save more for today, while the income effect suggests that an increase in interest rates should have a positive effect on permanent income, leading to an increase in current consumption. (Baumol, 1973 and Autor and Duggan, 2007).

A fundamental founding block of modern macroeconomic models are consumption Euler equation, which links real interest rate to households' consumption and provides a channel how monetary policy can affect the consumption (Attanasio and Weber 1993, and Canzoneri, Cumby and Diba, 2007). According to the theory of consumption Euler equation, consumption equals to income minus savings. Since both the future income and consumption are discounted at interest rates, monetary policy can influence household consumption by adjusting interest rates or deposit rates. Moreover, banks are also argued to be instrumental in transmitting interest rate shocks to consumption. Bernanke and Gertler (1995) claim that monetary policy shocks can be amplified by the supply of credit from banks.

The existing literature indicates that the household's balance sheet condition acts as a major factor in transmitting interest rate shocks to household's decisions on consumption. For instance, Iacoviello (2005) develops a monetary business cycle model in which the collateral constraint on household borrowing is tied to housing values. He finds the collateral effects dramatically affect the response of the aggregate demand. Moreover, the empirical work suggests the household with a mortgage, who holds less liquid asset tend to have higher marginal propensity to consume. For instance, Kaplan and Violante (2014) find the monetary policy has strong impact on mortgagor cohort's consumption, as they have substantial amounts of real assets and low liquidity. Mian, Rao and Sufi (2013) study the consumption behaviour of households in the 2006-2009 housing collapse episode and find that the marginal propensity to consume is significantly higher in postcodes of households with poorer and more leveraged households.

Cloyne, Ferreria and Surico (2020) investigate cohort data from the United Kingdom and the United States. The findings reveal that the response of consumption to interest rates is largely driven by whether households have a mortgage, and that these effects are driven by balance sheet-driven heterogeneity. However, no studies have investigated the role of deposit rate changes on household's consumption.

4.3 Data and Methodology

This section describes the data and methodology adopted in this chapter and data from a variety of sources, sampling from 2001:Q1 to 2019:Q4, are included in this chapter, which are presented below:

4.3.1 Data

This subsection presents the description of all data used in the chapter, including sources, frequency, sample period and the methodology of cleaning the raw data.

4.3.1.1 The heterogeneity in deposit rates

This chapter uses the standard deviation to measure the heterogeneity in deposit rates. The raw data are from RateWatch, which collects data on deposit rates at the branch level. An average deposit rate at the bank level is first calculated using 'certificate numbers' and then at state level. Also, the frequency used in the empirical study is quarterly after converted. This chapter focuses on 4 types of deposits, namely 1-month/12-month certificates of deposit with an account size of $10,000 and 1-month/12-month certificates of deposit with an account size of $100,000, which are referred as 01MCD10K, 12MCD10K, 01MCD100K and 12MCD100K.

4.3.1.2 U.S. GDP growth rate

In this chapter, US state-level GDP growth rates provided by the US Bureau of Economic Analysis (BEA) are adopted at quarterly frequency. The sample period is from 2001:Q1 to 2019:Q4. It is worth of noticing that BEA only provides annually frequency data from 2001:Q1 to 2004Q4. Thus, interpolation method is applied to to generate observations of quarterly frequencies during this period.

4.3.1.3 Syndicated loan

Syndicated loan information is obtained from Thomson Reuters Dealscan. Dealscan collects syndicated loans data at loan level. As the main data set is reported by borrowers, this chapter converts loan level data to bank level by using lender information provided by Dealscan.

4.3.1.4 S&P Municipal bond index

The S&P municipal bond index per state is downloaded from DataStream, this chapter then calculates quarterly change in S&P Municipal bond index.

4.3.1.5 Households' consumption and salary

Households' consumption data are obtained from Consumer Expenditure Survey (CEX) dataset, which includes both durable and non-durable expenditure for households. CEX reports quarterly households' expenditure on a rotating basis for each quarter (each household should be surveyed for 5 consecutive quarters). Households' salary data are obtained also from the Consumer Expenditure Survey (CEX) dataset.

4.3.2 Sample selection strategy

We choose the sample period from 2001Q1:2019Q4. Because the main purpose of this study is to investigate the role of deposits channel on output and household’s balance sheets during 2002 and 2008 economic downturns. In addition, we obtain the most recent data[17] until 2019:Q4. The regressions are executed at quarterly frequency because the state level GDP growth rate and households' consumption and salary data are at quarterly frequency. We calculate the standard deviation of deposit rate by using the end month of each quarter observations in RateWatch. The data in the range of 1%-99% were carefully checked and adjusted for any errors within these outliers.

We establish a naive time series model to show the role of deposits on output and economic downturns. Then, following Cloyne, Ferreria and Surico (2020), who study the response of household's consumption across different periods of monetary policy, we construct household's durable and non-durable consumption, and group them into different cohorts based on their balance sheet conditions.

4.3.3 Summary statistics

This subsection provides the summary statistics for this chapter and Table 4.1 shows the summary statistics.

[Please insert Table 4.1 here]

In this chapter, state-level regressions are conducted. Thus, at first the raw deposit rate data at branch level are converted to bank level data by calculating the average of the deposit rates, using only data at the end of each quarter, as GDP growth rates at state level are reported on a quarterly basis. To merge the bank data with state level variables, the information provided by Call Report from the bank's headquarters is adopted. Then, we calculate the standard deviation of deposit rates for each quarter. In the regressions investigating the household variables, family size, child age and age of reference person are used as control variables.

[Please insert Table 4.2 here]

Table 4.2 presents the pairwise correlation matrix of the key variables in Chapter 2 and it can be seen that estimated models do not suffer from multicollinearity.

4.4 Methodology and Hypotheses

This section introduces the methods and hypotheses investigated in this study.

[17] This chapter was completed by March 2020.

4.4.1 Methodology

This subsection introduces three major methodologies to construct dependent or independent variables in this chapter.

4.4.1.1 Peak to trough GDP declines as the measurement of severity of economic downturns

To measure the severity of a recession, a peak to trough decline in GDP is presented in this chapter, which is also widely used in numerous publications, such as those of Sichel (1994), Boldin (1994) and Reinhart and Rogoff (2014). This chapter constructs state-level peak-to-trough falls in GDP in two recessions (2002 and year 2008). Moreover, the magnitudes of crises vary from state to state.

The state-level economic downturns overed in this chapter are from 2002Q1 to 2002Q4 and 2007Q3 to 2009Q2. As the dates of the recessions coincide with those captured by the narrative approach, based on Jorda, Schularick and Taylor's (2013) chronology, the recession periods are referred to in this chapter as "ST dates".

4.4.1.2 Modified "FZ" model

Krishnamurthy and Muir (2017) suggest that coupled with a high degree of fragile financial stability condition (captured by an increase in the debt to GDP ratio, "F"), an unexpected narrow in credit spread ("Z") can lead to a more severe economic downturn. It can be found in their study that "FZ" has good predictive power on the future economic downturns.

This study modifies the original 'FZ' model to include changes in the heterogeneity of deposit rates as 'Z' and an increase in the heterogeneity of deposit rates can be found, which, combined with the fragile state of the financial sector, leads to a severe economic downturn. It is also found in this study that the heterogeneity in deposit rates increases significantly in the one to five quarters prior to the onset of a recession.

4.4.1.3 Household cohorts' construction

To study whether changes in interest rate (deposit rate) influence heterogeneity among households with different balance sheet conditions, pseudo cohorts are constructed in this chapter based on the housing on the three housing tenure groups. The identification is as the follows. Mortgagor cohort is defined as households that own property but have outstanding mortgage to pay back; Renter cohort is defined as households which own no property and pay renting fees; Property owner cohort is defined as households own at least one property and have no outstanding mortgage to pay back.

4.4.2 Hypotheses

Subsection 4.4.2 introduces the hypotheses tested in the chapter.

4.4.2.1 Heterogeneity in deposit rates as a forecaster of peak to trough output declines

The first hypothesis of this chapter is that heterogeneity in deposit rates can predict the peak to trough GDP declines in the economic downturns.

$$Decline_{i,t} = a + b_1 STD_{i,t} + SFE + \varepsilon_{i,t}, \quad (4\text{-}1)$$

$$Decline_{i,t} = a + b_2 STD_{i,t-1} + SFE + \varepsilon_{i,t}, \quad (4\text{-}2)$$

where the $Decline_{i,t}$ is the peak to trough GDP declines for state i at quarter t, $STD_{i,t}$, $STD_{i,t-1}$ is the standard deviation of deposit rates for state *i* at quarter *t* and at quarter *t-1*, respectively and SFE denotes state fixed effects. Eq. (4-1) and Eq. (4-2) examine the independent predicting power of heterogeneity in deposit rates on the peak to trough output declines around the "ST dates". Four kinds of deposit rates are used including 01MCD10K, 01MCD100K, 12MCD10K and 12MCD100K.

Hypothesis I:An increase in the heterogeneity in deposit rates can predict negative peak to trough output declines. ($b_1 < 0, b_2 < 0$).

4.4.2.2 An increase in the heterogeneity in deposit rates is associated with declines in state level GDP growth rates

We then hypothesize that the increase in heterogeneity in deposit rates is associated with a decline in GDP growth at state level.

$$\Delta y_{i,t} = \alpha + b_3 STD_{i,t} + SFE + \varepsilon_{i,t}, \quad (4\text{-}3)$$

$$\Delta y_{i,t} = \alpha + b_4 STD_{i,t-1} + SFE + \varepsilon_{i,t}, \quad (4\text{-}4)$$

where $\Delta y_{i,t}$ is the GDP growth rate for state i at quarter t, $STD_{i,t}$, $STD_{i,t-1}$ is the standard deviation of deposit rates for state *i* at quarter t and at quarter *t-1*, respectively and *SFE* denotes state fixed effects. Eq. (4-3) and Eq. (4-4) examine whether an increase in the heterogeneity in deposit rates is associated with a decrease in state level GDP growth rate for the whole sample period (from 2001:Q1 to 2019:Q4), as the following hypothesis II suggests:

Hypothesis II: An increase in the heterogeneity in deposit rates is associated with a decrease in *the state level GDP growth rate ($b_3 < 0, b_4 < 0$).*

4.4.2.3 Deposits Channel and Financial Crises: The "FD" model

It has been suggested by theories, for example Kiyotaki and Moore (1997); Gertler and Kiyotaki (2010), that shocks to the fragile financial sector can lead to financial crises, with increased risk premia, contraction in bank lending and increases in lending rates and in credit spreads. Accordingly, empirical literature builds on these works to provide evidence that fluctuations in credit spreads serve as strong predictors of economic activity and financial crises. In this chapter, we hypothesize that fluctuations in deposit rates, or more precisely an increase in the heterogeneity of deposit rates, coupled with a fragile financial condition, have important implications to a subsequent decline in economic activity, which we refer to as the "FD" model.

$$\Delta y_{i,t+h} = a + b_5 dummy_{HighHeter} \times STD_{i,t} + b_6 \Delta y_{i,t+h-1} + b_7 \Delta y_{i,t+h-2}, \quad (4\text{-}5)$$

$$\Delta \mathrm{y_{i,t+h}} = \mathrm{a} + \mathrm{b_8 dummy_{HighHeter}} \times \mathrm{dummy_{Highloangrowth}} \times \mathrm{STD_{i,t}} + \mathrm{b_9}\, \Delta \mathrm{y_{i,t+h-1}} + \mathrm{b_{10}}\, \Delta \mathrm{y_{i,t+h-2}}, \quad (4\text{-}6)$$

where $\Delta y_{i,t+h}$ is the GDP growth rate for state i at quarter $t+h$, in which h takes the value from 1 to 5 and the $dummy_{HighHeter}$ refers to the dummy takes the value of 1 if the standard deviation for state *i* is above the 80th percentile at quarter t. While the $dummy_{Highloangrowth}$ takes the value of 1 if the loan growth to GDP is above the median at quarter t. $STD_{i,t}$ is the standard deviation of deposit rates for state *i* at quarter *t*. The regressions also include $\Delta y_{i,t+h-1} + \Delta y_{i,t+h-2}$, which are GDP growth rate for state *i* with 1 and 2 quarter lags as control variables.

Hypothesis III: An increase in the heterogeneity in deposit rates, coupled with a fragile financial sector condition leads to a more severe crisis. ($b_8 < b_5 < 0$).

4.4.2.4 The heterogeneity in deposit rates is "too high" on average before economic downturns

The fourth hypothesis is the heterogeneity in deposit rates is "too high" on average before crises.

$$STD_{i,t} = a + b_{11} \times dummy_{t-5.t-1} + b_{12} \times \Delta Bank\ loans\ to\ GDP_{t-1} + \Delta y_{i,t-1} + \Delta y_{i,t-2}. \quad (4\text{-}7)$$

The dependent variable in Eq. (4-7) is the standard deviation of deposit rates for state *i* at quarter *t*. $dummy_{t-5.t-1}$ takes the value of 1 if the observations are within 1 to 5 quarter lags. $\Delta Bank\ loans\ to\ GDP_{t-1}$ denotes the bank loan to GDP growth, while $\Delta y_{i,t-1}$ and $\Delta y_{i,t-2}$ are the GDP growth rate for state i at quarter t-1 and t-2, respectively. If the heterogeneity in deposit rates is on average higher in the pre-recession period than in the normal periods, then the coefficients of

$dummy_{t-5.t-1}$ should be positive.

Hypothesis IV: The heterogeneity in deposit rates is "too high" on average before (from 1 to 5 quarters prior) economic downturns (b_{11} > 0).

4.4.2.5 An increase in the heterogeneity in deposit rates is associated with a negative credit condition

In the existing literature, for example in the works of Friedman and Kuttner (1992), Gertler (1999), Gilchrist and Zakrajsek (2012) and Krishnamurthy and Muir (2017), it can be seen that credit condition has significant forecasting power for future GDP growth rates. These papers find that a deterioration in credit conditions coupled with a fragile financial sector leads to an adverse outcome in terms of GDP growth rate. The chapter finds that increased heterogeneity in deposit rates is associated with worsening credit conditions in terms of the returns on the S&P municipal bond index.

$$SP\ Municipal\ Return_{i,t} = a + b_{13} \times STD_{i,t-h} + SFE, \quad (4\text{-}8)$$

where $SP\ Municipal\ Return_{i,t}$ refers to the quarterly return on the S&P municipal bond index for state i at time t and $STD_{i,t-h}$ is the standard deviation of deposit rates for state i at time $t-h$. Here, $h = 1{,}2{,}3{,}4$ is set with the purpose of testing how the heterogeneity is associated with the returns on the S&P municipal bond index with a forecasting horizon of 1-4 quarters.

Hypothesis V: An increase in the heterogeneity in deposit rates is associated with a worsening credit condition.

4.4.2.6 An increase in the interest rate/deposit rate/deposit spread has a negative impact on household's consumption, and the effects are heterogeneous according to the household's balance sheet condition.

Fifthly, this chapter hypothesizes that increases in interest rates/deposit rates/deposit spreads have negatively affect household's consumption and salary. Moreover, households are divided into three cohorts, namely the mortgage cohort, the renter cohort and the house owner cohort, and changes in interest rates/deposit rates/deposit spreads are assumed to have a heterogeneous impact on these three cohorts.

$$\Delta Consumption_{i,t} = a + b_{14} \times \Delta interest\ rate_{t-h}/\Delta deposit\ rate_{t-h}/\Delta deposit\ spread$$
$$SFE + TFE + Household\ control\ variables, \quad (4\text{-}9)$$

$$.....\Delta Salary_{i,t} = a + b_{15} \times \Delta interest\ rate_{t-h}/\Delta deposit\ rate_{t-h}/\Delta deposit\ spread + SFE + TFE +$$
$$Household\ control\ variables, \quad (4\text{-}10)$$

where the $\Delta Consumption_{i,t}$ and $\Delta Salary_{i,t}$ are the change in consumption and salary for household *i* at quarter *t*, the consumption is either durable consumption or non-durable consumption.

$\Delta interest\ rate_{t-h}$, $\Delta deposit\ rate_{t-h}$, $\Delta deposit\ spread$ are changes in interest rates, deposit rates or the change in deposit spreads. SFE and TFE are the state fixed effects and quarter fixed effects, respectively. Two household control variables, namely number of household member and the age of interviewee, are also included.

Furthermore, as mentioned earlier, the mortgagor cohort, the renter cohort and the house owner cohort in this chapter (identification has been introduced in Subsection 4.4.1.3). The effects on three cohorts are supposed to be different under Hypothesis VI.

Hypothesis VI: An increase in the interest rate/deposit rate/deposit spread has a negative impact on household's consumption and salary (b_{13}<0,b_{14}<0), and the effects are heterogeneous among three cohorts (b_{14}<0,b_{15}<0).

4.5 Empirical Investigation

Section 4.5 presents the empirical investigation IN this chapter. This section firstly reviews the role of heterogeneity in deposit rates on output and future crises in subsection 4.5.1. The results of the "FD model" are then presented in Subsection 4.5.2. Furthermore, Subsection 4.5.3 reveals the relationship between heterogeneity in deposit rates and the credit condition. Finally, Subsection 4.5.4 to 4.5.6 reveal how the interest rate shocks, and the deposit rate shocks affect households' consumption and salary.

4.5.1 Heterogeneity in deposits as a forecaster of output and future crises

Firstly, this chapter illustrates the magnitudes of the crisis at state level can be forecast by an increase in the standard deviation of deposit rates during the two economic downturns.

$$Decline_{i,t} = a + b_1 STD_{i,t} + SFE + \varepsilon_{i,t}, \tag{4-1}$$

$$Decline_{i,t} = a + b_2 STD_{i,t-1} + SFE + \varepsilon_{i,t}, \tag{4-2}$$

Eq. (4-1) and Eq. (4-2) examine the explanatory power of standard deviation of deposit rates on the peak-to-trough GDP growth rate decline with 0 or 1 quarter lag. The peak-to-trough GDP declines are mainly around two recession dates (ST dates as mentioned before).

[Please insert Table 4.3 here]

Table 4.3 presents the results. Column (1) to (6) indicate that the heterogeneity in the deposit rates offers statistical explanation of the severity of the crisis. For instance, a closer look at the data in column (5) and column (6) reveals that a 0.1% increase in the standard deviations of 12MCD10K rates is associated with a -2.906% and -1.804% peak-to-trough GDP decline at the starting point of the crisis and 1 quarter before the crisis, respectively. In addition, it is found that 01MCD100K rate is the most effective predictor among 4 kinds of deposit rates. These above findings demonstrate that the heterogeneity of deposit rates increases substantially in the transition to recession. Moreover, the severity of the peak to trough in GDP growth rates at state level is determined by the size of the increase in heterogeneity of deposit rates. These results supports the validity of Hypothesis I.

Furthermore, this chapter investigates the relation between GDP growth rate and the heterogeneity in deposit rates at state level by regressing the following equations:

$$\Delta y_{i,t} = \alpha + b_3 STD_{i,t} + SFE + \varepsilon_{i,t}, \tag{4-3}$$

$$\Delta y_{i,t} = \alpha + b_4 STD_{i,t-1} + SFE + \varepsilon_{i,t}, \tag{4-4}$$

We interact a recession dummy with the intercept as it is shown in Eq. (4-4) to investigate the role of heterogeneity in deposit rates is playing prior the crisis. $\Delta y_{i,t}$ is the GDP growth rate for state i at time t. $STD_{i,t-3}$ and $STD_{i,t-4}$ denote the standard deviations of deposit rates for state i at time $t-3$ and time $t-4$, respectively. In addition, a dummy variable that equals to one when the observations are at the ST dates is included. Two lags of the GDP growth rate are applied as controlle, along with state fixed effects. The number of lags is set to 3 and 4 because the heterogeneity of deposit rates has a significant negative effect on the GDP growth rate after 9 and 12 months. And after 12-month horizon, this effect dies away and becomes insignificant.

[Please insert Table 4.4 here]

Table 4.4 suggests a significant negative relationship between the heterogeneity of deposit rates and the GDP growth rate. A 1% increase in the standard deviation of deposit rates for MCD10K is associated with a -0.95% decline in the subsequent GDP growth rate (1 quarter lag). However, the coefficients are too small to allow for meaningful interpretation.

[Please insert Table 4.5 here]

The results are presented in Table 4.5, where an increase in the heterogeneity for both 01MCD10K and 01MCD100K has a significantly negative effect at 9-month and 12-month future GDP growth rates, mainly concentrated in column (1) and column (2) of each panel. Consistent with the results in Table 4, the absolute values of the coefficients become larger when recession dummies are included. A 1% increase in the standard deviation of 01MCD10K rate decreases GDP growth in the trailing 9 months by -2.17% in the absence of recession dummies and by -1.27% in the trailing 9 months in the presence of recession dummies.

However, as can be seen in column (3) and column (4), increased heterogeneity in the 12MCD10K and 12MCD100K rates negatively affects future GDP growth rates at both 9 and 12 months, but only when the recession dummy variable is excluded.

In the previous section, this chapter has shown that high heterogeneity in deposit rates coupled with a high ratio of bank lending to GDP growth leads to adverse outcomes for GDP growth rate. A further attempt is made to explore whether the deposit rates are on average high prior to the crises compared to the other episodes, by estimating the following equation:

$$STD_{i,t} = a + b_{11} \times dummy_{t-5.t-1} + b_{12} \times \Delta Bank\ loans\ to\ GDP_{t-1} + \Delta y_{i,t-1} + \Delta y_{i,t-2}. \qquad (4\text{-}7)$$

The dependent variable in Eq. (4-7) is the standard deviation of deposit rates for state i at quarter t. $\mathrm{dummy}_{t-5.t-1}$ takes the value of 1 if the observations are within 1 to 5 quarter lags. $\Delta\mathrm{Bank\ loans\ to\ GDP}_{t-1}$ denotes the bank loan to GDP growth, while $\Delta y_{i,t-1}$ and $\Delta y_{i,t-2}$ are the GDP growth rate for state i at quarter t-1 and t-2, respectively.

[Please insert Table 4.6 here]

Table 4.6 shows that the degree of heterogeneity in deposit rates is on average "too high" prior to the crisis. When we look closely at the column (1) and column (2) for each panel from Table 6, the coefficient on the dummy ranges from 0.171 to 0.559 without year fixed effects, implying the standard deviation in the deposit rates are 0.171% to 0.559% higher than one would have expected ahead of a crisis. Column (3) and column (4) in each panel from Table 6 indicate the coefficient on the dummy is much lower, ranging from 0.045% to 0.057%, after controlling for country fixed effects. These results indicate hypothesis IV stands.

Krishnamurthy and Muir (2017) discover a pre-crisis spread of around 25% 'too low' in their "FZ model". In the "FD model" built in this study, it is found that the heterogeneity of deposit rates in the five quarters before the crisis is 'too high' as compared to other periods.

4.5.2 "FD" model: Heterogeneity in the deposit rates, Fragility financial condition and Recessions

The "FD model" suggests that increased heterogeneity in deposits rate, coupled with a fragile financial stability condition, can lead to more severe economic downturns. To demonstrate this, an event of high heterogeneity in deposit rates is first defined as a period in which the standard deviation of deposit rates exceeds the 80th percentile. This cut-off point helps us capture the dynamics of the increasing in the degree of heterogeneity of deposit rates from banks during the pre-crisis periods. The following equation can then be estimated:

$$\Delta y_{i,t+h} = a + b_5 dummy_{HighHeter} \times STD_{i,t} + \ b_6 \Delta y_{i,t+h-1} + b_7 \ \Delta y_{i,t+h-2}, \quad (4\text{-}5)$$

$$\Delta \mathrm{y}_{\mathrm{i,t+h}} = \mathrm{a} + \mathrm{b}_8 \mathrm{dummy}_{\mathrm{HighHeter}} \times \mathrm{dummy}_{\mathrm{Highloangrowth}} \times \mathrm{STD}_{\mathrm{i,t}} + \ \mathrm{b}_9 \ \Delta \mathrm{y}_{\mathrm{i,t+h-1}} + \mathrm{b}_{10} \ \Delta \mathrm{y}_{\mathrm{i,t+h-2}}, \quad (4\text{-}6)$$

As introduced before, where $\Delta \mathrm{y}_{\mathrm{i,t+h}}$ is the GDP growth rate for state i at quarter t+h, h takes the value from 1 to 5, the $\mathrm{dummy}_{\mathrm{HighHeter}}$ is the dummy takes the value of 1 if the standard deviation for state i is above the 80th percentile at quarter t. While the $\mathrm{dummy}_{\mathrm{Highloangrowth}}$ takes the value of 1 if the loan growth to GDP is above the median at quarter t. $\mathrm{STD}_{\mathrm{i,t}}$ is the standard deviation of deposit rates for state i at quarter t. The regressions also include $\Delta \mathrm{y}_{\mathrm{i,t+h-1}}$ and $\Delta \mathrm{y}_{\mathrm{i,t+h-2}}$, which are GDP growth rate for state i with 1 and 2 quarter lags as control variables.

[Please insert Table 4.7 here]

The findings reported in Table 4.7 suggest that the effect of heterogeneity in deposit rates on the future GDP growth rate becomes significant after three quarters. In addition, GDP declines more when the credit to GDP growth is high prior to the crisis. Under a high heterogeneity event, a 1% increase in the standard deviation of the 12MCD10K interest rate can lead to a -5.45% decline in GDP growth after 5 quarters, but under a high heterogeneity plus a high bank lending event, it leads to a -6.29% decline in GDP growth after 5 quarters. Moreover, as compared to the results from Table 5, the effect of heterogeneity in deposit rates within the high heterogeneity events (including high heterogeneity/high loan growth events) are more persistent, suggesting hat increasedheterogeneity in deposit rates has a negative impact on future GDP growth rates on average, but is particularly detrimental and persistent the case of high leverage.

The results corroborate previous theories explaining financial crisis. "FZ model" suggests that crises are the result of shocks or triggers. And these shocks can be amplified by the fragility of financial sector, which is usually measured by leverage or high short-term debt financing, as detailed in He and Krishnamurthy (2012) and Kiyotaki and Moore (1997)'s works. Here we use bank credit growth as the measurement of fragility of financial sector, and this chapter proposes "FD" model by showing an increase in the heterogeneity in deposit rate is more harmful when the shock is coupled with a fragile financial sector condition.

4.5.3 Heterogeneity in deposit rates and credit condition

Furthermore, in this chapter, how changes in deposit rate heterogeneity affect credit conditions is examined through regression, as can be seen as follows:

$$SP\ Municipal\ Return_{i,t} = a + b_{13} \times STD_{i,t-h} + SFE, \tag{4-8}$$

where the $\mathrm{SP\ Municipal\ Return}_{i,t}$ is the quarterly return on the S&P municipal bond index for state i at time t and $\mathrm{STD}_{i,t-h}$ is the standard deviation of deposit rates for state i at time $t-h$. Here $h = 1,2,3,4$ is set with the purpose of testing how the heterogeneity is associated with the returns on the S&P municipal bond index with a forecasting horizon of 1-4 quarters.

[Please insert Table 4.8 here]

Table 4.8 presents the results. It can be observed that an increase in the heterogeneity in deposit rates is associated with a large declines in the returns on the state municipal bond indexes. For instance, an increase in the standard of deviation of 01MCD10K or 01MCD100K deposit rate predicts significant negative impact on the returns of the state municipal bond indexes starting from 3 or 4 quarters. Heterogeneity in deposit rates, using a sample of 1-month maturity certificates of deposit sample, is associated with a deterioration in future credit conditions from 3 or 4 quarters onwards. This result can be partially reconciled with Woodford (2010), who demonstrates that credit spreads do not alter much even if the Federal Funds rate increases during the pre-crisis period of 2004-2006.

4.5.4 Interest rate and household' s spending and salary

In this subsection, the chapter investigates whether an increase in the interest rate affects household's spending and salary. This chapter begins by regressing the logarithmic change in household's durable/non-durable expenditure on the lagged change in the interest rate, which is shown in the following equation. The durable expenditure includes the spending on household furnishings, vehicle purchasing, maintenance, etc. Non-durable expenditures, on the other hand, include expenditures on food, utilities, etc. The Federal Funds rates are adopted in here as interest rate. During the zero-lower bound period from July 2009 to October 2015, Wu-Xia shadow rate are applied instead.

$$\Delta Consumption_{i,t} = a + b_{14} \times \Delta interest\ rate_{t-h}/\Delta deposit\ rate_{t-h}/\Delta deposit\ spread$$
$$SFE + TFE + Household\ control\ variables, \quad (4\text{-}9)$$

Also, state fixed effects, quarter fixed effects and household control variables are included in each regression. Household control variables include the age of reference person, household size and number of children.

[Please insert Table 4.9 here]

The findings are presented in Table 4.9. It can be seen from Panel A, that with time and state fixed effects, a rise in interest rates correlates with a fall in durable and non-durable consumption over the next 2 or 3 quarters. The impact on non-durable is even greater and more persistent.

Furthermore, the whole sample period is split into two periods, expansionary monetary policy period of 2008Q4 to 2015Q4 and 2019Q1 to 2019Q4, when interest rates are falling, and contractionary monetary policy period of 2001Q1 to 2008Q3 and 2016Q1 to 2018Q4, when the interest rates are increasing. Clear evidence of heterogenous responses in household's consumption within expansionary and contractionary monetary periods can be seen from Panel B and Panel C. During expansionary monetary episode, the negative effect of interest rate changes on non-durable consumption peaks after 2 quarters and then dies away, while the impact on durable consumption is not significant at all. However, during contractionary monetary policy, it is found the effects on durable and non-durable consumption are significant and more persistent, ranging from 2 to 4 quarters. These results are consistent with Cloyne, Ferreria and Surico (2020), whose empirical evidence suggests that the response of consumption is heterogeneous across different periods of monetary policy.

Moreover, the chapter investigates the change in household's salary on the lagged change in the interest rate. As it is shown in the following equation.

$$\ldots\ldots \Delta Salary_{i,t} = a + b_{15} \times \Delta interest\ rate_{t-h} / \Delta deposit\ rate_{t-h} / \Delta deposit\ spread + SFE + TFE + Household\ control\ variables, \quad (4\text{-}10)$$

where $\Delta\ salary_{i,t}$ is the change in salary for household *i* at quarter *t*. $\Delta interest\ rate_{t-h}$ is the lagged change in interest rate at quarter *t-h*, while h if from 1 to 4. In each regression, state fixed effects, quarter fixed effects and household control variables are included. Household control variables include the age of reference person, household size and number of children.

[Please insert Table 4.10 here]

In Panel A of Table 4.10, it can be seen that a 1% increase in the interest rate with a 1 quarter lag is associated with a $1,304 reduction in household salary. However, the sign of the coefficients reverses rapidly after a lag of 2 quarters and then becomes insignificant.

The sample is also then divided into two sub-samples by monetary policy regimes. The expansionary monetary policy period is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4, while the contractionary monetary policy is from 2001Q1 to 2008Q3 and 2016Q1 to 2018Q4 when interest rates are increasing. Notably, rising interest rates have significant negative impact on salary from one to four quarters. The study also finds that there were three lags in the impact of interest rate changes on salary due to changes in salaries being overly sensitive to changes in interest rates during periods of expansionary monetary policy, when interest rates are close to the zero lower bound.

4.5.5 Deposit rate and household's spending and salary

In addition, this chapter analyses the behavior of deposit rates, household's durable and non-durable expenditure at state level, by through following regressions:

$$\ldots\ldots\ldots\ldots Durable\ expenditure/\ non\ durable\ expenditure = a + b_1 \times deposit\ rate_{i,t-h} + FE_{state} + TFE + State\ Fixed\ effects, \quad (4\text{-}11)$$

where the $Durable\ expenditure/\ non\ durable\ expenditure$ and $non\ durable\ expenditure$ are the household's durable expenditure and non-durable expenditure at level. In contrast, the deposit rate is the state average deposit rate of the 1-month certificates of deposit with an account size of $10,000. This deposit type is selected particularly because it is the smallest and most liquid time deposit in our dataset. To test the relationship between deposit rates from zero to a two-quarter lag and household durable and non-durable expenditures, we set h at a value of 0 to 2.

[Please insert Table 4.11 here]

Column (1) - (3) of Table 4.11 present state-quarter fixed effects and household's control variables, while (4) - (6) contain state fixed effects, quarter fixed effects and household's control variables. All regressions are executed at state level. Panel A shows the results of household's non-durable expenditure. Clearly, this regression captures a significant negative relationship between 1-month certificates of deposit (01MCD10K) rate and household's non-durable consumption. And this effect peaks two quarters after. Controlling for state and quarterly fixed effects, or for state-quarterly fixed effects, a 1% increase in the 01MCD10K interest rate is associated with an $85 decrease in household consumption of non-durable goods after two quarters. However, it can be seen from Panel B that the relationship between 1-month certificates of deposit (01MCD10K) rate and household's durable consumption is insignificant.

Similarly, this chapter investigates the effects of changes in deposit spreads on changes in household durable and non-durable consumption.

[Please insert Table 4.12 here]

Panel A of Table 4.12 reveals that an increase in the deposit spread is associated with a decrease in both durable and non-durable consumption. And the responses are strong and significant 2 quarters after. And these effects last at least for 4 quarters. Also, the effects are found to be stronger and more persistent following increases in interest rates and deposit spreads during episodes of tight monetary policy, suggesting that fluctuations in deposit spreads are more "painful" during periods of tightness.

Similarly, we regress the change in household's salary on the lagged change in the deposit spread, as the following equation shows:

$$\Delta\, salary_{i,t} = a + b_1 \times \Delta deposit\ spread_{,t-h} + FE_{state} + TFE + Household\ control, \qquad (4\text{-}12)$$

where $\Delta\,\mathrm{salary}_{i,t}$ is the change in salary for household i at quarter t, $\Delta \mathrm{deposit\ spread}_{,t-h}$ is the lagged change in interest rate at quarter t-h, while h is at the range of 1 to 4. Within each regression, state fixed effects, quarter fixed effects and household control variables are included. Household control variables include the age of reference person, family size and number of children.

[Please insert Table 4.13 here]

Table 4.13 shows the results. A negative relationship between deposit spreads and household salaries is identified. It can be observed that 1% increase in the deposit spread is associated with 721 and 1086 dollars decrease in household's salary 2 and 4 quarters, respectively.

4.5.6 The heterogeneous response of household's expenditure and salary

To examine how different types of households change their expenditure and salary in response to changes in interest rate and deposit spread, three unique variables from CEX dataset are adopted to construct the three pseudo-cohorts despitethe lack of detailed information on household wealth and household balance sheets. The variables used in this chapter are property owning number, rent payment last month and outstanding mortgage amount. Two potential issues are worth mentioning. The first concerns endogenous changes in group composition, which implies that households may change their housing status in response to shocks in interest rate or deposit spreads. Also, the other issue is that the three cohorts are not random which means some other characteristics may account for the heterogeneous responses we find.

[Please insert Table 4.14 here]

From Table 4.14, it can be observed that the durable consumption, non-durable consumption and the household's salary are all in steadily growing trends. And among the three cohorts, the mortgagor cohort tends to earn the highest salary and spend the most in both durable consumption and non-durable consumption. This is partially because the average age of this cohort is smaller than the mortgagor cohort.

The regression for three different cohorts is executed separately in this study.

[Please insert Table 4.15 here]

[Please insert Table 4.16 here]

[Please insert Table 4.17 here]

Clear evidence of heterogeneous effects across groups can be seen from Table 4.15, Table 4.16, and Table 4.17. Firstly, it is found that the response of both durable consumption and non-durable consumption peaks two quarters after the shock initializes. The responses of durable consumption are more persistent and statically larger than the responses of non-durable consumption.

Moreover, it can be found in this chapter that he mortgagor cohort has the largest response to interest rate changes of three cohorts, peaking -0.0945 2 quarters after in the whole sample period, as compared to -0.0595 and -0.0882 of renter cohort and property owner cohort, respectively. Also, when we separate the whole sample according to monetary policy regimes, remarkably, under the tight monetary policy regime, the mortgagor group has the largest response to interest rate changes of the three groups. This indicates that the mortgagor cohort, who holds the most illiquid asset seems to be the first order to understand the effects of interest rate shocks and deposit channel on household's expenditure and salary.

Furthermore, this chapter investigates the effects of the change in deposit spread on household's consumption by separating the sample into three different cohorts.

[Please insert Table 4.18 here]

[Please insert Table 4.19 here]

[Please insert Table 4.20 here]

Table 4.18 and Table 4.19 and Table 4.20 present the empirical evidence on heterogeneous responses to deposit spread changes across cohorts. It can be observed that the responses are significantly positive one quarter after the shock initiates within the whole sample regression, but the sign of coefficients quickly reverts to negative afterwards. In addition, mortgagor cohort is the most sensitive cohort when it comes to changes in deposit spreads. For example, a 1% increase in deposit spreads leads to a -0.0452 decrease in the log of consumer durables, while the renter cohort and the property owner cohort decrease by -0.0248 and -0.0118 respectively. In addition, when the entire sample is split according to monetary policy regimes, it is found the responses of three cohorts are significantly negative under the expansionary monetary regime. However, during contractionary regimes, most of these responses are statistically indistinguishable from zero.

In summary, the reduction in expenditure tends to be larger and more significant for the mortgagor cohort in response to rising interest rates, but smaller for the property owner cohort and the renter cohort. In addition, there is greater heterogeneity in the response to durable consumption compared to non-durable consumption. Based on the results shown in Subsection 4.5.6 and 4.5.7, hypothesis VI stands. These results are consistent with Mian, Rao and Sufi (2013), who identify significantly higher MPCs for households with higher leverage. Our results show that the mortgagor cohort experiences the largest drop in consumption among the three cohorts when faced with rising interest rates.

4.5.7 Monetary policy shocks and household's consumption

Finally, this chapter investigates the effects of monetary policy shocks on household consumption. The first issue observed here is the identification of monetary policy shocks. An inappropriate approach to identifying monetary policy shocks establishes a relationship between monetary policy and other economic variables, but without any real causal relationship (Romer and Romer, 2004). The typical approach to measuring monetary policy is introduced by Romer and Romer (2004), who construct a measure of shocks from the component of policy changes prior to each FOMC meeting. The monetary policy shocks are defined as innovations in the regression of changes in federal fund rates on an information set that includes inflation, output and unemployment rate. However, oen of the drawbacks of this methodology is that the Greenbook, which contains the forecasting information set, is available for FOMC committee but is kept as confidential to the public for at least 3 years. In this chapter, therefore, changes in 1-month federal funds futures during the FOMC window are taken as a measure of monetary policy shocks. Then we regress the households' durable consumption and non-durable consumption on the monetary policy shocks, as shown in the following equation:

$$Durable/non\ durable\ consumption_{i,t} = a + b_1 \times MP_{t-h} + FE_{state} + TFE + Household\ control, \quad (4\text{-}13)$$

where $Durable/non\ durable\ consumption_{i,t}$ are the durable or non-durable for household i at quarter t, MP_{t-h} denotes the monetary policy shocks variable at quarter *t-h, h* takes the value from 0 to 2.

[Please insert Table 4.21 here]

The results presented in Table 4.21 indicate that the monetary policy shocks have greater impact on the non-durable consumption compared to on the durable consumption. The impact of monetary policy on non-durable consumption are significant positive contemporarily but quickly revert to significant negative after two quarters. It can be found that an unexpected increase of 1% in interest rate changes leads to a reduction in households' non-durable consumption of around US$1,000 after two quarters. However, this effect is not significant on durable consumption.

4.6 Conclusion

To conclude, this chapter investigates the role of deposits on output, credit condition and household's consumption and salary. Firstly, the deposits channel of monetary policy suggests that heterogeneity in deposit rates acts on output and consumption by affecting lending provided by banks (Drechsler, Savov and Schnabl, 2017). In this chapter, firstly, the heterogeneity of deposit rates is shown to independently predict the peak to trough GDP growth rate at state level. Furthermore, existing literature, such as Krishnamurthy and Muir (2017), has shown that an increase in credit spread, coupled with fragile financial conditions, can lead to a more severe economic downturn ("FZ" model). The contribution of this chapter is to demonstrate that increased heterogeneity in deposit rates coupled with a fragile financial condition can lead to more severe crises ("FD model"). Furthermore, this chapter demonstrates the heterogeneity in deposit rates can be a good predictor of future crises by revealing that this variable is significantly higher in the 1-5 quarters preceding a crisis than in the rest of the period.

In addition, this chapter highlights the role of interest rates and deposit rates on household durable consumption, non-durable consumption and salary by using household level data. It is found in this chapter that an increase in deposit rates negatively affects household consumption and salary after two quarters in a significant way. Furthermore, it is shown in this chapter that the characteristics of household balance sheets act in shaping the household's expenditure and salary when confronted the changes in interest rate, deposit spread and monetary policy stance. The empirical evidence above demonstrates that mortgagors, renters and property owners adjust their consumptions heterogeneously when encounter the monetary policy shocks. And among the three cohort, the mortgagor cohort is found to be the most marginally inclined to consume under both contractionary and expansionary monetary policy regimes.

This chapter begins with a further exploration of the deposit channel in Drechsler, Savov and Schnabl (2017), highlighting the relationship between the heterogeneity in deposit rates, economic downturns and output. The findings in this chapter suggest that heterogeneity in deposit rates has significant predicting power on both the severity of economic downturns and state-level GDP growth rate. In addition, this chapter modifies the original "FZ model" in Krishnamurthy and Muir (2017) into "FD model", which indicates the heterogeneity of deposit rates, coupled with a fragile financial condition leads to a more severe crisis. This chapter also contributes to the work of Cloyne, Ferreria and Surico (2020) by investigating the effect of interest rate, deposit rate and monetary policy shock on households' consumption and salary. It can be revealed in this study that the effects are heterogeneous due to the different balance sheets of households.

To summarize, this chapter finds: i) An increase in the heterogeneity in deposit rates is associated with a larger peak to trough declines in the economic downturns ($b_1 < 0, b_2 < 0$), and ii) an increase in the heterogeneity in deposit rates is associated with a decrease in the state level GDP growth rate ($b_3 < 0, b_4 < 0$).iii) In addition, our empirical evidence supports the "FZ" model by showing an increase in the heterogeneity in deposit rates, coupled with a fragile financial sector condition leads to a more severe crisis, in terms of GDP growth rate declines ($b_8 < b_5 < 0$), and iv) The heterogeneity in deposit rates is "too high" on average before (from 1 to 5 quarters prior) economic downturns ($b_{11} > 0$). v) Furthermore, regarding the deposit rates and credit conditon, our study shows an increase in the heterogeneity in deposit rates is associated with a worsening credit condition, in terms of declines in S&P municipal bond index. Finally, our study suggests vi) An increase in the interest rate/deposit rate/deposit spread has a negative impact on household's consumption and salary (b_{13}<0,b_{14}<0), and the effects are heterogeneous among three cohorts (b_{14}<0,b_{15}<0).

Future research can start by constructing the heterogeneity in deposit rates by considering the deposit amount. This is because the RateWatch dataset only provides deposit rates at branch level without deposit amount. This improvement can get rid of influences caused by some utlying institutions. In addition, this chapter studies the role of heterogeneity in deposit rates on output and the severity of economic downturns by using state-level historical level data. Future research can study whether the heterogeneity in deposit rates can affect the expectations on output and inflation by using data from the Survey of Professional Forecasters provided by Federal Reserve Bank of Philadelphia. Furthermore, the findings of our empirical evidence are consistent with the view that tight monetary policy negatively affects aggregate demand through its impact on household expenditure.

Table 4.1. Summary statistics

	Summary Statistics				
Branch level	**Obs**	**Mean**	**Std. Dev**	**Min**	**Max**
Deposit rates of 01MCD10K (%)	1546858	0.272	0.488	0.000	9.990
Deposit rates of 01MCD100K (%)	1801611	0.433	0.766	0.000	6.600
Deposit rates of 12MCD10K (%)	8690361	1.874	1.466	0.001	7.930
Deposit rates of 12MCD100K (%)	5102802	0.966	1.043	0.000	45.900
State level variables	**Obs**	**Mean**	**Std. Dev**	**Min**	**Max**
3-year loan to GDP growth rate (%)	3797	0.270	0.477	-0.634	6.818
GDP growth rate (%)	3700	1.937	4.674	-25.100	58.500
S&P municipal bond index quarterly returns (%)	3581	0.125	5.162	-25.817	32.660
Standard deviation of 01MCD10K rate (%)	2521	0.212	0.254	0.000	2.786
Standard deviation of 01MCD100K rate (%)	2990	0.280	0.308	0.000	2.451
Standard deviation of 12MCD10K rate (%)	3677	0.342	0.166	0.066	1.558
Standard deviation of 12MCD100K rate (%)	3335	0.332	0.168	0.000	1.584
Bank level variables	**Obs**	**Mean**	**Std. Dev**	**Min**	**Max**
Cash (mn)	581157	147.731	4065.863	0.000	508253.000
Treasury (mn)	543269	29.360	1065.677	0.000	141580.000
Return on assets (%)	608534	0.460	40.918	-31089.11	2171.99
Equity to assets ratio (%)	608534	11.773	7.677	-519.469	100.00
Tier 1 capital to total assets ratio (%)	613896	11.202	7.362	-519.469	100.00
Tier 1 capital to risk weighted assets ratio (%)	613891	21.973	273.995	-2300.000	74283.33
Size (Total assets) (mn)	585268	1715.025	31486.850	0.066	2367127.00
Household dataset	**Obs**	**Mean**	**Std. Dev**	**Min**	**Max**
Family Salary	25523	66854.24	82130.24	0	739006
Non-durable consumption	25523	3192.18	2741.62	320.333	113984
Durable Consumption	25523	1637.91	3448.76	0	170595
Family Size	25523	2.38	1.44	1	16
Child Age	25523	1.61	2.52	0	7
Age of Reference person	25523	52.91	17.65	21	87

Notes: This table reports the number of observations, mean, standard deviation, minimum and maximum value for key variables used in this chapter.

Table 4.2. Pairwise correlation matrix

	Durable consumption	Non-durable consumption	Family income	Age of reference person	Age of child	Family size	Standard deviation of 12MCD10K rate	Standard deviation of 12MCD100K rate	Standard deviation of 01MCD10K rate	Standard deviation of 01MCD100K rate	Effective Federal Funds rate	State GDP growth rate
Durable consumption	1											
Non-durable consumption	0.3352	1										
Family income	0.2173	0.4335	1									
Age of reference person	-0.0358	-0.0591	-0.1995	1								
Age of child	0.0817	0.185	0.2018	-0.053	1							
Family size	0.1129	0.2809	0.2833	-0.2696	0.5996	1						
Standard deviation of 12MCD10K rate	0.0118	-0.0129	-0.001	-0.0077	0.0021	0.0092	1					

Table 4.2 (Continued). Pairwise correlation matrix

Standard deviation of 12MCD100K rate	0.0117	-0.006	0.0064	-0.0013	-0.0008	0.0023	0.9334	1				
Standard deviation of 01MCD10K rate	-0.0057	-0.0388	-0.0332	-0.0347	0.0127	0.0255	0.682	0.6345	1			
Standard deviation of 01MCD100K rate	-0.004	-0.0372	-0.0259	-0.0251	0.0066	0.0143	0.7066	0.681	0.9066	1		
Effective Federal Funds rate	0.0055	-0.0612	-0.0341	-0.0251	0.0074	0.0153	0.7728	0.6931	0.7492	0.7649	1	
State GDP growth rate	0.0035	-0.0128	-0.0018	-0.0086	0.0033	0.0102	-0.1181	-0.1537	-0.1221	-0.1029	0.0032	1

Notes: This table reports the the pairwise correlation matrix for key variables used in this chapter.

Table 4.3. The forecasting power of the heterogeneity in deposit rates

		Dependent Variable: Dummy of ST crisis								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Independent Variable		ST crisis	ST crisis	ST crisis	ST crisis	ST crisis	ST crisis	ST crisis	ST crisis	ST crisis
01MCD10K	Std. Dev	-0.741 (5.18)								
	1 lag Std.Dev		-2.221 (3.46)							
01MCD100K	Std. Dev			-11.361** (4.87)						
	1 lag Std.Dev				-14.858** (5.87)					
12MCD10K	Std. Dev					-29.057*** (10.33)				
	1 lag Std. Dev						-18.044 (12.45)			
12MCD100K	Std. Dev							-24.108** (10.30)		
	1 lag Std.Dev								-12.134 (11.65)	
	% Change in bank loans to GDP									-0.2700*** (0.08)
Observations		24	24	44	43	69	69	60	61	68
R-squared		0.0009	0.0184	0.1144	0.1352	0.1056	0.0304	0.0864	0.0181	0.1479

Notes: This table shows the forecasting power of the heterogeneity in deposit rates of banks in terms of the peak to trough declines in GDP during the economic downturns. Jorda et al. (2011) and Jorda et al. (2013) crisis dates are used that mark the start of recessions and calculate the peak to trough GDP growth rates. The standard deviations of deposit rates lagged standard deviations, and percentages of 3-year bank loans growth are included as independent variables. Standard errors in parenthesis, * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.4. GDP growth and heterogeneity in deposit rates

Variables	(1)		(2)		(3)		(4)	
	01MCD10K		01MCD100K		12MCD10K		12MCD100K	
01MCD10K standard deviation	-1.235***							
	(0.36)							
1 lag of 01MCD10K standard deviation		-1.521***						
		(0.36)						
01MCD100K standard deviation			-0.955***					
			(0.27)					
1 lag of 01MCD100K standard deviation				-1.181***				
				(0.27)				
12MCD10K standard deviation					-1.041**			
					(0.47)			
1 lag of 12MCD10K standard deviation						-0.948**		
						(0.48)		
12MCD100K standard deviation							-1.468***	
							(0.48)	
1 lag of 12MCD100K standard deviation								-1.687***
								(0.49)
Observations	2521	2473	2990	2941	3677	3627	3335	3285
R-squared	0.0516	0.0498	0.0416	0.0423	0.0289	0.0286	0.0231	0.04
State FE	✓	✓	✓	✓	✓	✓	✓	✓

Notes: This table provides regressions of GDP growth on the standard deviations of current and 1 quarter lagged deposit rates. The first to fourth column use the standard deviation of 01MCD10K, 01MCD100K, 12MCD10K and 12MCD100K rates, respectively. Standard errors in parenthesis, * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.5. 9-month/12-month ahead GDP growth rate and heterogeneity in deposit rates

Panel A. 9-month GDP growth				
VARIABLES	(1)	(2)	(3)	(4)
Std of 01MCD10K	-2.172***			
	(0.38)			
Std of 01MCD100K		-1.765***		
		(0.28)		
Std of 12MCD10K			-1.725***	
			(0.52)	
Std of 12MCD100K				-1.629***
				(0.53)
State Fixed effect	✓	✓	✓	✓
Lagged GDP controlled	✓	✓	✓	✓
Observations	2329	2773	3456	3114
R-squared	0.0820	0.0898	0.0604	0.0745

Panel B. 9-month GDP growth interacted with recessions dummies				
VARIABLES	(1)	(2)	(3)	(4)
Std of 01MCD10K	-1.273***			
	(0.44)			
Std of 01MCD100K		-1.016***		
		(0.32)		
Std of 12MCD10K			-0.236	
			(0.57)	
Std of 12MCD100K				-0.168
				(0.57)
State Fixed effect	✓	✓	✓	✓
Lagged GDP controlled	✓	✓	✓	✓
recessions dummies	✓	✓	✓	✓
Observations	2329	2773	3456	3114
R-squared	0.0890	0.0980	0.0702	0.0896

Panel C. 12-month GDP growth				
VARIABLES	(1)	(2)	(3)	(4)
Std of 01MCD10K	-2.541***			
	(0.38)			
Std of 01MCD100K		-2.112***		
		(0.28)		
Std of 12MCD10K			-2.233***	
			(0.52)	
Std of 12MCD100K				-2.278***
				(0.54)
State Fixed effect	✓	✓	✓	✓
Lagged GDP controlled	✓	✓	✓	✓
Observations	2282	2727	3407	3065
R-squared	0.0933	0.0949	0.0618	0.0749

Table 4.5 (Continued). 9-month/12-month ahead GDP growth rate and heterogeneity in deposit rates

Panel D. 12-month GDP growth interacted with recessions dummies				
VARIABLES	(1)	(2)	(3)	(4)
Std of 01MCD10K	-1.394***			
	(0.46)			
Std of 01MCD100K		-1.394***		
		(0.34)		
Std of 12MCD10K			-0.536	
			(0.61)	
Std of 12MCD100K				-0.666
				(0.60)
State Fixed effect	✓	✓	✓	✓
Lagged GDP controlled	✓	✓	✓	✓
recessions dummies	✓	✓	✓	✓
Observations	2282	2727	3407	3065
R-squared	0.1008	0.1000	0.0699	0.0868

Notes: This table provides the regressions of future GDP growth on the standard deviations of deposit rates at the 9- and 12-month horizon. The recession dummy is included. Controls include two lags of GDP growth, and state fixed effects are included. Standard errors in parenthesis, * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.6. The heterogeneity in the deposit rates prior to the crisis

Panel A: Standard deviations of deposit rates before a crisis (01MCD10K)

	(1)	(2)	(3)	(4)
$1_{t-5.t-1}$	0.537***	0.495***	0.057**	0.050**
	(0.02)	(0.02)	(0.02)	(0.02)
$\Delta Bank\ loans\ to\ GDP_{t-1}$	-0.008	0.074**	-0.042***	0.004
	(0.02)	(0.00)	(0.02)	(0.02)
ΔGDP_{t-1}	-0.001	-0.001	-0.008	-0.001*
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	2454	2454	2454	2454
R-squared	0.2672	0.3356	0.6756	0.6983
State FE	N	Y	N	Y
Year FE	N	N	Y	Y

Panel B: Standard deviations of deposit rates before a crisis (01MCD100K)

	(1)	(2)	(3)	(4)
$1_{t-5.t-1}$	0.559***	0.519***	0.052**	0.053***
	(0.02)	(0.02)	(0.02)	(0.02)
$\Delta Bank\ loans\ to\ GDP_{t-1}$	-0.013	0.153***	-0.039**	-0.024
	(0.03)	(0.04)	(0.02)	(0.03)
ΔGDP_{t-1}	-0.002	-0.002*	-0.002**	-0.001**
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	2887	2887	2887	2887
R-squared	0.2608	0.3288	0.7511	0.7755
State FE	N	Y	N	Y
Year FE	N	N	Y	Y

Panel C: Standard deviations of deposit rates before a crisis (12MCD10K)

	(1)	(2)	(3)	(4)
$1_{t-5.t-1}$	0.207***	0.206***	0.045***	0.046***
	(0.01)	(0.01)	(0.01)	(0.01)
$\Delta Bank\ loans\ to\ GDP_{t-1}$	0.121***	0.134***	0.085***	0.079***
	(0.01)	(0.02)	(0.01)	(0.00)
ΔGDP_{t-1}	-0.001***	-0.001**	-0.002***	-0.002***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	3555	3555	3555	3555
R-squared	0.1728	0.2055	0.7618	0.7942
State FE	N	Y	N	Y

Table 4.6 (Continued). The heterogeneity in the deposit rates prior to the crisis				
Year FE	N	N	Y	Y

Panel D: Standard deviations of deposit rates before a crisis (12MCD100K)

	(1)	(2)	(3)	(4)
$1_{t-5.t-1}$	0.183***	0.171***	0.054***	0.054***
	(0.01)	(0.01)	(0.01)	(0.01)
$\Delta Bank\ loans\ to\ GDP_{t-1}$	0.123***	0.213***	0.091***	0.128***
	(0.01)	(0.02)	(0.01)	(0.01)
ΔGDP_{t-1}	-0.002***	-0.002	-0.003***	-0.002***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	3226	3226	3226	3226
R-squared	0.1267	0.1898	0.6710	0.7142
State FE	N	Y	N	Y
Year FE	N	N	Y	Y

Notes: Is the heterogeneity in the deposit rates prior to the crisis too high? The standard deviation of deposit rates is regressed on a dummy which takes the value 1 in the 5 quarters before a crisis, labelled ($1_{t-5.t-1}$) in order to assess whether the heterogeneity in the deposit rates going into a crisis too high. The results are univariate, as well as the results controlling for time fixed effects and state fixed effects. Then changes in loan in GDP growth and lagged GDP are added as control variables. Standard errors clustered by time in parenthesis.

Table 7. “FD” model

Panel A											
VARIABLES		(1) 1qr	(2) 1qr	(3) 2qrs	(4) 2qrs	(5) 3qrs	(6) 3qrs	(7) 4qrs	(8) 4qrs	(9) 5qrs	(10) 5qrs
01MCD10K	HighHeter	-1.491***		-0.931		-1.082*		-2.007***		-2.253***	
		(0.55)		(0.57)		(0.65)		(0.66)		(0.68)	
	(HighHeter) * (Highloan)		-1.146		-0.776		-1.379		-2.304**		-2.593***
			(0.83)		(0.88)		(0.96)		(0.90)		(0.95)
	Observations	455	217	446	216	436	210	432	209	429	208
	R-squared	0.0387	0.0366	0.0539	0.0981	0.0594	0.0900	0.1074	0.1231	0.1689	0.2098
	Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Panel B											
VARIABLES		(1) 1qr	(2) 1qr	(3) 2qrs	(4) 2qrs	(5) 3qrs	(6) 3qrs	(7) 4qrs	(8) 4qrs	(9) 5qrs	(10) 5qrs
01MCD100K	HighHeter	-0.864		-0.480		-1.255**		-1.865***		-3.176***	
		(0.57)		(0.53)		(0.53)		(0.56)		(0.60)	
	(HighHeter) * (Highloan)		-0.068		0.456		-0.941		-2.488***		-4.122***
			(0.84)		(0.90)		0.90		(0.91)		(0.92)
	Observations	547	264	556	265	551	262	548	260	545	259
	R-squared	0.0449	0.0646	0.0482	0.1068	0.0804	0.0786	0.0939	0.1326	0.1274	0.1571
	Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Panel C											
VARIABLES		(1) 1qr	(2) 1qr	(3) 2qrs	(4) 2qrs	(5) 3qrs	(6) 3qrs	(7) 4qrs	(8) 4qrs	(9) 5qrs	(10) 5qrs
12MCD10K	HighHeter	-0.960		-2.293		-1.633		-2.890		-5.452***	
		(1.42)		(1.66)		(1.64)		(1.79)		(1.81)	
	(HighHeter) * (Highloan)		-0.722		-2.341		-1.562		-3.943*		-6.294***
			(1.99)		(2.20)		(2.09)		(2.33)		(2.42)
	Observations	638	324	600	315	555	303	524	289	514	283
	R-squared	0.0129	0.0309	0.0351	0.0421	0.0621	0.0674	0.0236	0.0507	0.0675	(0.0931)
	Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Panel D											
VARIABLES		(1) 1qr	(2) 1qr	(3) 2qrs	(4) 2qrs	(5) 3qrs	(6) 3qrs	(7) 4qrs	(8) 4qrs	(9) 5qrs	(10) 5qrs
12MCD100K	HighHeter	0.947		-1.621		-1.021		-3.367*		-3.316*	
		(1.52)		(1.69)		(1.77)		(1.89)		(1.94)	
	(HighHeter) * (Highloan)		2.487		1.020		-2.213		-4.261		-6.633***
			(2.26)		(2.34)		(2.44)		(2.58)		(2.74)
	Observations	583	310	538	296	493	281	457	263	438	251
	R-squared	0.0600	0.0717	0.0181	0.0289	0.0279	0.0531	0.0500	0.0984	0.0764	0.1157
	Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: The equation is estimated where the left-hand side is GDP growth at various horizons. In the top panel, the right-hand side contains a dummy labelled HighHeter which is equal to one if the standard deviation of deposit rates in a given period is above the 80th percentile. This cutoff can help capture the dynamic of the increasing in the degree of heterogeneity of deposit rates from banks during the pre-crisis periods. It then splits these HighHeter into two equal buckets based on whether the loan growth was high or low. The table shows that high degree of the heterogeneity of deposit rates have negative impact on future GDP growth rates on average but are particularly bad and long lasting when leverage is high. Controls include two lags of GDP growth. * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.8. Heterogeneity in deposit rates and municipal bond index

Panel A: Standard deviations of 01MCD10K

Variables	(1)	(2)	(3)	(4)
Lag1_Standard deviation of 01MCD10K	-0.264			
	(0.44)			
Lag2_Standard deviation of 01MCD10K		0.103		
		(0.45)		
Lag3_Standard deviation of 01MCD10K			-0.601	
			(0.45)	
Lag4_Standard deviation of 01MCD10K				-1.203***
				(0.45)
Observations	2183	2139	2099	2058
R-squared	0.0426	0.0449	0.0440	0.0509
State FE	Y	Y	Y	Y

Panel B: Standard deviations of 01MCD100K

Variables	(1)	(2)	(3)	(4)
Lag1_Standard deviation of 01MCD100K	0.086			
	(0.33)			
Lag2_Standard deviation of 01MCD100K		-0.208		
		(0.33)		
Lag3_Standard deviation of 01MCD100K			-0.691**	
			(0.33)	
Lag4_Standard deviation of 01MCD100K				-1.555***
				(0.33)
Observations	2584	2538	2498	2454
R-squared	0.0390	0.0393	0.0399	0.0496
State FE	Y	Y	Y	Y

Panel C: Standard deviations of 12MCD10K

Variables	(1)	(2)	(3)	(4)
Lag1_Standard deviation of 12MCD10K	-2.051***			
	(0.58)			
Lag2_Standard deviation of 12MCD10K		-2.064***		
		(0.59)		
Lag3_Standard deviation of 12MCD10K			-2.087***	
			(0.60)	
Lag4_Standard deviation of 12MCD10K				-2.586***
				(0.61)
Observations	3166	3122	3079	3035
R-squared	0.0081	0.0091	0.0100	0.0124
State FE	Y	Y	Y	Y

Panel D: Standard deviations of 12MCD10K

Variables	(1)	(2)	(3)	(4)
Lag1_Standard deviation of 12MCD10K	-4.579***			
	(0.59)			
Lag2_Standard deviation of 12MCD10K		-4.013***		
		(0.61)		
Lag3_Standard deviation of 12MCD10K			-3.341***	
			(0.63)	
Lag4_Standard deviation of 12MCD10K				-3.736***
				(0.65)
Observations	2894	2850	2807	2763
R-squared	0.0429	0.0371	0.0314	0.0304
State FE	Y	Y	Y	Y

Notes: Is the increase in the heterogeneity in the deposit rates associated with a worse municipal bond performance. The equation is estimated where the left-hand side is the returns on municipal bond index, and right-hand side is the standard deviations of deposit rates from 1 lag to 4 lags. The table shows that an increase in heterogeneity in the deposit rates is associated with a worse municipal bond index performance. * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.9. How does the changes in interest rate affect the durable/non-durable consumption

Panel A. Whole sample: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.247***	-0.109***	0.047	-0.068	1.249***	-0.353***	-1.096***	-0.171
	(5.81)	(4.21)	(0.43)	(1.03)	(9.39)	(4.35)	(3.19)	(0.83)
State Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0055	0.0054	0.0053	0.0053	0.0094	0.0090	0.0088	0.0089
No. of obs.	296735	292179	287786	283511	267755	263675	259740	255905
Panel B. Expansionary monetary policy period: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-dusrable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.021***	-0.541***	3.244***	0.056***	0.002	-0.062	0.371	0.006
	(3.32)	(3.32)	(3.32)	(3.32)	(0.12)	(0.12)	(0.12)	(0.12)
State Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0040	0.0040	0.0040	0.0040	0.0092	0.0092	0.0092	0.0092
No. of obs.	122491	122491	122491	122491	110876	110876	110876	110876
Panel C. Contractionary monetary policy period: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	-0.460***	-0.101***	-0.097***	-0.187***	-1.850***	-0.407***	-0.3914***	-0.754***
	(5.24)	(5.24)	(5.24)	(5.24)	(6.81)	(6.81)	(6.81)	(6.81)
State Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0054	0.0054	0.0054	0.0054	0.0079	0.0079	0.0079	0.0079
No. of obs.	120024	120024	120024	120024	108210	108210	108210	108210

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in interest rate. In each regression, state fixed effects, quarter fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.10. How does the changes in interest rate affect the change in household's salary

Panel A. Whole sample:				
	(1)	(2)	(3)	(4)
	i=1	i=2	i=3	i=4
	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary
Δ Interest rate (t-i)	-1304.554**	3398.704**	-7238.965	-5376.030
	(1.97)	(1.97)	(0.99)	(1.22)
State Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes
R-squared	0.0040	0.0040	0.0040	0.00399
No. of obs.	292440	292440	288153	283891
Panel B. Expansionary monetary policy period				
	(1)	(2)	(3)	(4)
	i=1	i=2	i=3	i=4
	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary
Δ Interest rate (t-i)	809.87*	-20786.62*	1247.21*	2150.34*
	(1.78)	(1.78)	(1.78)	(1.78)
State Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes
R-squared	0.0058	0.0058	0.0058	0.0058
No. of obs.	122646	122646	122646	122646
Panel C. Contractionary monetary policy period				
	(1)	(2)	(3)	(4)
	i=1	i=2	i=3	i=4
	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary
Δ Interest rate (t-i)	-40306.95***	-8867.524***	-8526.463***	-16421.34***
	(6.82)	(6.82)	(6.82)	(6.82)
State Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes
R-squared	0.0026	0.0026	0.0026	0.0026
No. of obs.	120220	120220	120220	120220

Notes: This table shows the regression of change in household's salary on 1-4 quarter lagged change in interest rate. In each regression, state fixed effects, quarter fixed effects and household control variables (number of children and age of interviewee) are included. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.11. Deposit rate and durable/non-durable consumption – Expansionary monetary policy period

Panel A. Expansionary period: Non-durable Expenditure and 01MCD10K deposit rate						
	(1)	(2)	(3)	(4)	(5)	(6)
	i=0	i=1	i=2	i=0	i=1	i=2
	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure
01MCD10K deposit rate (t-i)	-45.933**	-82.050***	-85.300***	-47.503**	-81.355***	-85.637***
	(2.26)	(4.90)	(6.05)	(2.33)	(4.84)	(6.05)
State and Quarter Fixed effects	Yes	Yes	Yes	No	No	No
State-Quarter Fixed effects	No	No	No	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.1668	0.1669	0.1672	0.1672	0.1666	0.1677
No. of obs.	188681	188196	187635	188681	188196	187635

Panel B. Expansionary period: Durable Expenditure and 01MCD10K deposit rate						
	(1)	(2)	(3)	(4)	(5)	(6)
	i=0	i=1	i=2	i=0	i=1	i=2
	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure
01MCD10K deposit rate (t-i)	24.602	10.890	2.932	24.128	11.801	2.783
	(1.22)	(0.65)	(0.21)	(1.19)	(0.71)	(0.20)
State and Quarter Fixed effects	Yes	Yes	Yes	No	No	No
State-Quarter Fixed effects	No	No	No	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0399	0.0399	0.0398	0.0403	0.0403	0.0403
No. of obs.	188681	188196	187635	188681	188196	187635

Notes: This table shows the regression of household's expenditure on 0-2 quarter lagged deposit rate. Household control variables (number of children and age of interviewee) are included. The sample period is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4. Panel A reports the results for non-durable consumption while Panel B reports the results for durable consumption * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.12. How does the changes in deposit spread affect the durable/non-durable consumption

Panel A. Whole sample: Expenditure and deposit spread								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.022***	-0.012***	-0.004*	-0.008***	0.141***	-0.041***	-0.018**	-0.039***
	(8.30)	(4.77)	(1.68)	(3.01)	(16.99)	(5.08)	(2.20)	(4.41)
State Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0011	0.0010	0.0009	0.0009	0.0016	0.0005	0.0004	0.0006
No. of obs.	250285	246163	241969	237636	225480	221729	217975	214025
Panel B. Expansionary monetary policy period: Expenditure and deposit spread								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.000	-0.021***	0.003	0.009**	0.099***	-0.047***	-0.040***	0.001
	(0.08)	(5.18)	(0.83)	(2.02)	(8.06)	(3.81)	(3.25)	(0.10)
State Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0008	0.0010	0.0008	0.0009	0.0011	0.0006	0.0006	0.0005
No. of obs.	117876	116820	115708	114720	106564	105571	104550	103626
Panel C. Contractionary monetary policy period: Expenditure and deposit spread								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.026***	-0.020***	-0.011**	-0.008*	0.118***	-0.094***	-0.035***	-0.0605***
	(6.57)	(4.20)	(2.56)	(1.79)	(9.53)	(6.44)	(2.56)	(4.14)
State Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0021	0.0019	0.0018	0.0016	0.0017	0.0012	0.0007	0.0009
No. of obs.	98579	98506	98773	98701	88600	88545	88795	88719

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in 01MCD10K deposit spread. In each regression, state fixed effects, year fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.13. How do the changes in deposit spread affect the change in household's salary

Panel A. Whole sample: Total amount of income received from salary and deposit spread				
	(1)	(2)	(3)	(4)
	i=1	i=2	i=3	i=4
	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary
Δ 01MCD10K spread (t-i)	-258.464	-721.179***	2419.37***	-1086.11***
	(1.44)	(4.11)	(13.62)	(5.70)
State Fixed effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes
R-squared	0.0011	0.0011	0.0018	0.0012
No. of obs.	250609	246498	242302	237962

Panel B. Expansionary monetary policy period: Total amount of income received from salary and deposit spread				
	(1)	(2)	(3)	(4)
	i=1	i=2	i=3	i=4
	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary
Δ 01MCD10K spread (t-i)	-751.712***	-2666.101***	5284.381***	-2262.227***
	(2.65)	(9.29)	(18.69)	(7.16)
State Fixed effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes
R-squared	0.0009	0.0016	0.0038	0.0013
No. of obs.	118031	116975	115862	114872

Table 4.12 (Continued). How does the changes in deposit spread affect the durable/non-durable consumption

Panel C. Contractionary monetary policy period: Total amount of income received from salary and deposit spread				
	(1)	(2)	(3)	(4)
	i=1	i=2	i=3	i=4
	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary	Δ Total amount of income received from salary
Δ 01MCD10K spread (t-i)	296.200	986.822***	378.678	-805.716**
	(1.10)	(3.13)	(1.26)	(2.54)
State Fixed effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes
R-squared	0.0014	0.0015	0.0015	0.0016
No. of obs.	98744	98669	98936	98859

Notes: This table shows the regression of change in household's salary on 1-4 quarter lagged change in 01MCD10K deposit spread. In each regression, state fixed effects, quarter fixed effects and household control variables (number of children and age of interviewee) are included. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.14. Mean Quarterly Expenditure and Salary in year 1999, 2004, 2009, 2014 and 2019

	Quarterly Non-durable expenditure	Quarterly Durable expenditure	Annual Salary
	Panel A: Year 1999		
Mortgagor cohort	2499.798	N/A	N/A
Property owner cohort	1876.839	N/A	N/A
Renter cohort	1435.244	N/A	N/A
	Panel B: Year 2004		
	Quarterly Non-durable expenditure	Quarterly Durable expenditure	Annual Salary
Mortgagor cohort	2876.285	1657.64	65772.51
Property owner cohort	2082.269	1016.115	27193.17
Renter cohort	1538.705	653.7095	24375.69
	Panel C: Year 2009		
	Quarterly Non-durable expenditure	Quarterly Durable expenditure	Annual Salary
Mortgagor cohort	3491.081	1576.655	80887.81
Property owner cohort	2619.131	1102.691	34717.27
Renter cohort	2022.645	751.489	30751.04
	Panel D: Year 2014		
	Quarterly Non-durable expenditure	Quarterly Durable expenditure	Annual Salary
Mortgagor cohort	3790.467	1577.236	81899.79
Property owner cohort	2917.458	1134.173	35512.25
Renter cohort	2215.797	761.080	33326.84
	Panel E: Year 2019		
	Quarterly Non-durable expenditure	Quarterly Durable expenditure	Annual Salary
Mortgagor cohort	4517.584	2026.042	98906.44
Property owner cohort	3137.595	1382.200	41540.92
Renter cohort	2455.141	963.298	40975.19

*Notes:*This table compares the mean durable consumption, non-durable consumption and salary for 3 cohorts (mortgagor, property owner and renter). From Panel A to Panel E, the sample year are 1999, 2004, 2009, 2014, and 2019.

Table 4.15. How does the changes in interest rate affect the durable/non-durable consumption - renter cohort

Panel A. Whole sample: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.0074**	-0.0116***	0.0046	0.0006	0.0178**	-0.0595***	0.0325***	0.0046
	(2.51)	(4.01)	(1.58)	(0.21)	(1.98)	(6.77)	(3.69)	(0.53)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0002	0.0001	0.0000	0.0002	0.0008	0.0004	0.0002
No. of obs.	95819	94366	93056	91817	78877	77686	76597	75574
Panel B. Expansionary monetary policy period: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.0015	0.0032	0.0722	-0.0070	-0.0080	-0.0636***	0.0485***	0.0187
	(0.29)	(0.62)	(1.38)	(1.27)	(0.52)	(4.04)	(3.05)	(1.13)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0000	0.0000	0.0001	0.0001	0.0003	0.0007	0.0005	0.0003
No. of obs.	41621	41621	41621	41621	34524	34524	34524	34524
Panel C. Contractionary monetary policy period: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.0063	-0.0200***	-0.0056	0.0053	0.0117	-0.0444***	0.0525***	0.0144
	(1.23)	(4.05)	(1.14)	(1.06)	(0.77)	(3.01)	(3.59)	(0.97)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0005	0.0001	0.0001	0.0001	0.0004	0.0005	0.0001
No. of obs.	37885	37885	37885	37885	31006	31006	31006	31006

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in interest rate for renter cohort. In each regression, state-year fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.16. How does the changes in interest rate affect the durable/non-durable consumption - property owner cohort

Panel A. Whole sample: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.0041	-0.0096***	0.0039	0.0046	0.0186*	-0.0802***	0.0318***	-0.0172*
	(1.38)	(3.26)	(1.34)	(1.57)	(1.86)	(8.16)	(3.26)	(1.77)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0002	0.0000	0.0000	0.0001	0.0010	0.0002	0.0001
No. of obs.	77453	79219	74986	73819	70112	69016	67941	66923
Panel B. Expansionary monetary policy period: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	-0.0028	-0.0043	0.0069	-0.0074	0.0028	-0.0802***	0.0409**	-0.0050
	(0.54)	(0.80)	(1.28)	(1.31)	(0.17)	(4.55)	(2.32)	(0.27)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0001	0.0001	0.0001	0.0000	0.0007	0.0002	0.0000
No. of obs.	31822	31822	31822	31822	29100	29100	29100	29100
Panel C. Contractionary monetary policy period: Expenditure and interest rate								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	-0.0044	-0.0157***	-0.0055	0.0077	0.0109	-0.0510***	0.0456***	0.0110
	(0.84)	(3.13)	(1.15)	(1.57)	(0.62)	(3.05)	(2.82)	(0.68)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0004	0.0001	0.0001	0.0000	0.0004	0.0003	0.0000
No. of obs.	31000	31000	31000	31000	28081	28081	28081	28081

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in interest rate for property owner cohort. In each regression, state-year fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.17. How does the changes in interest rate affect the durable/non-durable consumption - mortgagor cohort

Panel A. Whole sample: Expenditure and interest rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.0100***	-0.0146***	0.0167***	0.0038*	0.0387***	-0.0945***	0.0580***	-0.0082
	(4.66)	(6.92)	(7.87)	(1.78)	(5.83)	(14.53)	(8.90)	(1.25)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0002	0.0004	0.0005	0.0001	0.0003	0.0018	0.0007	0.0000
No. of obs.	123962	122093	120243	118374	119237	117444	115673	113879

Panel B. Expansionary monetary policy period: Expenditure and interest rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.0029	-0.0030	0.0255***	0.0001	0.0223*	-0.1092***	0.0795***	0.0043
	(0.76)	(0.77)	(6.47)	(0.02)	(1.86)	(8.90)	(6.43)	(0.34)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0000	0.0000	0.0009	0.0000	0.0001	0.0017	0.0009	0.0000
No. of obs.	49436	49436	49436	49436	47614	47614	47614	47614

Panel C. Contractionary monetary policy period: Expenditure and interest rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ Interest rate (t-i)	0.0065*	-0.0248***	0.0016	-0.0036	0.0211*	-0.0882***	0.0476***	0.0122
	(1.78)	(7.04)	(0.47)	(1.01)	(1.91)	(8.29)	(4.54)	(1.14)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0010	0.0001	0.0001	0.0001	0.0014	0.0005	0.0001
No. of obs.	51250	51250	51250	51250	49232	49232	49232	49232

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in interest rate for property mortgagor cohort. In each regression, state-year fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.18. How does the changes in deposit spread affect the durable/non-durable consumption - renter cohort

Panel A. Whole sample: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.0099**	-0.0025	-0.0033	-0.009**	0.0622***	-0.0248*	-0.0125	-0.0252**
	(2.32)	(0.57)	(0.76)	(2.15)	(4.77)	(1.89)	(0.96)	(1.96)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0001	0.0001	0.0001	0.0005	0.0002	0.0002	0.0003
No. of obs.	81570	80391	79185	77873	67057	66070	65108	64025

Panel B. Expansionary monetary policy period: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	-0.0147**	-0.0085	0.0010	-0.0078	0.0485**	-0.0279	-0.0164	0.0109
	(2.06)	(1.18)	(0.14)	(1.36)	(2.24)	(1.29)	(0.78)	(0.63)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0002	0.0001	0.0001	0.0001	0.0004	0.0003	0.0003	0.0002
No. of obs.	40190	39884	39585	39300	33306	33041	32801	32558

Panel C. Contractionary monetary policy period: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.0245***	0.0047	-0.0072	-0.0056	0.0496**	-0.0586***	-0.0247	-0.0644**
	(3.77)	(0.73)	(1.09)	(0.68)	(2.50)	(2.96)	(1.22)	(2.55)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0006	0.0002	0.0002	0.0001	0.0004	0.0005	0.0002	0.0005
No. of obs.	31340	31280	31342	31292	25587	25546	25605	25560

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in 01MCD10K deposit spread for renter cohort. In each regression, state-year fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.19. How does the changes in deposit spread affect the durable/non-durable consumption – property owner cohort

Panel A. Whole sample: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.0093**	-0.0052	-0.0071*	-0.0144***	0.0956***	-0.0118	-0.0148	-0.0235*
	(2.22)	(1.23)	(1.69)	(3.45)	(6.77)	(0.84)	(1.05)	(1.68)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0000	0.0001	0.0002	0.0008	0.0000	0.0000	0.0001
No. of obs.	66324	65210	64092	62951	60063	59074	58089	57051

Panel B. Expansionary monetary policy period: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	-0.0048	-0.0159**	-0.0016	-0.0132**	0.0550**	-0.0140	-0.0029	-0.0049
	(0.67)	(2.25)	(0.23)	(2.25)	(2.39)	(0.61)	(1.29)	(0.26)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0003	0.0001	0.0003	0.0002	0.0000	0.0001	0.0007
No. of obs.	30738	30491	30221	29998	28061	27828	27579	23629

Panel C. Contractionary monetary policy period: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.0199***	0.0025	-0.0075	-0.0065	0.0856***	-0.0140	-0.0290	-0.0049
	(3.10)	(0.40)	(1.17)	(0.83)	(3.92)	(0.61)	(1.29)	(0.26)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0004	0.0000	0.0001	0.0000	0.0007	0.0000	0.0001	0.0000
No. of obs.	26120	26098	26173	26155	23629	27828	27579	27375

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in 01MCD10K deposit spread for property owner cohort. In each regression, state-year fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.20. How does the changes in deposit spread affect the durable/non-durable consumption – mortgagor cohort

Panel A. Whole sample: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.0171***	-0.0186***	-0.0039	-0.0103***	0.1129***	-0.0452***	-0.0162*	-0.0563***
	(5.61)	(6.05)	(1.26)	(3.35)	(11.98)	(4.76)	(1.70)	(5.93)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0003	0.0004	0.0000	0.0001	0.0015	0.0003	0.0001	0.0004
No. of obs.	102867	101035	99162	97282	98809	97031	95221	93392

Panel B. Expansionary monetary policy period: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	-0.0073	-0.0296***	-0.0078	-0.0023	0.1039***	-0.0535***	-0.0490***	-0.0218
	(1.40)	(5.76)	(1.56)	(0.55)	(6.41)	(3.32)	(3.11)	(1.63)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0001	0.0007	0.0001	0.0000	0.0009	0.0003	0.0003	0.0001
No. of obs.	47324	46817	46271	45791	45548	45049	44514	44047

Panel C. Contractionary monetary policy period: Expenditure and deposit spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	i=1	i=2	i=3	i=4	i=1	i=2	i=3	i=4
	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Non-durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure	Δln Total Durable expenditure
Δ 01MCD10K spread (t-i)	0.0302***	-0.0081*	0.0086*	-0.0103*	0.1072***	-0.0455***	-0.0198	-0.0753***
	(6.56)	(1.76)	(1.80)	(1.76)	(7.66)	(3.24)	(1.37)	(4.21)
State-year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0011	0.0002	0.0002	0.0002	0.0015	0.0003	0.0001	0.0005
No. of obs.	41219	41229	41359	41355	39482	39490	39620	39613

Notes: This table shows the regression of change in household's expenditure in ln on 1-4 quarter lagged change in 01MCD10K deposit spread for property owner cohort. In each regression, state-year fixed effects and household control variables (number of children and age of interviewee) are included. Column (1) to column (4) report the results for non-durable expenditure with 1 to 4 lags while column (5) to column (8) report the results for durable consumption with 1-4 lags. The sample period of panel A is from 2001Q1-2019:Q4, while panel B is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4 and panel C is from 2016Q1 to 2018Q4 * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Table 4.21. Monetary policy shocks and durable/non-durable consumption – Expansionary monetary policy period

Panel A. Expansionary period: Non-durable Expenditure and monetary policy shocks						
	(1)	(2)	(3)	(4)	(5)	(6)
	i=0	i=1	i=2	i=0	i=1	i=2
	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure	Total Non-durable expenditure
Monetary policy shocks (t-i)	362.587**	46.947	-962.636***	365.346**	64.352	-991.275***
	(2.11)	(0.27)	(5.57)	(2.12)	(0.37)	(5.72)
State and Quarter Fixed effects	Yes	Yes	Yes	No	No	No
State-Quarter Fixed effects	No	No	No	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.1659	0.1659	0.1660	0.1664	0.1664	0.1665
No. of obs.	171807	171807	171807	171807	171807	171807

Panel B. Expansionary period: Durable Expenditure and interest rates						
	(1)	(2)	(3)	(4)	(5)	(6)
	i=0	i=1	i=2	i=0	i=1	i=2
	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure	Total Durable expenditure
Monetary policy shocks (t-i)	130.945	129.116	-90.872	136.356	132.157	-108.363
	(0.76)	(0.75)	(0.53)	(0.79)	(0.77)	(0.63)
State and Quarter Fixed effects	Yes	Yes	Yes	No	No	No
State-Quarter Fixed effects	No	No	No	Yes	Yes	Yes
Household control variables	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0399	0.0399	0.0399	0.0405	0.0405	0.0405
No. of obs.	171807	171807	171807	171807	171807	171807

Notes: This table shows the regression of non-durable and durable consumption on monetary policy shock with 0 to 2 quarter lags. The sample period is from 2008Q4 to 2015Q4 and from 2019Q1 to 2019Q4. Panel A reports the results for non-durable consumption while Panel B reports the results for durable consumption. * denotes significant at 10% level, ** denotes significant at 5% level, and *** denotes significant at 1% level.

Chapter 5: Conclusion

5.1 Overview and Concluding Remarks

The recent global financial crisis and COVID-19 pandemic have highlighted the importance of bank liquidity. Any failure to properly manage liquidity on the part of banks will lead to serious consequences including economic collapses, and pose a further threats to financial stability. In this thesis, the role of deposits in bank liquidity management is explored, as deposits are the most stable source of funding for banks. Mismatches between illiquid assets (loans) and liquid liabilities (deposits) is claimed to be natural source of bank bankruptcies (Diamond and Dybvig, 1983).

An investigation into how banks managed their liquidity during the COVID-19 pandemic is first undertaken, examining both the supply and demand sides of banks' liquidity creation through three mechanisms (as described in Chapter 2). Our empirical results show deposits rates are not negatively correlated with banks' capitalization, which contradicts the theory of market discipline theory during the pandemic. In addition, strong evidence is provided that deposit growth is positively correlated with loan growth but negatively correlated with lagged deposit rates, suggesting that internal capital market theory is neither effective during the pandemic. Then, using the unused loan commitments ratio as a measurement of bank liquidity demand risk, a weakly capitalized bank with higher liquidity demand risk is found to favor increased exposure to the liquidity facilities introduced by the Federal Reserve compared to banks with lower unused commitment ratios. Also, banks with high exposure to the Federal Reserve's liquidity facilities are found to have extended significantly more loans than banks with lower exposure. An overarching policy implication of the first study is that policy makers can use banks; exposure to liquidity risk as a signal for tightening (or loosening) the time-varying loan-to-value ratios, as well as counter-cyclical capital buffers.

In the first study, the following conclusions can be reached:

During the pandemic, research indicates that there is no market discipline theory or internal capital market theory. Instead, banks create liquidity by increasing their exposures to the liquidity facilities offered by the Federal Reserve.

Moreover, this thesis analyzes the functioning of the US tri-party repo market, as banks are using repo financing as one of the most important sources of short-term funding (see Chapter 3). Given the scarcity of repo market data, the US tri-party repo market is examined with a focus on the relationship between market perceptions of dealers' riskiness (measured by the credit default swap), the repo volume and repo amount the dealers undertake. Our empirical results suggest that dealers with higher risk tend to take few reverse repos with higher repo rates to avoid liquidity losses. Furthermore, following Bai, Krishnamurthy and Weymuller (2017), a Liquidity Mismatch Index is constructed as a measurement of banks' liquidity condition. The thesis provides evidence that the liquidity condition affects bank's decisions on repo market in times of liquidity tightness. Chapter 3 highlights the importance of repo market as the short-term liquidity funding source for banks.

In the second chapter, the following finding can be yielded:

Market perceptions of riskiness are instrumental in shaping the volume of repo (and reverse repo) undertaken by banks, and the Liquidity Mismatch Index (LMI) has a degree of degree of explanatory power on the volume of repo undertaken by banks.

Lastly, this thesis also investigates the role of heterogeneity in deposit rates in predicting the severity of crisis, output and credit condition (as can be seen in Chapter 4). It can be found in this study that an increase in the heterogeneity in deposit rates has significant predicting power on output and future economic downturns. Also, in our own 'FD' model, it is suggested that increased heterogeneity in deposit rates coupled with a fragile financial condition can lead to a more severe economic downturn. In addition, Chapter 4 investigates the effect of change in interest rate, deposit rate and monetary policy shocks on household consumption and salary. Our empirical results suggest that positive changes in interest rates (deposit rates or monetary policy) are associated with reductions in household consumption and salary. Based on the balance sheet position of households, households are also divided into three cohorts and it is found that the mortgagor group has the largest fall in consumption when faced with an increase in deposit rates or interest rates.

In the third chapter, it can be found that:

Heterogeneity in deposit rates (as measured by standard deviation of deposit rates) has good predicting power for the future crises. Moreover, contributing to Krishnamurthy and Muir (2017), this study shows that an increase in the heterogeneity in deposit rates coupled with a high financial fragile condition will lead to a more severe economic downturn ("FD model"). Also, this study reveals that an increase in deposit spreads is associated with a decrease in households' expenditure. This effect is heterogenous across households, based on their balance sheet position.

Taken together, this study has examined how banks manage their liquidity, particularly in times of liquidity stress. This thesis also highlights the importance of bank deposits by providing evidence of their important predictive power for economic downturns. Our empirical evidence also suggests policy that makers should be aware that repo market have a significant effect in liquidity provision for banks, particularly in times of liquidity stress. Lastly, the third study suggests heterogeneity in deposit rates has predictive power for future crises. Policymakers can implement this variable when forecasting future crises, especially in periods when there is credit expansion.

However, there are several limitations to this thesis. Firstly, the repo dataset applied in the thesis only takes into account tri-party repo transactions. Due to data limitations, bilateral repo transactions, which are primarily OTC instruments, are overlooked in the study. Currently, Office of Financial Research (OFR) is conducting Bilateral Repo Data Collection Pilot Project, which might fill the gaps in data about bilateral repo transactions. Future studies can use this new dataset to better understand the US repo market. Moreover, in the third study related to households, the maximum survey period for each household is five months, making it difficult to track the consumption and income behaviour of the same household over a five quarter period. Future studies can include different datasets related to households (e.g., U.S. Census Bureau Household Pulse Survey) to address this limitation.

Appendix A with Supplementary Materials

Banks' Liquidity Management During the COVID-19 Pandemic

Table 2.1A. Deposit growth, Net Loans and Leases Growth, and Deposit Rates of Large Accounts

Panel A. Deposit Growth, Loan Growth and Deposit Rates

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			-6.099	29.469
			(0.28)	(1.27)
12-Month CD $500k account rate *(t-i)* * I (*q≥2020Q1)*			-275.610***	-222.678***
			(7.26)	(7.05)
Net Loans and Leases *(t-i)* * I (q<2020Q1)	-0.384***	-0.119***	-0.347***	-0.106***
	(39.73)	(11.73)	(32.84)	(9.56)
Net Loans and Leases *(t-i)* * I (q≥2020Q1)	0.587***	0.121***	0.658***	0.0769***
	(85.77)	(14.65)	(86.09)	(8.89)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.289	0.227	0.322	0.248
No. of obs.	105,581	105,552	75,691	78,532

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			12.479	2.003
			(0.67)	(0.10)
12-Month CD $500k account rate *(t-i)* * I (*q≥2020Q1)*			-63.529**	-46.218*

Table 2.1A (Continued). Deposit growth, Net Loans and Leases Growth, and Deposit Rates of Large Accounts

			(2.02)	(1.73)
Net Loans and Leases *(t-i)* * I (q<2020Q1)	-1.551***	-0.571***	-0.818***	0.254***
	(11.84)	(3.92)	(15.48)	(4.20)
Net Loans and Leases *(t-i)* * I (q≥2020Q1)	-0.802***	1.138***	-0.354***	0.109**
	(10.39)	(10.97)	(10.78)	(2.30)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.289	0.135	0.261	0.182
No. of obs.	10,536	10,533	8,054	8,044

Panel C. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% highly capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			-33.341	-25.561
			(1.55)	(1.07)
12-Month CD $500k account rate *(t-i)* * I *(q≥2020Q1)*			-50.141	-67.307**
			(1.33)	(1.99)
Net Loans and Leases *(t-i)* * I (q<2020Q1)	-0.248***	0.441***	-0.089***	-0.010
	(11.35)	(19.68)	(3.27)	(0.35)
Net Loans and Leases *(t-i)* * I (q≥2020Q1)	0.216***	0.374***	0.129***	0.337***
	(4.31)	(6.62)	(3.11)	(6.97)
Bank Fixed effects	Yes	Yes	Yes	Yes

Table 2.1A (Continued). Deposit growth, Net Loans and Leases Growth, and Deposit Rates of Large Accounts

Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.114	0.184	0.178	0.252
No. of obs.	10,680	10,677	6,905	6,912

This table presents regressions of quarter-on-quarter deposits growth on lagged quarter-on-quarter loan growth and 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter loan growth. The CD rates are for accounts of $500k. Loan growth is defined as quarterly change in net loans and leases. In Panel A the whole sample of banks is used. Panel B splits the sample by bank capitalization using the bottom 10% decile. Panel C splits the sample by bank capitalization using the top 10% decile. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1) and In columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.2A. Deposit Growth, Commercial and Industrial Loans Growth, and Deposit Rates of Large Accounts

Panel A. Deposit Growth, Loan Growth and Deposit Rates

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			-7.972	31.865
			(0.38)	(1.38)
12-Month CD $500k account rate *(t-i)* * I *(q≥2020Q1)*			-263.759***	-242.399***
			(7.15)	(7.71)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	-1.033***	-0.441***	-0.930***	-0.444***
	(39.67)	(16.25)	(33.69)	(15.34)
Commercial and Industrial Loans *(t-i)* * I (q>=2020Q1)	1.299***	-0.299***	1.550***	-0.383***
	(101.88)	(19.61)	(108.68)	(22.73)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.310	0.229	0.359	0.253
No. of obs.	105,581	105,552	75,691	78,532

Panel B. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			37.043**	15.877
			(2.10)	(0.85)
12-Month CD $500k account rate *(t-i)* * I *(q≥2020Q1)*			41.619	-4.487

			(1.37)	(0.18)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	-3.398***	-2.628***	-0.443***	0.308**
	(9.12)	(6.89)	(3.25)	(2.12)
Commercial and Industrial Loans *(t-i)* * I (q≥2020Q1)	-0.476***	-0.260	-2.082***	-0.603***
	(3.19)	(0.84)	(18.20)	(5.19)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-Squared	0.281	0.123	0.368	0.226
No. of obs.	10,536	10,533	7,254	7,538

Panel C. Deposit Rates and Bank Tier 1 Capital to Risk-Weighted-Assets Ratio (10% low-capitalized banks)

	Dependent Variable: Deposit Growth			
	(1)	(2)	(3)	(4)
	i=1	i=2	i=1	i=2
12-Month CD $500k account rate *(t-i)* * I (q<2020Q1)			-40.998*	-15.793
			(1.88)	(0.64)
12-Month CD $500k account rate *(t-i)* * I (*q≥2020Q1)*			-54.863	-48.174
			(1.40)	(1.36)
Commercial and Industrial Loans *(t-i)* * I (q<2020Q1)	1.564***	-0.416***	1.929***	-0.644***
	(17.48)	(4.53)	(24.28)	(7.48)
Commercial and Industrial Loans *(t-i)* * I (q≥2020Q1)	0.736***	0.798***	1.120***	0.778***
	(6.42)	(5.59)	(10.57)	(6.40)
Bank Fixed effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes

R-Squared	0.131	0.152	0.278	0.257
No. of obs.	10,680	10,677	6,175	6,413

This table presents regressions of quarter-on-quarter deposits growth on lagged quarter-on-quarter loan growth and 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter loan growth. The CD rates are for accounts of $500k. Loan growth is defined as quarterly change in net loans and leases. In Panel A the whole sample of banks is used. Panel B splits the sample by bank capitalization using the bottom 10% decile. Panel C splits the sample by bank capitalization using the top 10% decile. In columns (1) and (3) independent variables are lagged by 1 quarter (i=1) and in columns (2) and (4) the independent variables are lagged by 2 quarters (i=2). The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.3A. Deposit Rates and Syndicated Loans

	Dependent Variables:					
	12-Month CD $10k rate		12-Month CD $100k rate		12-Month CD $500k rate	
	i=1	i=2	i=1	i=2	i=1	i=2
Syndicated Loans (t-i) × I *(q<2020Q1)*	0.0036***	0.0022*	0.0000	0.0026*	0.0000	0.0040**
	(2.96)	(1.68)	(0.07)	(1.85)	(1.12)	(2.49)
Syndicated Loans (*t-i*) × I (*q≥2020Q1)*	0.0042*	0.0022	0.0006	0.0034	0.0000	0.0041
	(1.76)	(1.02)	(0.24)	(1.41)	(0.46)	(1.33)
Bank Fixed Effects	Y	Y	Y	Y	Y	Y
Quarter Fixed Effects	Y	Y	Y	Y	Y	Y
R-squared	0.6888	0.6865	0.6579	0.659	0.66	0.6619
Observations	907	907	879	879	739	739

This table presents regressions of 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter syndicated loans. The CD rates are for accounts of $10k., $100k., and $500k. Independent variables are lagged by 2 quarters (i=2) and therefore for the pandemic period it reflects results for Q1 2020 only. The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Standard errors are double-clustered by bank and quarter. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.4A. Deposit Rates and Commercial and Industrial loans

Panel A. Bottom 10% banks by size (assets)						
	Dependent Variables					
	12-Month CD $10K rate		12-Month CD $100K rate		12-Month CD $500K rate	
	i=1	i=2	i=1	i=2	i=1	i=2
C&I loans growth (t-i) × I (q<2020Q1)	-9.740	-9.790	-10.500	-5.950	-11.20*	-12.10*
	(1.49)	(1.47)	(1.57)	(0.88)	(1.66)	(1.77)
C&I loans growth (t-i) × I (q>=2020Q1)	3.090	-5.700	-5.480	-28.50*	-45.60**	-5.90**
	(0.42)	(0.34)	(0.07)	(1.73)	(2.10)	(2.32)
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.7170	0.7168	0.7179	0.7189	0.7346	0.7339
No. of obs.	6,446	6,441	6,117	6,115	5,501	5,505

Panel B. Top 10% banks by size (assets)	Dependent Variables					
	12MCD10K rate		12MCD100K rate		12MCD500K rate	
	i=1	i=2	i=1	i=2	i=1	i=2
C&I loans growth (t-i) * I (q<2020Q1)	-0.0062	-0.0061	-0.0012	-0.0026	-0.0000	-0.0028
	(1.05)	(1.05)	(0.20)	(0.44)	(0.00)	(0.45)
C&I loans growth (t-i) * I (q>=2020Q1)	0.0035	0.0058*	-0.0033	0.0055*	0.0053	0.0036
	(1.20)	(1.79)	(1.13)	(1.65)	(1.19)	(0.45)
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.6781	0.6784	0.6733	0.6729	0.6999	0.6997
No. of obs.	8,616	8,609	8,531	8,526	7,284	7,280

Table 2.4A (Continued). Deposit Rates and Commercial and Industrial loans

This table presents regressions of 12-month Certificate of Deposit (CD) rate, and lagged quarter-on-quarter loan growth. The CD rates are for accounts of $10k., 100k., and $500k. Loan growth is defined as quarterly change in Commercial and Industrial (C&I) Loans. Panel B presents the results for banks with the lower size as measured by bank assets, using the bottom 10% decile. Panel B presents the results for banks with the higher size as measured by bank assets, using the top 10% decile. Independent variables are lagged by 1 quarter (i=1) and therefore for the pandemic period it reflects results after Q1 2020. Also, independent variables are lagged by 2 quarters (i=2) and therefore for the pandemic period it reflects results for Q1 2020 only. The sample is from January 2016 till December 2019 for the pre-pandemic period, and from January 2020 till December 2020 for the pandemic period. All regressions are ordinary least square regressions and have bank and quarter (time) fixed effects. Standard errors are double-clustered by bank and quarter. Inside the parentheses are the t-statistics. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

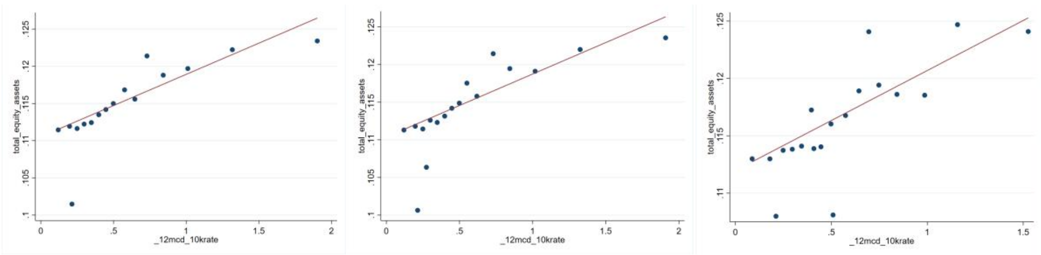
Table 2.5A. t-test of mean comparison of variables before and during the pandemic.

	t value	The variable is significantly smaller/larger during the pandemic
12MCD10K rate	-1.722**	Smaller
12MCD100K rate	-2.512***	Smaller
Syndicated loans	-3.383***	Smaller
Total deposits	3.991***	Larger
Total loans and leases	3.530***	Larger
Commercial and industrial loans	4.459***	Larger
Net loans and leases	3.455***	Larger
Unused commitment ratio	-0.428	
Tier 1 capital ratio	0.780	
Net loans to total assets ratio	7.375***	Larger

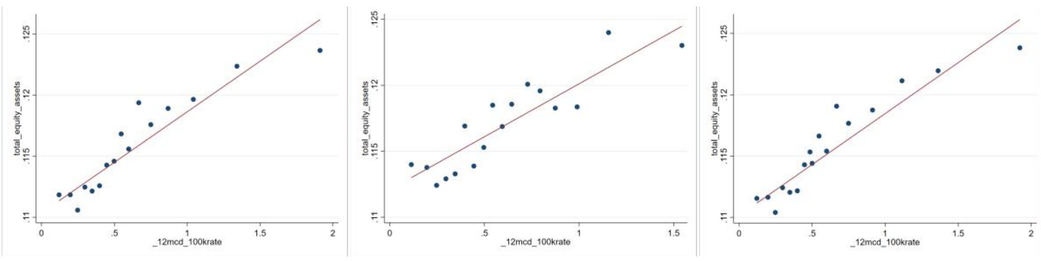
This table presents the t-test of mean comparisons for deposit rates, deposit amount, loan amount and ratios before and during the pandemic. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Graph A1. Binned scatterplots for key variables

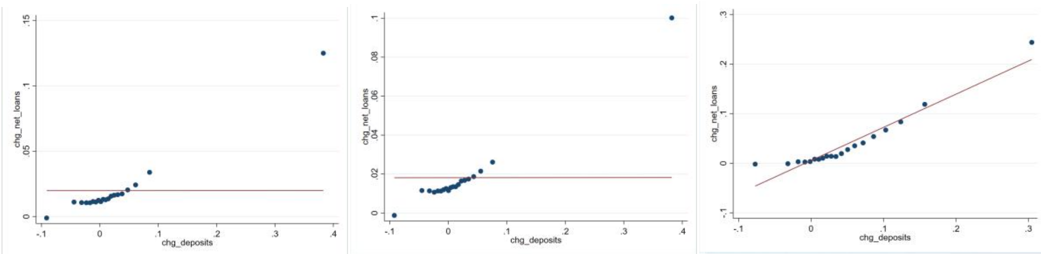
Panel A. Equity to total and 12MCD10K rate (whole sample, pre-pandemic and during the pandemic from left to right)



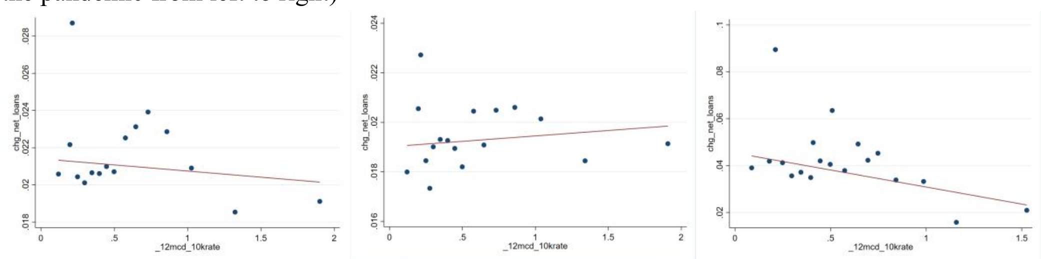
Panel B. Equity to total and 12MCD100K rate (whole sample, pre-pandemic and during the pandemic from left to right)



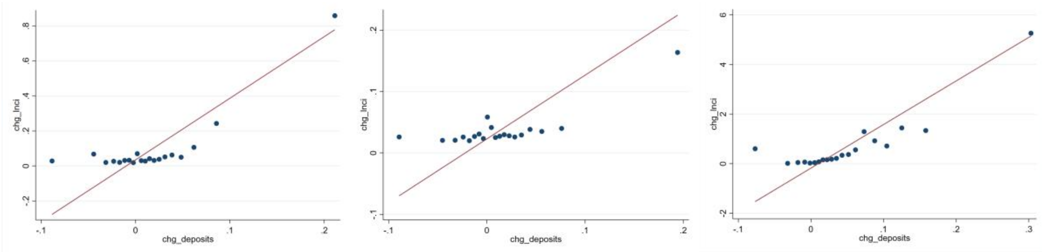
Panel C. Net loans and leases growth and deposits growth (whole sample, pre-pandemic and during the pandemic from left to right)



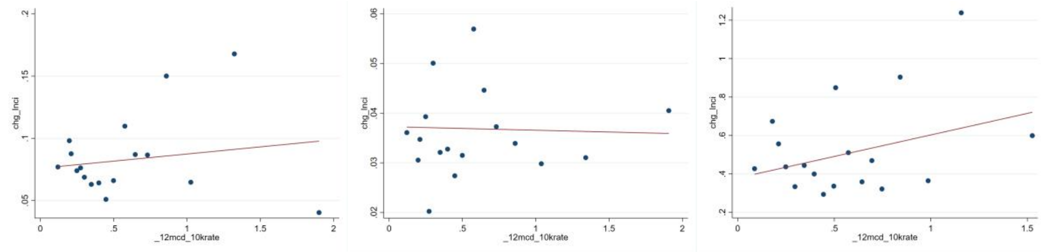
Panel D. Net loans and leases growth and 12MCD10K rate (whole sample, pre-pandemic and during the pandemic from left to right)



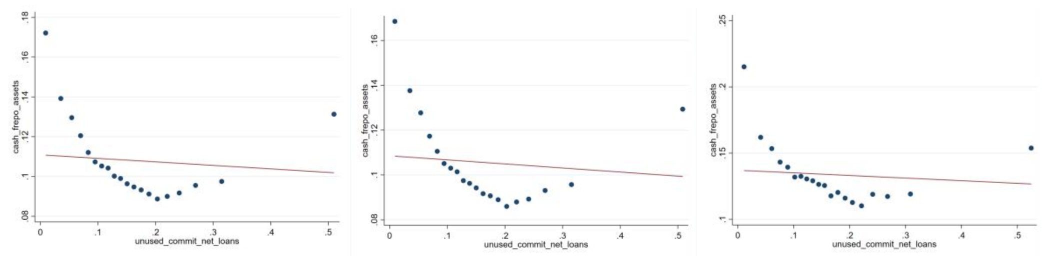
Panel E. Commerial and industrial loans growth and deposits growth (whole sample, pre-pandemic and during the pandemic from left to right)



Panel F. Commerial and industrial loans growth and 12MCD10K rate (whole sample, pre-pandemic and during the pandemic from left to right)



Panel G. Bank liquidity (federal reverse repo+cash) and unused loan commitmments (whole sample, pre-pandemic and during the pandemic from left to right)



Appendix B with Supplementary Materials

US repo market, dealer risk and liquidity

Table 3.1B. Repo Transaction rate and Liquidity Mismatch Index (LMI) – bank dealers 2020 1st quarter

Dealer name	bank/non-bank
Morgan Stanley	Bank
Alliance Bernstein	Bank
Ally Bank	Bank
Bank of America	Bank
Bank of Montreal	Bank
Barclays	Bank
Citi Bank	Bank
Deutsche Bank	Bank
Discover Bank	Bank
Edward Jones Trust Company	Bank
Fidelity Bank	Bank
First American Bank	Bank
Goldman Sachs & Co. LLC	Bank
HSBC Bank	Bank
State Street Bank	Bank
J. P. Morgan	Bank
Mizuho Bank, Ltd.	Bank
Mount Vernon	Bank
The Northern Trust Company	Bank
PNC Bank	Bank
RBC Bank	Bank
Royal Bank of Canada	Bank
Schwab	Bank
State Street Bank	Bank
Sumitomo Mitsui Banking Corporation	Bank
The Bank of New York Mellon	Bank

Table 3.1B (Continued). Repo Transaction rate and Liquidity Mismatch Index (LMI) – bank dealers 2020 1st quarter

UBS Bank	Bank
Wells Fargo Bank	Bank
BNP Paribas Securities Corp.	Non-bank
Credit Agricole Corporate and Investment Bank	Non-bank
Natixis	Non-bank
AB Fixed-Income Shares, Inc	Non-bank
AIM STIT Liquid Assets Portfolio	Non-bank
Abbey National Treasury Services plc (US Branch)	Non-bank
American Funds US Government Money Market Fund	Non-bank
Amherst Pierpont Securities LLC	Non-bank
BMO Capital Markets Corp.	Non-bank
Bank of Nova Scotia	Non-bank
BlackRock	Non-bank
Cantor Fitzgerald & Co.	Non-bank
Columbia Funds Series Trust II	Non-bank
Boerenleen bank B.A	Non-bank
Credit Suisse AG	Non-bank
Daiwa Capital Markets America Inc.	Non-bank
Dreyfus	Non-bank
Federal Agricultural Mortgage Corporation	Non-bank
Federal Home	Non-bank
Federated	Non-bank
Franklin Money Market Portfolio	Non-bank
General Money Market Fund	Non-bank
Government Cash Management Portfolio	Non-bank
Institutional Liquid Reserve Portfolio	Non-bank
Invesco STIT	Non-bank
Jefferies & Company, Inc.	Non-bank

Table 3.1B (Continued). Repo Transaction rate and Liquidity Mismatch Index (LMI) – bank dealers 2020 1st quarter

MF Global Inc.	Non-bank
Master Premier Government Institutional Portfolio	Non-bank
Merrill Lynch	Non-bank
NTAM Treasury Assets Fund	Non-bank
NatWest Markets Securities Inc.	Non-bank
Nomura Securities International, Inc.	Non-bank
Oppenheimer Institutional Government Money Market Fund	Non-bank
PFM Funds	Non-bank
Prime Master Fund	Non-bank
Prudential Investment	Non-bank
RBS Securities Inc.	Non-bank
Reich & Tang Daily Income Fund	Non-bank
SG Americas Securities, LLC	Non-bank
SSGA	Non-bank
STIT	Non-bank
Société Générale	Non-bank
Svenska Handelsbanken	Non-bank
T. Rowe	Non-bank
TD Securities (USA) LLC	Non-bank
TDAM Money Market Portfolio	Non-bank
The DFA Investment Trust Company	Non-bank
Vanguard	Non-bank
Western Asset	Non-bank
Wilmington US Government Money Market Fund	Non-bank

Details of LMI construction

This chapter calibrates the Liquidity Mismatch Index (LMI) by following the methodology provided by Bai, Krishnamurthy and Weymuller (2017). The LMI can be viewed as the difference between the mismatch between the market liquidity of assets and the funding liquidity of liabilities.

$$LMI_{i,t} = \sum_{k} \varphi_{t,a_k} \alpha^i_{t,k} + \sum_{k'} \delta_{t,a_{k'}} l^i_{t,k'}$$

As it is shown in the equation above, φ_{t,a_k} is the weight for asset k at time *t,* while $\delta_{t,a_{k'}}$ is the weight for liability k' at time *t*. $\alpha^i_{t,k}$ and $l^i_{t,k'}$ are the amount for asset k and liability k' at time *t*, respectively, which are available from Call Report.

Assets Weight

The weight of assets φ_{t,a_k}, is constructed by following the equation:

$$\varphi_{t,a_k} = \exp\left(-\left(m_k + \tau * \beta_k m_{pc1,t}\right)\right)$$

Where m_k is the average haircut for asset k, we use the value of m_k from Table 2 in the original work. While β_k is the absolute value of risk exposure calculated by $m_{k,t} = c + \beta_k * m_{pc1,t} + \varepsilon_t$. Details on the value of β_k under different asset categories are provided in the following Table 3.2B. τ is constant set to be 5 according to Bai, Krishnamurthy and Weymuller (2017).

Table 3.2B Values of β_k

k (items in Call Report)	β_k
Cash	-
federal funds sold	-
US Treasury securities	0.059
US Government agency obligations	0.059
Securities issued by states & political subdivisions	0.558
Mortgage-backed securities (non-agency MBS)	0.303
Structured financial products - Total	0.303
Commercial mortgage-backed securities	0.508
Equity securities available-for-sale	0.652
All real estate loans	1.004
Commercial and industrial loans	1.004
Other loans	1.004
Lease financing receivables	1.004
Fixed assets*	-
Intangible assets**	-

Notes: * Fixed assets including premises and fixed assets, other real estate owned, investment in unconsolidated subsidiaries and ** intangible assets are assumed to provide no liquidity. Thus, the φ of these two asset types are set to be 0.

Liabilities Weight

The weight of liabilities $\varphi_{t,a_{k'}}$, is constructed by following the equation:

$$\varphi_{t,a_{k'}} =- \exp\left(-k * \mu_t T_{k'}\right)$$

Where k is the constant set to be 0.5 according to Bai, Krishnamurthy and Weymuller (2017), μ_t

is the quarterly TED spread provided by the Federal Reserve Bank of St. Louis. While $T_{k'}$ is the average maturity of different liabilities, which is calibrated from the original paper. The value of $T_{k'}$ can be seen from the following Table 3.3B.

Table 3.3B. Values of $T_{k'}$

k' (items in Call Report)	T_k'
Federal funds purchased and repurchased agreements	0
Deposits (insured)	10
Deposits (uninsured)	1
Other borrowed funds	0.083
Subordinated debt	10
Equity	30
All other liabilities	10
Unused commitments	5
Credit lines	10
Securities lent	5

Table.3.4B t-test of mean comparison of variables before and during the pandemic.

	t value	The variable is significantly smaller/larger during the pandemic
Repo transaction amount	6.086***	Larger
Repo rate	45.627***	Larger
Liquidity Mismatch Index	6.612***	Larger
6-Month Credit default swap spread	7.183***	Larger
1-Year Credit default swap spread	8.175***	Larger
3-Year Credit default swap spread	4.056***	Larger
5-Year Credit default swap spread	1.468	
10-Year Credit default swap spread	-1.464*	Smaller

Notes: This table presents the t-test of mean comparisons for deposit rates, deposit amount, loan amount and ratios. . ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3.5B. Robustness check to Table 3.2

	Repo Volume (Dependent variable: Collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-0.330***	-0.021	-0.304***	0.147***	-0.585***	-0.133**	-0.816***	-0.166***	-1.099***	-0.119*
	(5.15)	(0.45)	(4.47)	(3.32)	(6.55)	(2.38)	(7.73)	(2.71)	(8.21)	(1.68)
Bank dealer dummy	2.975***	0.587***	2.947***	0.521***	2.951***	0.535***	2.963***	0.519***	3.059***	0.534***
	(3.68)	(7.23)	(3.70)	(6.60)	(3.72)	(6.79)	(3.74)	(6.56)	(3.89)	(6.74)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Quarter Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.1599	0.0248	0.1606	0.0254	0.1630	0.0250	0.1647	0.0252	0.1643	0.0247
Observations	8484	8484	8784	8784	8799	8799	8798	8797	8774	8774
Number of dealers	25	25	25	25	25	25	25	25	25	25

Table 3.6B. Robustness check to Table 3.3

	Repo Volume (Dependent variable: Reverse Repo collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-0.496***	-0.469***	-0.416***	-0.547***	-0.571***	-0.567***	-0.809***	-0.598***	-1.072***	-0.712***
	(5.56)	(8.71)	(4.45)	(9.41)	(4.96)	(10.12)	(6.35)	(10.34)	(7.98)	(11.34)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Quarter Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.2945	0.1054	0.2968	0.1153	0.3004	0.1230	0.3073	0.1255	0.3163	0.1362
Observations	1523	1523	1558	1558	1561	1561	1561	1561	1558	1558
Number of dealers	9	9	9	9	9	9	9	9	9	9

Table 3.7B. Robustness check to Table 3.4

	Repo Volume (Dependent variable: Reverse Repo collateral value in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-0.286***	-0.006	-0.277***	0.270***	-0.682***	-0.196**	-0.954***	-0.204*	-1.319***	0.143
	(3.76)	(0.09)	(3.40)	(4.07)	(6.11)	(2.18)	(7.06)	(1.94)	(7.18)	(1.11)
log (total assets, t-1)	-0.461**	0.053***	-0.433**	0.055***	-0.548***	0.046***	-0.573***	0.046***	-0.510***	0.054***
	(2.31)	(4.57)	(2.24)	(4.84)	(2.82)	(4.01)	(2.96)	(4.00)	(2.63)	(4.68)
Bank liquidity ratio (t-1)	1.569*	3.642***	1.597**	3.037***	2.393***	3.742***	2.779***	3.720***	2.954***	3.381***
	(1.95)	(10.14)	(2.02)	(8.68)	(2.98)	(10.52)	(3.43)	(10.42)	(3.61)	(9.55)
Equity to assets (t-1)	4.697	-9.858***	4.427	-9.887***	2.601	-8.751***	1.832	-8.682***	1.974	-9.686***
	(1.63)	(8.27)	(1.56)	(8.51)	(0.91)	(7.56)	(0.64)	(7.43)	(0.69)	(8.15)
Return on equity (t-1)	-0.062***	0.035***	-0.061***	0.036***	-0.061***	0.031***	-0.059***	0.031***	-0.059***	0.032***
	(5.33)	(4.47)	(5.41)	(4.71)	(5.36)	(4.06)	(5.18)	(4.13)	(5.20)	(4.26)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Quarter Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.1532	0.0383	0.1546	0.0398	0.1578	0.0382	0.1592	0.0381	0.1583	0.0383
Observations	6961	6961	7226	7226	7238	7238	7237	7237	7216	7216
Number of dealers	16	16	16	16	16	16	16	16	16	16

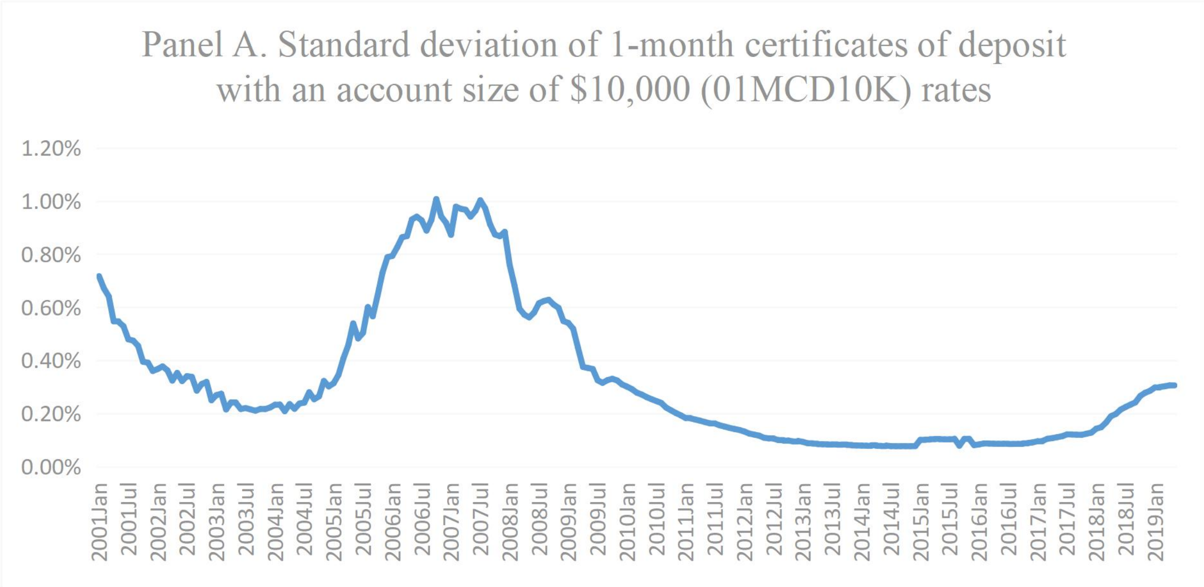
Table 3.8B. Robustness check to Table 3.5

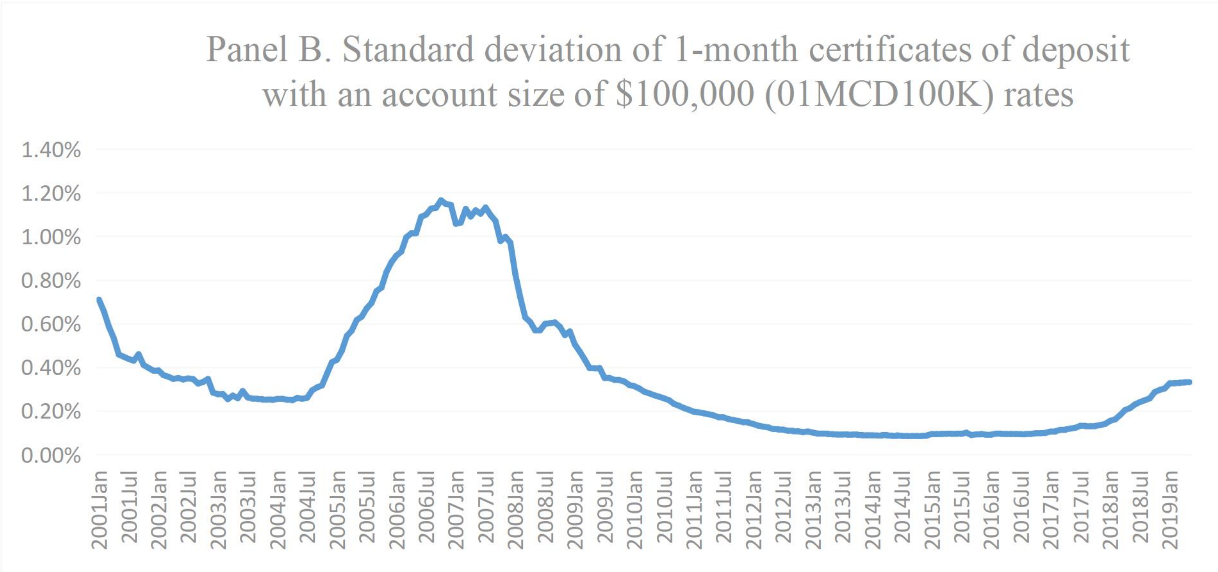
	Repo rates (Dependent variable: Reverse Repo rates in log)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	6-Month	6-Month	1-Year	1-Year	3-Year	3-Year	5-Year	5-Year	10-Year	10-Year
log (CDS, day t-1)	-0.350***	-0.125***	-0.486***	-0.1399***	-1.006***	-0.225***	-1.232***	-0.181***	-1.317***	-0.133***
	(12.30)	(5.71)	(16.09)	(6.36)	(25.92)	(8.37)	(26.97)	(6.16)	(22.43)	(3.87)
Collateral type control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter Fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-quarter fixed effects	No	No	No	No	No	No	No	No	No	No
R-squared	0.2628	0.0107	0.2854	0.0108	0.3170	0.0141	0.3210	0.0105	0.3040	0.0078
Observations	8484	8484	8784	8784	8799	8799	8798	8798	8774	8774
Number of dealers	25	25	25	25	25	25	25	25	25	25

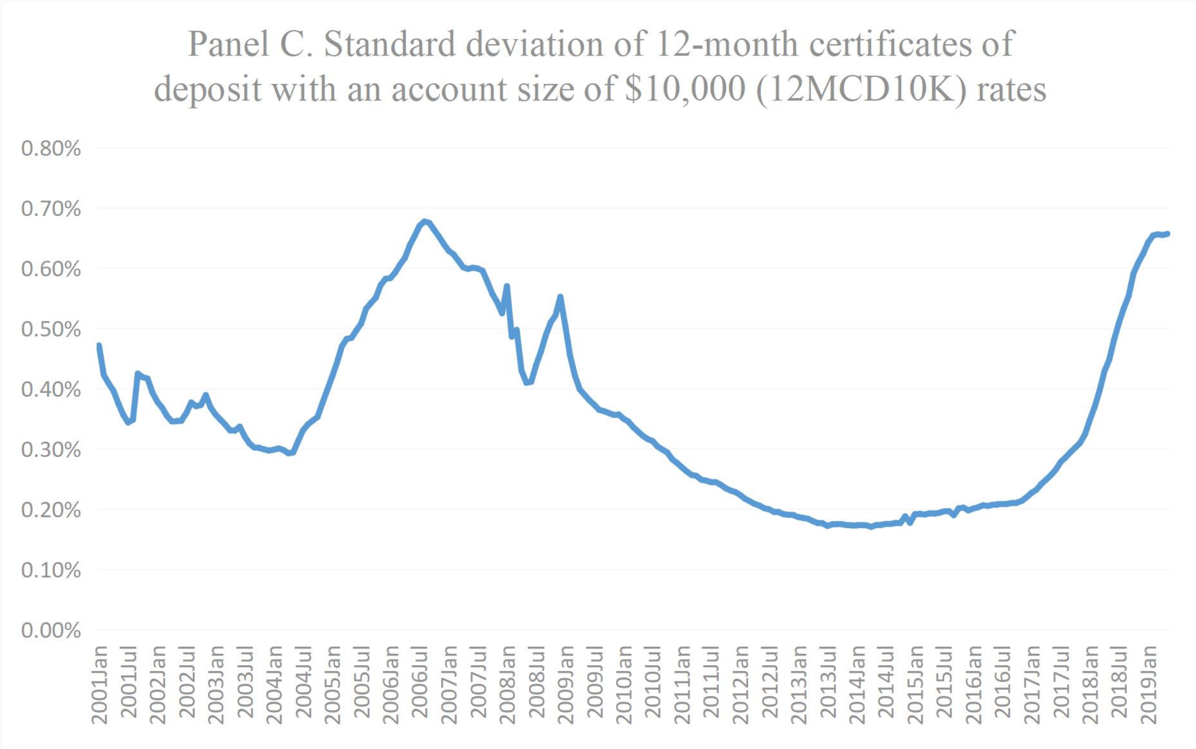
Appendix C with Supplementary Materials

The Deposits Channel, Financial Stability, and Household

Figure C1. Standard deviation in deposit rates of 4 kinds of deposits from 2001Q1 to 2019Q2 (Source: Ratewatch, calculated by the author)






Panel C. Standard deviation of 12-month certificates of deposit with an account size of $10,000 (12MCD10K) rates
0.80%
0.70%
0.60%
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
2001Jan
2001Jul
2002Jan
2002Jul
2003Jan
2003Jul
2004Jan
2004Jul
2005Jan
2005Jul
2006Jan
2006Jul
2007Jan
2007Jul
2008Jan
2008Jul
2009Jan
2009Jul
2010Jan
2010Jul
2011Jan
2011Jul
2012Jan
2012Jul
2013Jan
2013Jul
2014Jan
2014Jul
2015Jan
2015Jul
2016Jan
2016Jul
2017Jan
2017Jul
2018Jan
2018Jul
2019Jan

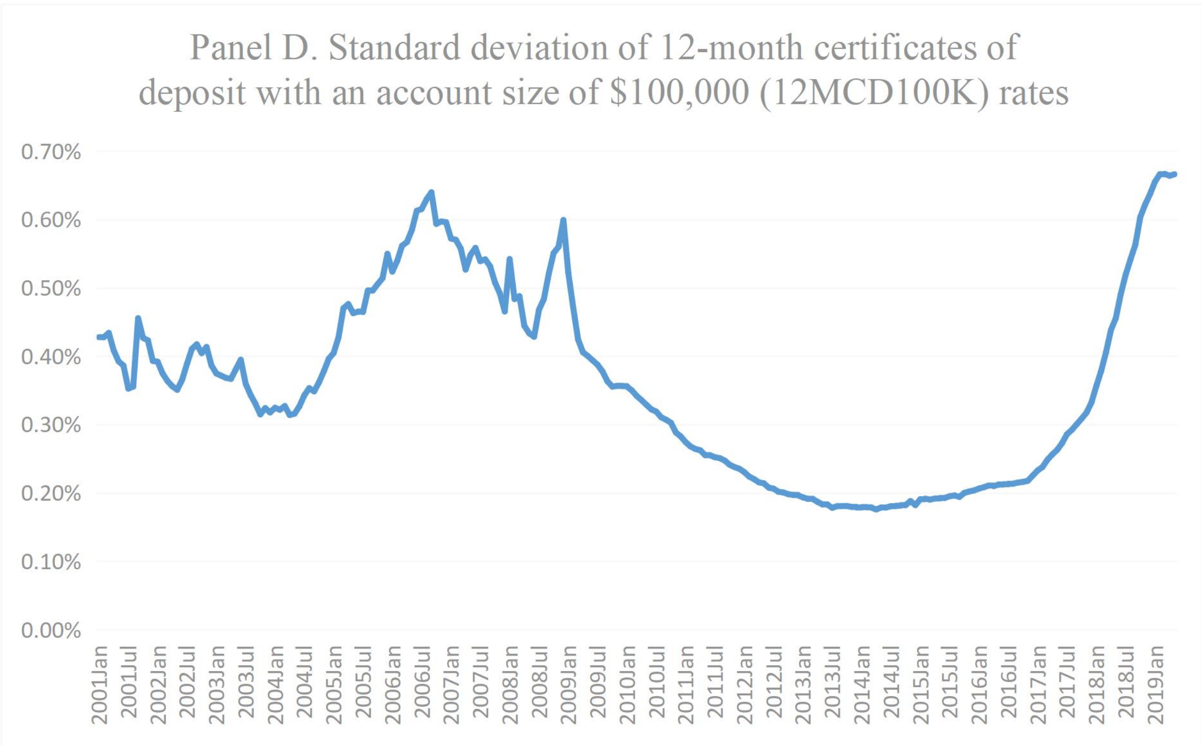
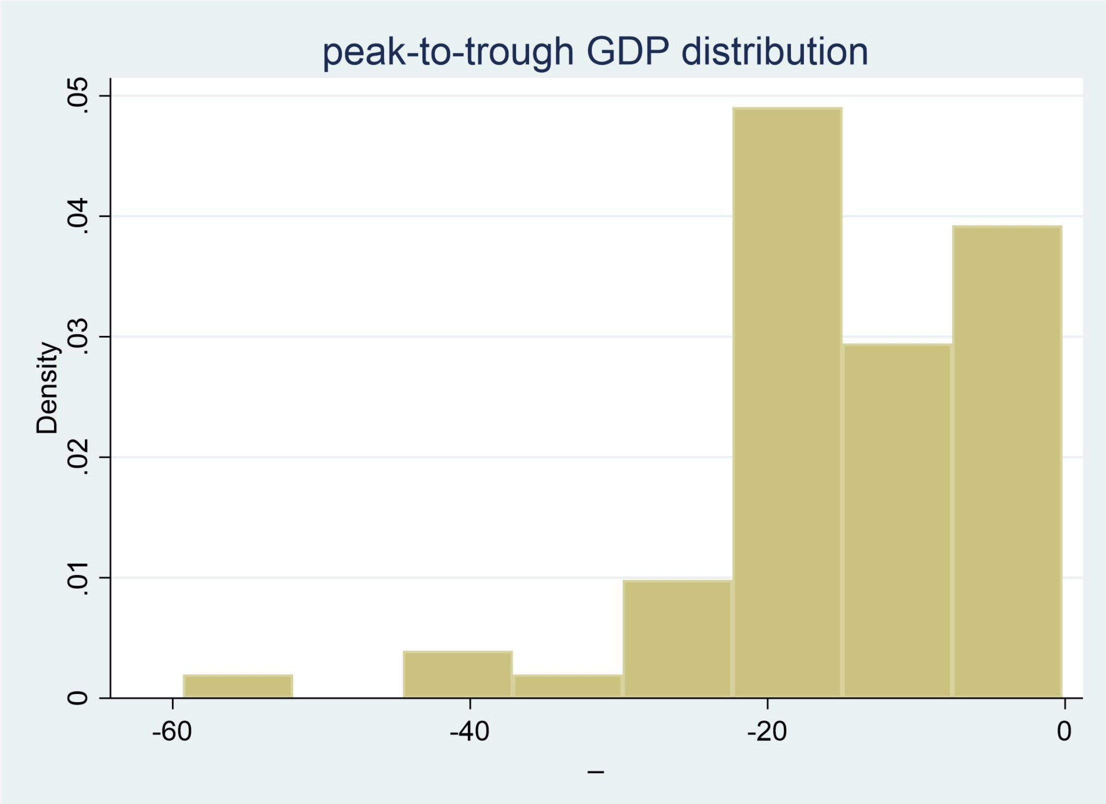

Panel D. Standard deviation of 12-month certificates of deposit with an account size of $100,000 (12MCD100K) rates
0.70%
0.60%
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
2001Jan
2001Jul
2002Jan
2002Jul
2003Jan
2003Jul
2004Jan
2004Jul
2005Jan
2005Jul
2006Jan
2006Jul
2007Jan
2007Jul
2008Jan
2008Jul
2009Jan
2009Jul
2010Jan
2010Jul
2011Jan
2011Jul
2012Jan
2012Jul
2013Jan
2013Jul
2014Jan
2014Jul
2015Jan
2015Jul
2016Jan
2016Jul
2017Jan
2017Jul
2018Jan
2018Jul
2019Jan

Figure C2. The distribution of peak-to-trough GDP declines across crises based on the ST dates. Heterogeneity exists in the outcomes of GDP growth between states.



Bibliography

Acharya, V., Engle, R.F., Steffen, S., 2021. Why did banks stocks crash during COVID-19? *NBER Working Paper 28559.*

Acharya, V., Mora, N., 2015. A crisis of banks as liquidity providers. *Journal of Finance* 70(1): 1-43.

Ashcraft, A., Campello, M., 2007. Firm balance sheets and monetary policy transmission. *Journal of Monetary Economics* 54: 1515-1528.

Attanasio, O. and Weber, G., 1993. Consumption Growth, the Interest Rate and Aggregation. *The Review of Economic Studies,* 60(3), pp. 631-649.

Autor, D. and Duggan, M.,2007. Distinguishing Income from Substitution Effects in Disability Insurance. *American Economic Review,* 97(2), pp.119-124.

Bai, J., Krishnamurthy, A. and Weymuller, C., 2017. Measuring Liquidity Mismatch in the Banking Sector. *The Journal of Finance*, 73(1), pp.51-93.

Bank of International Settlements, 2013. Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools.

Bank of International Settlements, 2014. Liquidity coverage ratio disclosure standards.

Baumol, W., 1973. Income and Substitution Effects in the Linder Theorem. *The Quarterly Journal of Economics*, 87(4), pp.629-633.

Ben-David, I., Palvia, A., Spatt, C., 2017. Banks' internal capital markets and deposit rates. *Journal of Financial and Quantitative Analysis* 52(5): 1797-1826.

Berger, A., Irresberger, F. and Roman, R., 2020. Bank Size and Household Financial Sentiment: Surprising Evidence from University of Michigan Surveys of Consumers. *Journal of Money, Credit and Banking*, 52(S1), pp.149-191.

Bernanke, B., 1983. Irreversibility, Uncertainty, and Cyclical Investment. *The Quarterly Journal of Economics*, 98(1), pp.85.

Bernanke, B. and Blinder, S., 1988. A. Credit, Money, and Aggregate Demand., *The American Economic Review*, 78(2), pp 435-439.

Bernanke, B., Gertler, M., Gilchrist, S., 1996. The financial accelerator and the flight to quality. *The Review of Economics and Statistics* 78:1-15.

Bernanke, B. and Gertler,M., 1990. Financial Fragility and Economic Performance, *The Quarterly Journal of Economics,* 105(1), pp 87-114.

Bhattacharya, S., Thakor, A., V., 1993. Contemporary banking theory. *Journal of Financial Intermediation* 3: 2-50.

Billett, M.T., Garfinkel, J.A., O'Neal, E.S., 1998. The cost of market versus regulatory discipline in banking. *Journal of Financial Economics* 48(3): 333-358.

Boldin, M., 1994. Dating Turning Points in the Business Cycle. *The Journal of Business,* 67(1), pp.97-131.

Brown, C.O., Dinc, S., 2011. Too many to fail? Evidence of regulatory reluctance in bank failures when the banking sector is weak. *Review of Financial Studies* 24: 1378-1405.

Breckenfelder, J., Grimm, N. and Hoerova, M., 2020. Do Non-Banks Need Access to the Lender of Last Resort? Evidence from Mutual Fund Runs. *SSRN Electronic Journal*.

Browning, M., Lusardi, A., 1996. Household saving: Micro theories and micro facts. *Journal of*

Economic Literature 34:1797-1785

Brunnermeier, M., Gorton, G. and Krishnamurthy, A., 2012. Risk Topography. *NBER Macroeconomics Annual*, 26(1), pp.149-176.

Boyd, J., Prescott, E.E., 1986. Financial intermediary-coalitions. *Journal of Economic Theory* 38: 211-232.

Calomiris, C., 1999. Building an incentive-compatible safety net. *Journal of Banking and Finance* 23(10): 1499-1519.

Calomiris, C., Kahn, C., 1991. The role of demandable debt in structuring optimal banking arrangements. *American Economic Review* 81(3): 497-513.

Calomiris, C., Mason, J.R., 1997. Contagion and bank failures during the Great Depression: The June 1932 Chicago banking panic. *American Economic Review* 87: 863-883.

Campello, M., 2002. Internal capital markets in financial conglomerates: Evidence from small bank responses to monetary policy. *Journal of Finance* 57: 2773-2805.

Canzoneri, M., Cumbu, R. and Diba, B., 2007. Euler equations and money market interest rates: A challenge for monetary policy models. *Journal of Monetary Economics*, 54(7), pp.1863-1881.

Capie, F., 2011. A history of the Federal Reserve - By Allan H. Meltzer. *The Economic History Review*, 64(1), pp.336-337.

Cetorelli, N., Goldberg, L., 2012a. Banking globalization and monetary transmission. *Journal of Finance* 67: 1811-1843.

Cetorelli, N., Goldberg, L., 2012b. Liquidity management of U.S. global banks: Internal capital markets in the Great Recession. *Journal of International Economics* 88: 299-311.

Cloyne, J., Ferreira, C., and Surico, P., 2020 Monetary Policy when Households have Debt: New Evidence on the Transmission Mechanism the Review of Economic Studies, 87(1), pp.102-129

Copeland, A., Martin, A. and Walker, M., 2014. Repo Runs: Evidence from the Tri-Party Repo Market. *The Journal of Finance*, 69(6), pp.2343-2380.

Copeland, A., Duffie, D., Martin, A., and McLaughlin, S., 2012. Key Mechanics of the US Tri-Party Repo Market. *Federal Reserve Economic policy review*.

Diamond, D. and Dybvig, P., 1983. Bank Runs, Deposit Insurance, and Liquidity. Journal of Political Economy, 91(3), pp.401-419.

Drechsler, I., Savov, A. and Schnabl, P., 2017. The Deposits Channel of Monetary Policy. *The Quarterly Journal of Economics*, 132(4), pp.1819-1876.

Eggertsson, G. and Krugman, P., 2012. Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach. *The Quarterly Journal of Economics,* 127(3), pp. 1469-1513.

Elmendorf, D., 1996. The effect of interest-rate changes on household saving and consumption : a survey. *Board of Governors of the Federal Reserve System Working paper*, 96(27).

Eren, E, A Schrimpf and V Sushko. 2020. US dollar funding markets during the COVID-19 crisis – the international dimension. *BIS Bulletin,* 15.

Falato, A., Goldstein, I. and Hortaçsu, A., 2021. Financial fragility in the COVID-19 crisis: The case of investment funds in corporate bond markets. *Journal of Monetary Economics*, 123, pp.35-52.

Federal Reserve. 2019. Supervision and Regulation Report - May 2019.

Fleming, M., 2012. Federal Reserve Liquidity Provision during the Financial Crisis of

2007–2009. *Annual Review of Financial Economics*, 4(1), pp.161-177.

Friedman, M., 1957. The Permanent Income Hypothesis. *National Bureau of Economic Research Chapters,* pp.20-37.

Friedman, B. and Kuttner, K., 1992. Money, Income, Prices, and Interest Rates. *American Economic Review*, 82(3), pp.472-492.

Gambacorta, L. and Iannotti, S., 2007. Are there asymmetries in the response of bank interest rates to monetary shocks? *Applied Economics,* 39(19), pp. 2503-2517

Gambacorta, L. and Marques-Ibanez, D., 2011. The bank lending channel: lessons from the crisis. *Economic Policy*, 26(66), pp.135-182.

Garbade, K. 2006. The Evolution of Repo Contracting Conventions in the 1980s. *Economic Policy Review,* 12(1).

Gertler, M. and Kiyotaki, N., 2010. Financial Intermediation and Credit Policy in Business Cycle Analysis. *Handbook of Monetary Economics*, 3, pp 547-599.

Gertler, M., & Lown, C. S. (1999). The information in the high-yield bond spread for the business cycle: Evidence and some implications. NBER working paper 7549.

Giese, J. and Haldane, A., 2020. COVID-19 and the financial system: a tale of two crises. *Oxford Review of Economic Policy*, 36 (Supplement_1), pp. S200-S214.

Gilchrist, S. and Zakrajšek, E., 2012. Credit Spreads and Business Cycle Fluctuations. American Economic Review, 102(4), pp.1692-1720.

Gorton, G. and Metrick, A., 2010. Regulating the Shadow Banking System. Brookings Papers on Economic Activity, 2010. pp.261-297.

Gorton, G. and Metrick, A., 2012. Securitized banking and the run on repo. *Journal of Financial*

Economics, 104(3), pp.425-451.

Gounopoulos, D., Luo, K., Nicolae, A. and Paltalidis, N., 2021. Banks' Liquidity Management During the COVID-19 Pandemic. *SSRN Electronic Journal*.

Hanson, S., Shleifer, A., Stein, J. and Vishny, R., 2015. Banks as patient fixed-income investors. *Journal of Financial Economics*, 117(3), pp.449-469.

He, Z. and Krishnamurthy, A., 2013. Intermediary Asset Pricing. American Economic Review, 103(2), pp.732-770.

He, Z. and Xiong, W., 2012. Rollover Risk and Credit Risk. *The Journal of Finance*, 67(2), pp.391-430.

Hearings Before a Subcommittee of the Committee on Banking and Currency (Operation of the National and Federal Reserve Banking Systems), United States Senate, Seventy-First Congress, Third Session, Pursuant to S. Res. 71 (1931)

Holton, S. and Costanza, R., 2018. Interest rate pass-through since the euro area crisis. *Journal of Banking & Finance*, 96(C), pp. 277-291

Hüser, A., Lepore, C. and Veraart, L., 2021. How Does the Repo Market Behave Under Stress? Evidence from the COVID-19 Crisis. *SSRN Electronic Journal*.

Iacoviello, M., 2005. House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. *American Economic Review*, 95(3), pp.739-764.

I. F. R. 1869. Court of Appeals of Maryland. Hinkley, Executor of Jarvis and Others, v. Wheelwright, Administrator c. t. a. of Wyeth. *The American Law Register (1852-1891)*, 17(10), 590–603.

Jappelli, T. and Scognamiglio, A., 2018. Interest rate changes, mortgages, and consumption:

evidence from Italy. *Economic Policy*, 33(94), pp.183-224.

Jorda, O., Schularick, M. and Taylor, A., 2013. When Credit Bites Back. *Journal of Money, Credit and Banking,* 45(s2), pp.3-28.

Kaplan, G. and Violante, G., 2014. A Model of the Consumption Response to Fiscal Stimulus Payments. *Econometrica*, 82(4), pp.1199-1239.

Kapoor, S. and Peia, O., 2021. The impact of quantitative easing on liquidity creation. *Journal of Banking and Finance*, 122, p.105998.

Kiyotaki, N. and Moore, J., 1997. Credit Cycles. *Journal of Political Economy*, 105(2), pp.211-248.

Krishnamurthy, A. and Muir, T., 2017. How Credit Cycles across a Financial Crisis., *NBER working paper*, 23850

Krishnamurthy, A., Nagel, S. and Orlov, D., 2014. Sizing Up Repo. *The Journal of Finance*, 69(6), pp.2381-2417.

Li, L., Strahan, P. and Zhang, S., 2020. Banks as Lenders of First Resort: Evidence from the COVID-19 Crisis. *The Review of Corporate Finance Studies*, 9(3), pp.472-500.

López-Salido, D., Stein, J. and Zakrajšek, E., 2017. Credit-Market Sentiment and the Business Cycle. The Quarterly Journal of Economics, 132(3), pp.1373-1426.

Mancini, L., Ranaldo, A. and Wrampelmeyer, J., 2015. The Euro Interbank Repo Market. *Review of Financial Studies*, 29(7), pp.1747-1779.

Marozva, G., 2020. Liquidity Mismatch Index and Banks' Stock Returns. *International Journal of Economics and Business Administration*, VIII (4), pp.930-945.

Mian, A., Rao, K. and Sufi, A., 2013. Household Balance Sheets, Consumption, and the Economic

Slump. *The Quarterly Journal of Economics*, 128(4), pp.1687-1726.

Mian, A., Sufi, A. and Verner, E., 2017. Household Debt and Business Cycles Worldwide*. The Quarterly Journal of Economics, 132(4), pp.1755-1817.

Mullin, J. 2020. The Repo Market is Changing (and What Is a Repo, anyway?): The market for repurchase agreements has repeatedly adapted to changing circumstances. *Econ Focus, Federal Reserve Bank of Richmond,* 1Q. pp.14-17.

Meltzer, A. 2003. A History of the Federal Reserve, Volume I: 1913-1951. Chicago: University of Chicago Press.

Pitoňáková, R., 2017. Household savings of Slovakia: effects of banks, dependency ratio, transitory income and unemployment. *International Journal of Trade and Global Markets*, 10(1), p.115.

R., I., 1869. Court of Appeals of Maryland. Hinkley, Executor of Jarvis and Others, v. Wheelwright, Administrator c. t. a. of Wyeth. *The American Law Register (1852-1891)*, 17(10), pp.590.

Richardson, P. 1928. *Journal of Accountancy*. 45th ed. New York, pp.197.

Reinhart, C. and Rogoff, K., 2014. Recovery from Financial Crises: Evidence from 100 Episodes. *American Economic Review*, 104(5), pp.50-55.

Repullo, R., 2020. The Deposits Channel of Monetary Policy. A Critical *Review. CEPR Discussion Papers,* 15553.

Roberts-Sklar, M., & Baines, T. 2020. Have hedge funds increased their use of repo borrowing? *Bank of England Overground Article*.

Salido, D., Stein, J., and Zakrajšek, E., 2017. Credit-Market Sentiment and the Business Cycle.

The Quarterly Journal of Economics, 132(3), pp.1373-1426.

Sichel, D., 1994. Inventories and the Three Phases of the Business Cycle. *Journal of Business & Economic Statistics,* 12(3), pp.269-277.

Silva, A., 2019. Strategic Liquidity Mismatch and Financial Sector Stability. *The Review of Financial Studies*, 32(12), pp.4696-4733.

Simmons, E., 1947. The Position of the Treasury Bill in the Public Debt. *Journal of Political Economy*, 55(4), pp.333-345.

Sollinger, A. 1994. The Triparty Is Just Beginning. *Institutional Investor,* 28(1) January: pp.133-5.

Stutfield G, Herbert., 1889. Modern gambling and gambling law. *The Nineteenth century*, 26(153), pp.840-860.

Welles, C. 1982. Drysdale: What Really Happened. *Institutional Investor*, September: pp.73-83.