Liquidity Backup from Commercial Banks to Shadow Banks

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Abstract

During the Great Recession, liquidity did not flow out of the banking sector but transferred internally. Deposits increased, but the volumes of all other short-term debt financing instruments except for T-Bills decreased. Commercial banks, which have stable funding sources from deposits, did not render liquidity backup to shadow banks but held the increased deposits as cash on hand. This paper uses deposits and financial commercial paper outstanding as proxies for commercial and shadow banking financing instruments because they are unique liabilities of commercial and shadow banks, respectively. I provide evidence that when liquidity falls in shadow banks, commercial banks experience funding inflows. In normal times, commercial banks render liquidity backup to shadow banks in the following weeks using the increased deposits. However, the dynamic correlation breaks down in crisis times.

Keywords— Shadow Banking; Deposit; Commercial Paper; Liquidity; Crisis

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1 Introduction

Shadow banks, the specialized financial intermediaries that channel funding from lenders to borrowers through a range of securitization and secured funding techniques[1], arguably played a critical role in undermining the whole financial system and bringing about the financial crisis from 2007 to 2008. In terms of the liability side of the balance sheet, unlike regulated commercial banks which are mainly and uniquely funded by deposits, shadow banks are primarily funded by issuing fixed-income securities in wholesale money markets. During the Great Depression, investors responded to the banking crisis by withdrawing deposits from commercial banks and holding the cash on hand. The ratio of deposits to currency plunged from about 12 to less than 5 between 1929 and 1933 (Schwartz (1963)). Hence, most old school studies about bank runs are highly focused on commercial banks. When there is a substantial and rapid decrease in deposits, commercial banks suffer high pressure in liquidity risks, and in the worst cases, asset liquidation in fire-sale price could happen. During the Great Recession, shadow banks suffered a similar experience to commercial banks in the Great Depression. The funds of shadow banks plunged because of the collapse of wholesale money markets. Shadow banks expected they could continuously issue fixed-income securities to raise money like deposits of commercial banks. However, investors lost confidence in the wholesale money markets, making it difficult for shadow banks to reissue their securities as they matured. As a result, the funds of shadow banks dried up when the outstanding levels of the fixed-income securities they issued shrank rapidly. The refinancing risks become the severe liquidity risks in a way that shadow banks had to find alternative channels to raise funds or liquidate their assets. After 2008, most of the literature concentrates on the collapse of two important fixed-income products: repurchase agreements (henceforth repos) and asset-backed commercial paper

[1]This definition closely follows that of Pozsar, Adrian, Ashcraft, and Boesky (2010). Although there exists plenty of borrowing and lending business within the banking system, lenders and borrowers are outsiders of the banking system in this paper unless otherwise stated. Lenders are mainly fixed-income investors who invest in mortgage-backed securities, asset-backed securities, repurchase agreements, commercial paper, money market mutual funds, etc., but not bank deposits or other commercial bank obligations. Investors in mutual funds or hedge funds could be generally considered lenders if the mutual fund or hedge fund invests in the fixed-income products above. Borrowers include (but are not limited to) producers who need funds to produce or consumers who need funds to invest in real estate or purchase automobiles. Borrowers may borrow money from shadow banks directly or from commercial banks, and commercial banks securitize the loans later as fixed-income products. For details, see Section 2.

(henceforth ABCP)[2]. Gorton and Metrick (2012) document a systematic run on one segment of bilateral repo markets. Both repo spreads and repo haircuts jumped up during the Great Recession. Copeland, Martin, and Walker (2014) point that the run on the tri-party repo market is more like the one in traditional commercial banks, which means the run is concentrated on some specific shadow banks (e.g. Lehman Brothers) but not system-wide. Acharya, Schnabl, and Suarez (2013) analyze the collapse of ABCP markets in 2008 and conclude that most losses of ABCP conduits are undertaken by the sponsors (large financial institutes) but not outside investors. Although shadow banks faced severe funds shortage during the Great Recession, commercial banks had a distinct experience this time. Deposits increased dramatically as investors sought a safe haven for their money.

This paper studies the interdependence between shadow banks and commercial banks. They offer similar financial products to investors. The fixed-income products offered by shadow banks have a higher interest rate and risks than deposits. Hence, they are competitors to attract the most risk-averse investors[3]. When the market risks increase, investors hold fewer securities issued by shadow banks and more deposits, and vice versa. One example is during the Great Recession, when investors lost confidence in the securities offered by shadow banks and transferred their wealth from shadow banks to commercial banks. Hence, commercial banks have a unique and natural advantage in providing liquidity insurance to shadow banks if they want. Consider a case where investors withdraw funds from shadow banks and deposit them into commercial banks during a period of market stress. If commercial banks lend the same volume of funds to shadow banks and all transactions work efficiently, no liquidity problem comes up in the whole banking system. Money just behaves like "what goes around comes around". Investors still hold the same wealth in the whole banking system if only they keep the same amount of fixed-income investment. Shadow banks cannot raise enough money from investors, but they find an alternative funding source from

[2]Other studies are concerned with runs on money market mutual funds. In this paper, I treat money market funds as investors like Krishnamurthy, Nagel, and Orlov (2014) because money market funds are the main investors in repos and commercial paper. In addition, little money flows from money market funds directly to outside borrowers. Hence, it is better to see money market funds as outside lenders but not shadow banks to avoid double counting errors. For details, see Section 2.

[3]Compared to the investors who invest in equities, real estate and so on.

commercial banks. For commercial banks, deposit inflows serve as a hedge for outflows from new loans given to shadow banks. I give the series of cash flows a name called "Flight-to-Quality" circle (henceforth FTQ circle) which is illustrated in Figure 1.

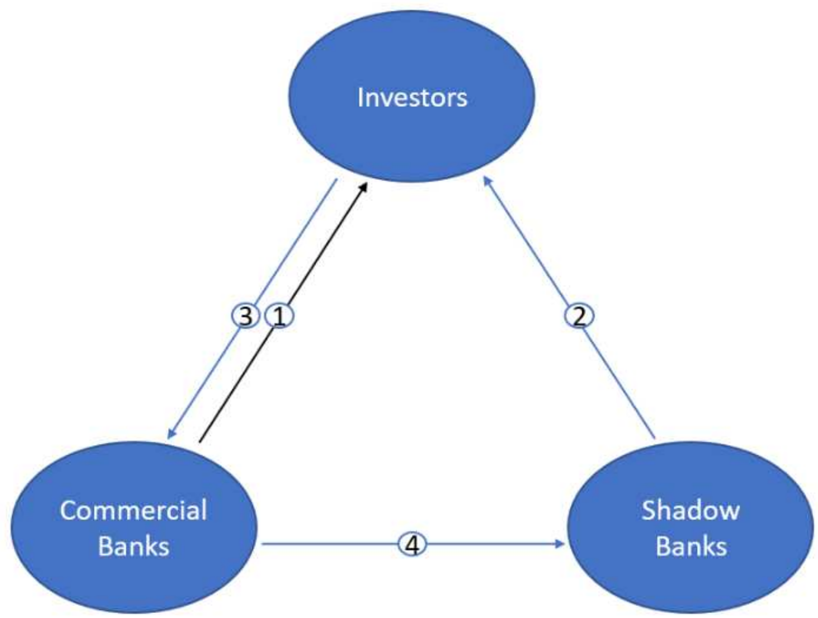

Figure 1: Flight-to-Quality Circle

The FTQ circle consists of blue links ②, ③ and ④. The blue links ② and ③ represent the fact that securities issued by shadow banks and deposits are substitutes. The blue link ④ happens later and is the key to the success of the FTQ circle. It represents that commercial banks lend increased deposits from the link ③ to shadow banks. The FTQ circle is not totally new and it follows the spirit of Kashyap, Rajan, and Stein (2002), and Gatev and Strahan (2006). They study the interdependence between commercial banks and large corporations that issue non-financial commercial paper (henceforth, CP) to raise money. During the periods of market stress, large corporations cannot issue enough non-financial CP in the wholesale money market, so they resort to commercial banks as the last lender by taking down the backup line of the non-financial CP (like the link ④).

In this paper, I argue that the FTQ circle is vulnerable to resist strong market impact and it only works when the link ④ happens. During normal times or periods of moderate market stress, the

FTQ circle functions well as commercial banks are willing to lend increased deposits to shadow banks through the link ④. However, the link ④ broke down during the Great Recession and it could possibly be one of the reasons that caused the collapse of shadow banking system[4].

Why is the link ④ in the FTQ circle important to the stability of the financial system? My argument is that the liquidity backup from commercial banks to shadow banks is the radical support for the confidence of investors when the financial market suffers the impact of credit risks. The securities offered by shadow banks usually have collateral to protect investors from credit risks, so they were considered to be safe assets before the Great Recession[5]. Based on the shadow banking model of Gennaioli, Shleifer, and Vishny (2013), fixed-income investors are extremely risk-averse. Hence, investors value the risky collateral at a much lower price than the risk-neutral financial intermediaries. The collateral is priced nearly risk-neutral during normal times because of the liquidity offered by banks. Even if investors dislike risks, they can accept collateral at about its risk-neutral price because they believe that they can sell their collateral in a liquid market dominated by risk-neutral banks if defaults happen. When moderate neglected credit risks are revealed in the market, investors ask for more collateral and higher interest rate to offset the credit risks, and the market price of the collateral temporarily decreases because of the underlying fundamental return rates based on the credit risks. However, we are still in a nearly risk-neutral world if the market has sufficient liquidity. Things change when the neglected credit risks are so large that the link ④ in the FTQ circle breaks down like it was the case during the Great Recession. The liquidity of the market declined largely due to the fact that commercial banks tighten their credit. Investors lose their confidence and reveal their extreme risk-averse preferences. Collateral is priced with a high risk premium because investors dominate the market this time. Risk-neutral arbitrageurs do not have sufficient funds to turn the market back to the nearly risk-neutral state individually. The market stays a long time with extreme risk-averse pricing before it goes back to risk-neutral again.

[4]According to the forecast model in this paper based on financial CP, the link ④ broke down from Sep. 2007 to Apr. 2009. For details, see Section 4.

[5]It is the reason we usually call them asset-backed or mortgage-backed securities. For repos, investors have even more controls over the collateral than normal collateralized borrowings. Collateral is exempted from the automatic stay, so a party to a repo can unilaterally enforce the termination provisions of the agreement as a result of a bankruptcy filing by the other party. For details, see Section 2.

My research differs from the existing literature in that it studies the liquidity risks based on concurrent and dynamic correlations between commercial banks and shadow banks (the FTQ circle). Studies before the Great Recession are mostly focused on runs on commercial banks, which is the black link ① in Figure 1. By contrast, when crises occur today, we observe increases in deposits, which are the blue link ③ in Figure 1[6]. The introduction of deposit insurance could probably explain the reverse cash flows in the links ① and ③. I also find that (uncovered) large time deposits behave more like the securities offered by shadow banks. Studies after the Great Recession are mostly focused on runs on shadow banks, which is the blue link ② in Figure 1. There also exists some literature that studies how runs on shadow banks (the link ②) can undermine the regulated commercial banking system because they are closely related in reality. However, no study proposes the runs that come from the breakdown of the link ④ in the FTQ circle.

Although there exists a large number of independent shadow banks, commercial banks and shadow banks are organizationally connected in two different frames. First, commercial banks themselves are not pure. Commercial banks are funded not only by deposits, but also through shadow banking channels. For example, repos are typical fixed-income products offered by shadow banks (mostly dealer banks) to raise money. However, commercial banks can also use them for financing like deposits. The amount funded by repo as a percentage of total assets of commercial banks from April 1, 2008, to February 29, 2009, was 63 basis points (mean) and the median was 2.7% (Afonso, Kovner, and Schoar (2010)). It is very small but still exists. Harvey and Spong (2001) point that growth in traditional deposit funding sources has stagnated at many commercial banks after 1990 and has largely failed to keep up with the growth in bank assets. Hence, commercial banks which face funding difficulties in core deposits have to use funding instruments from shadow banking activities. Obviously, the runs on shadow banking activities can influence the commercial banks directly in such a way. Second, commercial banks and shadow banks can have the same parent company. In the United States, commercial banks are held by bank holding companies (henceforth, BHCs), which can have shadow banking subsidiaries. Copeland (2012)

[6]Not only during the Great Recession. According to Gatev and Strahan (2006), the deposits increased when the market suffered liquidity shocks from 1988 to 2002.

points out that shadow banking subsidiaries of BHCs have been increasing over time and represent a quantitatively important share of the BHCs' total earnings. For example, ABCP conduits are special purpose vehicles sponsored by large financial institutions, which are mostly BHCs[7]. In January 2007, commercial banks (BHCs) accounted for $\$903$ billion or 74.8% of ABCP outstanding. Among them, the largest BHC sponsoring ABCP conduits in the United States was Citigroup, with 16 conduits and $\$92.6$ billion of ABCP outstanding. According to Acharya, Schnabl, and Suarez (2013), regulatory arbitrage was an important motive that BHCs set up ABCP conduits. ABCP conduits are off-balance sheet financing for commercial banks. Although BHCs need to satisfy capital requirements based on consolidated balance sheets, they could enjoy reduced regulatory capital if guarantees (they provide to ABCP conduits in order to protect outside investors[8]) were skillfully structured before the Great Recession[9]. Admittedly, there are regulations that require BHCs to prioritize the interests of their commercial banks. During periods of market stress, it is difficult to believe that BHCs can stand by while their shadow banking subsidiaries are getting in trouble. Hence, the runs on shadow banking subsidiaries can influence the commercial banks indirectly in such a way. Actually, Acharya, Schnabl, and Suarez (2013) find that most losses of ABCP conduits are undertaken by the commercial banks instead of outside investors during the Great Recession.

Because the probable problem of endogeneity lies in the real world as I stated in the last paragraph, empirical counterparts identified to the FTQ circle need to avoid the conflict of interest based on the organizational relations. In this paper, I use the volume of deposits but not total liabilities or total assets of commercial banks as the proxy for commercial banks in the FTQ circle because of its purity. Only commercial banks can legally issue deposits to raise funds and it is the

[7]A special purpose vehicles or entity is a subsidiary of a company which is protected from the parent company's financial risk. Hence, the bankruptcy of the parent company would not jeopardize the subsidiary. In the context of ABCP, investors do not need to worry about the failure risks of the sponsoring BHC.

[8]Almost all sponsors provide guarantees to outside investors in ABCP conduits. ABCP has not only backed assets which play a role like collateral but also guarantees from the sponsors. Hence, they were considered safe investment even for the extreme risk-averse investors before the Great Recession. For details, see Section 2.

[9]In June 2009, the Financial Accounting Standard Board (FASB) announced the Statements of Financial Accounting Standards (FAS) 166 and 167, amending existing accounting rules for the consolidation of securitization transactions. The United States banking agencies clarified in September 2009 that depository institutions (commercial banks) would have to hold normal regulatory capital against consolidated securitization transactions and ABCP conduits.

essential difference between commercial banks and shadow banks. A decrease in deposits means commercial banks can only raise fewer funds from the investors and it is the failure of refinancing of deposits. Although commercial banks can also issue some kinds of shadow banking instruments to raise funds, they are usually not allowed to issue financial CP. Hence, I use financial CP outstanding as the proxy for shadow banks in the FTQ circle given that only shadow banks can legally issue financial CP to raise funds. A decrease in financial CP outstanding means shadow banks can only raise fewer funds from the investors and it is the failure of refinancing of financial CP. Albeit BHCs may use shadow banking subsidiaries to issue financial CP and pass the proceeds downstream into commercial banks, the main issuers of financial CP are independent shadow banks (foreign financial institutions, captive finance companies, and dealer banks) and they are competitors to commercial banks as illustrated in the FTQ circle.

In the analysis at the industry level, I use weekly time series data regarding total deposits of domestically chartered commercial banks and total financial CP issued in the domestic market to estimate a series of vector autoregressions (henceforth, VARs). The change of deposits and that of financial CP outstanding are concurrently negatively correlated all the time. They are substitutes for fixed-income investors, and the blue links ② and ③ in the FTQ circle demonstrate the concurrent correlation. In normal times, there is a dynamic correlation between deposits and financial CP outstanding. An increase in deposits leads to an increase in financial CP outstanding in 1 to 3 weeks. Considering financial CP with an average maturity of about 30 days, it is enough time for shadow banks to rebuild liquidity. However, the dynamic correlation as shown by the blue link ④ in the FTQ circle disappears in times of market stress. In addition to the Great Recession, the liquidity backup from the dynamic correlation also broke down from 2010 to 2011 (the peak of the European sovereign debt crisis), and in the second half of 2014 (the oil prices crash). Given that a large number of issuers of financial CP are foreign financial institutions headquartered in Europe, we can easily expect that domestic commercial banks aborted the liquidity backup for them during the peak of the European sovereign debt crisis in 2010 and 2011. In 2014, after the period of the shale oil boom in the united states, the oil price slumped by more than 50% since peaking in June.

There is no doubt that large oil and gas companies suffered severe impact because of the price crash. Their captive finance companies (subsidiaries), the issuers of financial CP, were therefore considered too risky to receive liquidity funds by commercial banks.

For BHCs, we can see them as mixtures of commercial banks and shadow banks. There indeed existed some commercial banks that suffer a severe liquidity impact during the Great Recession. However, the shortage of liquidity does not come from the deposits, but from the shadow banking activities in which the commercial banks are involved. When liquidity dried up during the Great Recession, commercial banks that relied more heavily on core deposit and equity capital financing could continue to lend compared to other banks (Cornett, McNutt, Strahan, and Tehranian (2011)). For the example stated above, Citigroup set up most ABCP conduits and we know it was insolvent in 2008 even if it had received funds from the Troubled Asset Relief Program (henceforth, TARP). In February 2009, the *New York Times* reported the following:

> ”It would seem obvious that helping banks, not holding companies, would be the most direct way to stimulate bank lending. But when TARP purchased preferred stock and warrants, it bought them from holding companies, not their bank subsidiaries. While TARP has been generous with bank holding companies, these companies have not been so generous with their banks. Four large holding companies (JP Morgan, Citigroup, Bank of America and Wells Fargo) initially received a total of $90 billion in TARP money in the fall, but by the end of 2008 they had contributed less than $15 billion in equity capital to their subsidiary banks[10].”

Thus BHCs had larger liquidity problems in their shadow banking subsidiaries than in their commercial banks. It is worth mentioning that although commercial banks can also face liquidity problems if their deposits increase by less than the reduction in shadow banking securities they issue, they still have much milder funding problems than independent shadow banks.

The two decades in the run-up to the Great Recession saw the emergence of a large number

[10] See ”The Bailout Is Robbing the Banks,” John C. Coates and David S. Scharfstein, *New York Times*, February 17, 2009.

of independent shadow banks. Some economists call the phenomenon dis-intermediation[11]. However, after the Great Recession, we saw the trend toward consolidation of independent shadow banks in BHCs. Some economists call the migration of independent shadow banks into BHCs re-intermediation. Cetorelli (2012) shows that, by 2011, BHCs controlled about 38% of assets of the largest insurance companies, 41% of total money market mutual fund (henceforth, MMMF) assets, and 93% of the assets of the largest brokers and dealers. Because BHCs have much higher regulation cost and limitations compared to the independent shadow banks, many economists think the re-intermediation is a paradox and expect more securitization-related activities will migrate from BHCs to independently run shadow banks over time[12]. The theory in this paper can partly explain the re-intermediation paradox after the Great Recession. First, commercial banks are virtual winners in the Great Recession compared to the independent shadow banks because they have stable funding sources from deposits. The finding of Cetorelli (2012) is direct evidence that how favorably BHCs thrive after the Great Recession. Hence, they had the ability to acquire independent shadow banks during or after the Great Recession. Second, in addition to that ability, BHCs also had the incentive to do so according to the FTQ circle. There are synergies for a BHC to hold commercial banks and shadow banks together. Commercial banks serve as a hedge for shadow banks as the consolidation internalizes the FTQ circle[13]. If the synergies from liquidity management are greater than the regulation cost, we can see the re-intermediation. Last but not least, the internalized FTQ circle can only hedge the liquidity risks in the fixed-income market, but cannot eliminate them. When market credit risks are large enough, the core deposits of commercial banks could be insufficient to hedge the shadow banking subsidiaries that BHCs hold. Call the case of Citigroup during the Great Recession. Nowadays, commercial banks play fewer roles in BHCs when they own more shadow banking subsidiaries. We need to care about not only the capital adequacy but

[11] For dis-intermediation, only commercial banks are considered intermediaries.

[12] The re-intermediation is not totally market-oriented. For example, Goldman Sachs and Morgan Stanley received government bailouts during the Great Recession. In return, they transited into BHCs to abide by more regulations in 2008, even if they did not hold any commercial bank back then.

[13] The synergy shares the same spirit of Kashyap, Rajan, and Stein (2002). In their study, that commercial banks take deposits and lend via commitments together can generate synergies in liquidity management between the two activities because both require banks to hold large balances of liquid assets. The increase in deposits can serve as a hedge for the take-down of commitments during the crisis times.

also the core deposits adequacy. Fortunately, liquidity requirements of BHCs have been introduced in recent years[14].

The paper proceeds as follows. Section 2 provides some background of shadow banks and a literature review. In Section 3, I estimate VAR models to provide empirical evidence that the FTQ circle exists in normal times, but the blue link ④ broke down during the Great Recession. Total data set is separated into three time periods: pre-crisis, crisis and post-crisis in advance. Because the split points that isolate the Great Recession period from the total data time span are chosen arbitrarily, I let the data itself reveal the exact times that the blue link ④ in the FTQ circle broke down in Section 4. If the dynamic correlation between deposits and financial CP outstanding via the blue link ④ exists, past deposits can help improve the prediction of future financial CP outstanding. Using one-step forward-chaining cross-validation, I find that including past deposits in the model can significantly increase the accuracy of prediction of financial CP outstanding measured by the mean squared error except for the times during the Great Recession, the peak of the European sovereign debt crisis, and the 2014 oil price crash. Section 5 contains the discussion and conclusions.

2 Shadow Banks and the Great Recession

Where does the liquidity risk of an entity come from? It comes from the refinancing risk when the entity has to roll over its debt. If an entity has borrowed money from others, it has to pay back the principal and interest when the loan matures. Most entities plan to keep a stable capital structure in the long term. They can issue long-term debt to achieve the goal, or issue short-term debt and reissue it when it matures, doing this over and over until they reach the same long-term goal. If an entity cannot reissue new debt when the old debt matures, it will experience a passive but obligatory cash outflow. The cash outflow has more liquidity risks if it is unexpected. For example, a non-financial company may raise funds for a 5-year investment by rolling over 3-month non-financial

[14]Liquidity Coverage Ratio (LCR) comes into full effect in 2019. Net Stable Funding Ratio (NSFR) was introduced in 2018.

CP or repeatedly getting 3-month loans from commercial banks. If it can successfully roll over its debt 20 times, it seems as if the company issued 5-year debt for the investment. However, if a credit crunch happens within 5 years, in which CP investors are not willing to repurchase the security or commercial banks contract their credit, the company has to find alternative funding sources, or in the worst case, liquidate the investment. In a way, we observe investors[15] withdraw their money from the company, which has been being lent to the company as debt investment.

Commercial banks are different from normal companies in corporate finance because they have a unique funding source from deposits. The principle of liquidity risks is totally the same if we see deposits as the debt of commercial banks. A second example is a commercial bank issuing 3-month time deposits over and over to raise funds. Some investors may not repurchase the new time deposits when the old ones mature; some investors may continue their time deposits; and there are some new investors who begin to make time deposits. If the total deposits that investors keep holding remain relatively steady, the commercial bank will have no liquidity risk. However, if investors are no longer willing to make the time deposits they have been making, we observe investors withdraw their money from the commercial banks. Hence, as a matter of fact, runs on a commercial bank are the bank cannot roll over its deposits.

Generally speaking, the shorter the maturity of the debt, the greater the potential liquidity risk of the entity because the entity has to roll over its debt more times. The exception is transaction deposits, also known as demand deposits. Transaction deposits have infinitely short maturities given that investors can withdraw them at any time. In other words, commercial banks have to reissue transaction deposits every second and the investors actually repurchase the deposits every second. For normal debt financing, it would have the highest refinancing risks and potential liquidity risks for the issuing entity, due to the extremely short maturity. However, transaction deposits together with small time deposits are called core deposits[16] which are considered the most stable funding source of commercial banks. When liquidity dried up during the Great Recession, commercial banks that relied more heavily on core deposit and equity capital financing could continue to lend

[15] When a commercial bank lends a loan to a company, it is also a debt investor for the company.

[16] Except for large time deposits, other deposits are core deposits.

compared to other banks (Cornett, McNutt, Strahan, and Tehranian (2011)).

Shadow banks also have their special kinds of debt financing instruments. The debt financing instruments are not only liabilities of shadow banks, but also the assets of investors. In plain words, investors no longer purchase the debt financing instruments which they used to purchase. In addition to the special funding instruments, shadow banks, and commercial banks also have higher financial leverage compared to normal companies. Commercial banks usually have 10 times leverage. Because of loose regulations, shadow banks can have much higher leverage. For example, independent primary dealer banks before the Great Recession usually had from 20 to 30 times leverage[17]. If an entity cannot roll over its debt, it may experience more liquidity risks if it has higher leverage. Because the debt issued by shadow banks plunged during the Great Recession, some literature also calls this phenomenon ”deleveraging”. When literature uses the term ”deleveraging”, it considers the decrease in debt comes from the supply side (shadow banks)[18]. The special mechanisms in shadow banks could make them have to reduce or liquidate a large asset holdings with only a little decrease of funding[19]. By contrast, the leverage of the commercial banking sector increased over the crisis because of the stable funding sources from deposits (He, Khang, and Krishnamurthy (2010)).

In addition to funding and leverage, the liquidity risks of an entity also depend on its liquid assets holdings. The more the liquid asset an entity has, the smaller the liquidation cost it suffers. For example, reducing cash assets holdings in response to a decrease in debt has no liquidation cost. Moreover, strictly speaking, the refinancing risks depend on the average remaining maturity of debt but not the average maturity of the debt. For example, in 2007, a company funded by 10-year bonds or loans with only 1 year left had more potential liquidity risks than another company funded by 5-year bonds or loans with 4 years left. Hence, we need detailed data regarding all items on and off the balance sheet of a commercial bank or shadow bank to measure its potential liquidity

[17]No independent primary dealer bank exists after the Great Recession. Goldman Sachs and Morgan Stanley transited into BHCs even if they did not hold any commercial bank back then. Lehman Brothers failed. Merrill Lynch and Bear Stearns were acquired by Bank of America and J.P. Morgan Chase.

[18]By contrast, when literature uses the term ”runs”, it considers the reduction in debt comes from the demand side (investors).

[19]For example, rehypothecation of collateral and haircuts of repos.

risks. Berger and Bouwman (2009) propose a measure called Liquidity Creation (henceforth, LC) for commercial banks. LC of a commercial bank is defined as the liquidity of liabilities minus the liquidity of assets. A commercial bank has large LC if it holds more long-term loans (illiquid) and is funded heavily by short-term time deposits or transaction deposits (liquid). LC is not precise to measure liquidity risks in two aspects. First, the liquidity of liabilities is not equivalent to the instability of them during crisis times. As stated above, core deposits could be highly liquid and short-term, but they are the most stable funding sources of commercial banks. Second, the liquidity of assets could change significantly during crisis times. Before the Great Recession, most short-term fixed-income products issued by shadow banks were considered highly liquid assets by investors[20], but they collapsed over the crisis and investors had large liquidation cost to sell them. Bai, Krishnamurthy, and Weymuller (2018) construct a measure called Liquidity Mismatch Index (henceforth, LMI) to evaluate the liquidity risks of BHCs. LMI fixes the problems of LC by giving liquidity risk weights to all assets, liabilities and off-balance sheet items. It is like the risk-based capital and assets in capital requirements. However, the liquidity risk weights in LMI are not fixed but matched to the market prices.

In this paper, I use weekly time series data regarding the commercial banking sector and the shadow banking sector to perform the analysis at the industry level, so it is impossible and unnecessary to evaluate liquidity risks of any particular bank. I only consider liquidity risks from the liability side when I evaluate the liquidity risks of commercial and shadow banking sectors. By definition, commercial banks are different from shadow banks in liabilities. Hence, I define deposits as the only commercial banking financing instrument to capture the essential difference between commercial banks and shadow banks. All other short-term debt financing channels except for treasury bills are shadow banking financing instruments[21]. Although it is possible to sum all liquid assets in the commercial banking sector, it may not help improve the measure of liquidity risks in the sector. We cannot simply add up the liquid assets of each entity to get the liquid buffer of the whole sector. Moreover, liquidity risks stem from the liability side. Thus, we can reasonably

[20] Here, investors could be commercial banks or shadow banks.

[21] Long-term debt financing is related to solvency problems but not liquidity risks.

think that a decrease in deposits means commercial banks are facing liquidity risks, and a decrease in shadow banking financing instruments means shadow banks are facing liquidity risks[22].

Table 1: Annual U.S. Main Short-Term Debt Financing Instruments ($ billions)

Year	Commercial Paper	Repurchase Agreements	Treasury Bills	Deposits	Agency Debentures
2003	1,341	1,244	929	4,095	445
2004	1,334	1,518	1,001	4,428	566
2005	1,529	1,838	961	4,817	485
2006	1,806	2,106	941	5,181	518
2007	2,005	2,427	1,000	5,477	832
2008	1,739	2,239	1,861	5,889	1,124
2009	1,303	1,728	1,793	6,548	652
2010	1,074	1,717	1,773	6,742	567
2011	1,081	1,871	1,521	7,208	517
2012	993	2,064	1,629	7,944	460
2013	1,034	1,932	1,592	8,490	533
2014	1,047	1,781	1,458	9,047	636
2015	1,028	1,801	1,514	9,657	718
2016	1,020	1,788	1,818	10,244	552
2017	996	1,958	1,956	10,752	529
2018	1,088	2,103	2,340	11,170	544

This table reports annual (2003-2018) main debt financing instruments with maturity less than 1 year, a.k.a. money market financing instruments, except for deposits. Deposits are total deposits of domestically chartered commercial banks including long-term time deposits and transaction deposits. They are the annual average value of weekly data obtained from the Federal Reserve's H.8 statistical release. Commercial Paper outstanding is the annual average value of weekly data obtained from the Federal Reserve's CP release. Repurchase Agreements are only tri-party repos. Their annual average collateral value is calculated by daily data obtained from the Federal Reserve Bank of New York. The data before 2008 is estimated by the author. Treasury bills outstanding is the year-end value of monthly data obtained from the U.S. Treasury. Agency debentures outstanding is the year-end value of quarterly data obtained from Securities Industry and Financial Markets Association (SIFMA). The data before 2006 is estimated by the author.

Although this paper only uses financial CP as the proxy for shadow banking financing in formal regressions, it is beneficial to check total U.S. short-term debt financing instruments, also known as money market financing instruments, and therefore build a big picture. Table 1 shows annual (2003-2018) main debt financing instruments with maturity less than 1 year except for deposits.

[22] Although commercial banks also use shadow banking financing instruments to raise funds and BHCs may have shadow banking subsidiaries, their funds are mainly from commercial banking financing instruments (deposits).

Because deposits are the only commercial banking financing instrument and they are most stable funding sources in crisis times, I list the total deposits in Table 1 which include long-term time deposits and transaction deposits. Apart from deposits and treasury bills (henceforth T-Bills), which are issued by the government, agency debentures, CP, and repos are typical shadow banking financing instruments[23]. Although repos in Table 1 only contain tri-party repos, and I estimate data for them before 2008 and data for agency debentures with tenor less than 1 year before 2006 because of unavailability, the data in Table 1 is precise enough to give a big picture[24].

All of the instruments had an increasing trend from 2003 to 2007. In 2007, the volume of total shadow banking financing instruments, the sum of CP, repos and agency debentures, almost equaled that of total deposits. CP and repos outstanding decreased from 2007 to 2009. The peak of agency debentures was $\$1.124$ trillion outstanding in 2008, and the volume fell to $\$652$ billion in 2009, since runs on government-sponsored enterprises (henceforth, GSEs), the issuer of agency debentures, happened in the last quarter of 2008 and agency debentures in Table 1 use the last quarter value in each year as the annual data[25]. Although the volume of all shadow banking financing instruments decreased during the Great Recession, deposits increased as we expected, especially from 2008 to 2009. It is worth mentioning that T-Bills increased from $\$1$ trillion in 2007 to $\$1.861$ trillion in 2008. There were many government bailouts during the Great Recession, so the government needed to raise funds from investors and lent them to financial institutions. For example, Krishnamurthy, Nagel, and Orlov (2014) find MMMFs, which are the main investors in repos, stopped accepting private asset-backed securities as collateral in the tri-party repo market during the crisis. T-Bills were the most preferred (or sometimes only) collateral that investors were

[23] Although corporate CP, which belongs to CP, is issued by large non-financial corporations. We can generally see them as shadow banks with lower leverage.

[24] According to the Securities Industry and Financial Markets Association (SIFMA), in early 2007, total U.S. short-term debt financing accounted for approximately $\$5$ trillion. CP was the largest instrument in this market with more than $\$1.97$ trillion outstanding. The second-largest instrument was T-Bills, which accounted for $\$940$ billion outstanding. Other important short-term debt instruments were time deposits and repos. In their statistics, they only consider short-term deposits and net tri-party repos without general collateral financing (GCF) trades. It is the reason that they have much fewer deposits and repos than that in my data. The main instruments listed in Table 1 covered most of the short-term debt financing market back then.

[25] Actually, repos also peaked in 2008 if we use higher frequency data. Repos outstanding in Table 1 is the annual average value of daily data.

willing to accept. The government helped dealer banks to exchange their collateral with T-Bills so that they could still issue repos over the crisis. Hence, the volume of shadow banking financing instruments should have been much lower if there had been no bailout. Investors only trusted the government during the crisis. Only the government and deposits covered by the government could raise more funds. After the Great Recession, deposits keep increasing but shadow banking financing instruments remain at a relatively low and constant level. Nowadays, compared to the size of total deposits, the size of shadow banking financing instruments listed in Table 1 is no longer large. Do we live in a safer banking sector with more sufficient deposits? No. Many emerging shadow banks use new shadow banking financing instruments that are not listed in Table 1. In addition, potential liquidity risks may transfer directly into mutual funds and hedge funds. I will discuss this in the section of concluding remarks.

Now, let's take a look at the demand side: investors. Few individual investors invest in shadow banking financing instruments directly. One of the main investors is MMMFs. According to regulations, MMMFs can only invest in short-term fixed-income products, so the instruments in Table 1 cover almost all of the products in the portfolio of MMMFs. MMMFs are also typical shadow banks, and they experienced runs during the Great Recession. The product issued by MMMFs to raise funds is also called the MMMF[26]. After Lehman Brothers' bankruptcy, some MMMF investors withdrew their money from their MMMFs when they realized their MMMFs were holding financial CP and repos issued by Lehman Brothers. MMMFs had to liquidate some of their assets listed in Table 1 and they also adjusted their portfolios. They reduced their holdings of CP and repos, and expanded that of T-Bills, agency debentures, and deposits. If I treat MMMFs as another shadow banking financing instrument, it will double count the money that flows from outside into the shadow banking system. MMMFs are investors in the FTQ circle. They withdrew their money from shadow banks and put it into commercial banks like the blue links ② and ③ in the FTQ circle during the Great Recession. In addition to MMMFs, general mutual funds and hedge funds may also invest small parts of their funds into shadow banking financing instruments.

[26] For funds, the money they raise is not like debt or equity. For details, see the section of concluding remarks.

Large corporations can purchase shadow banking financing instruments to manage their liquidity assets. Hence, individual investors can indirectly invest in shadow banking products by holding MMMFs (mainly), mutual funds and equity of large non-financial companies.

Table 2 shows the liquid financial assets of individual investors and their share of total[27]. According to their share of the total, equity and mutual funds bottomed out and all fixed-income assets peaked in 2008. It may be partly caused by the larger decline in the market value of equity compared to that of fixed-income securities. Anyway, the market value of all fixed-income assets increased from 2007 to 2008, which demonstrates that individual investors did not transfer their funds from fixed-income investments to the other investments during the Great Recession. Individual investors increased their holdings of MMMFs over the crisis, so in total, institution investors could be the main trigger of runs on MMMFs[28]. The jump in the value of corporate bonds from $\$1.195$ trillion in 2007 to $\$2.150$ trillion in 2008 is more likely from the supply side. Corporations had difficulties issuing short-term CP and getting loans from commercial banks over the crisis, so they resorted to issuing long-term bonds. Owing to the high interest rate, individual investors were willing to keep more bonds for corporations that still have good fundamentals.

2.1 Shadow Banks

In this subsection, I concisely introduce the typical shadow banks discussed in this paper. Because this paper studies the liquidity risks of shadow banks, the introduction is organized by the order of shadow banking financing instruments in Table 1. Shadow banks, the entities, are mentioned as issuers when each instrument is introduced.

Shadow banks first come from the securitization. When a traditional commercial bank makes a loan to a borrower, it keeps the loan as an asset on its balance sheet. If a commercial bank securitizes its loans and sells them to investors, a shadow bank emerges. To sell its securitized

[27]The term ”liquid” is not equal to ”short-term”. For example, corporate bonds are long-term debt instruments but considered liquid financial assets by individual investors.

[28]Runs stopped on September 19, 2008, three days after it started, when the U.S. government announced that it would provide deposit insurance to investments in MMMFs.

Table 2: Annual U.S. Household Liquid Financial Assets ($ billions, Percent)

Year	Equity	Deposits	Mutual Funds	Treasury & Agency	Municipal Bonds	MMMF	Corporate Bonds	Total
2003	6,973	4,524	2,674	762	626	909	670	17,111
	40.8%	26.4%	15.5%	4.5%	3.7%	5.3%	3.9%	100%
2004	7,640	4,941	3,074	884	1,514	878	601	19,531
	39.1%	25.3%	15.7%	4.5%	7.7%	4.5%	3.1%	100%
2005	8,307	5,311	3,299	866	1,630	926	810	21,150
	39.3%	25.1%	15.6%	4.1%	7.7%	4.4%	3.8%	100%
2006	10,220	5,789	3,858	815	1,687	1,097	831	24,297
	42.1%	23.8%	15.9%	3.4%	6.9%	4.5%	3.4%	100%
2007	10,075	6,210	4,343	919	1,777	1,343	1,195	25,862
	39.0%	24.0%	16.8%	3.6%	6.9%	5.2%	4.6%	100%
2008	5,601	6,660	2,795	1,140	1,916	1,577	2,150	21,839
	25.6%	30.5%	12.8%	5.2%	8.8%	7.2%	9.8%	100%
2009	7,338	6,798	3,875	1,154	1,994	1,306	1,706	24,171
	30.4%	28.1%	16.0%	4.8%	8.2%	5.4%	7.1%	100%
2010	8,704	6,937	4,503	1,352	2,073	1,121	1,332	26,021
	33.5%	26.7%	17.3%	5.2%	8.0%	4.3%	5.1%	100%
2011	8,191	7,605	4,489	960	1,969	1,103	1,325	25,643
	31.9%	29.7%	17.5%	3.7%	7.7%	4.3%	5.2%	100%
2012	9,496	8,114	5,331	1,113	1,830	1,119	1,091	28,094
	33.8%	28.9%	19.0%	4.0%	6.5%	4.0%	3.9%	100%
2013	12,649	8,480	6,340	1,410	1,839	1,120	1,087	32,925
	38.4%	25.8%	19.3%	4.3%	5.6%	3.4%	3.3%	100%
2014	14,314	9,063	6,829	1,060	1,696	1,033	1,090	35,085
	40.8%	25.8%	19.5%	3.0%	4.8%	2.9%	3.1%	100%
2015	13,837	9,563	6,758	1,680	1,642	1,044	1,144	35,668
	38.8%	26.8%	18.9%	4.7%	4.6%	2.9%	3.2%	100%
2016	15,209	10,187	7,251	1,847	1,673	1,023	846	38,036
	40.0%	26.8%	19.1%	4.9%	4.4%	2.7%	2.2%	100%
2017	17,877	10,331	8,685	1,882	1,570	1,054	456	41,855
	42.7%	24.7%	20.7%	4.5%	3.7%	2.5%	1.1%	100%

Households include nonprofit organizations. Liquid financial assets exclude such illiquid assets as pension fund reserves, equity in the non-corporate business, etc. Source: Federal Reserve Flow of Funds, L.101.

loans, the commercial bank will set up a special purpose vehicle (henceforth, SPV), a bankruptcy remotely subsidiary, to issue the securities. The SPV securities issuer is a shadow bank. Investors are willing to buy the securities from the SPV but not the commercial bank because the failure of the commercial bank will not affect the SPV and the securities. For the commercial bank, it gets money from selling its loans and it can lend the money again. For the SPV, if it can sell the securities with no debt from investors, then it has no liquidity risks. It is a process of dis-intermediation. Security investors will receive the payment from the borrower directly and it seems as if investors lend their money to the borrower. In most cases, the securities have collateral in case borrowers default. If the collateral is real estate, the securities are mortgage-backed securities (henceforth, MBSs). For the other collateral, they are asset-backed securities (henceforth, ABSs).

Table 3: Annual U.S. Asset-Backed and Mortgage-Related Securities Outstanding ($ billions)

Year	ABS	Non-Agency MBS	Agency MBS	Total
2003	995	1,366	4,349	6,710
2004	1,100	1,896	4,405	7,402
2005	1,281	2,556	4,662	8,499
2006	1,657	3,299	5,091	10,047
2007	1,964	3,585	5,801	11,349
2008	1,830	3,188	6,279	11,297
2009	1,712	2,716	6,636	11,065
2010	1,508	2,424	6,835	10,766
2011	1,359	2,128	6,948	10,434
2012	1,280	1,878	6,960	10,118
2013	1,286	1,703	7,040	10,028
2014	1,349	1,623	7,219	10,191
2015	1,384	1,528	7,367	10,278
2016	1,397	1,385	7,638	10,420
2017	1,469	1,299	8,005	10,773
2018	1,677	1,294	8,089	11,060

Source: Securities Industry and Financial Markets Association (SIFMA).

Table 3 shows the ABSs and MBSs outstanding in the United States from 2003 to 2018. Agency MBSs are issued by GSEs such as Ginnie Mae, Fannie Mae or Freddie Mac. They should not be confused with agency debentures. Agency debentures are the debt of GSEs, so they are financing instruments for GSEs. However, GSEs issue agency MBSs for business and they are not debt. Shadow banks usually prefer to have more funds to issue MBSs or ABSs. Hence, they use the shadow banking financing instruments listed in Table 1 to raise funds. For examples, GSEs issue agency debentures to raise funds. One the asset side, shadow banks hold MBSs and ABSs before they can sell them or use them as collateral to raise more funds such as repos. When shadow banking financing instruments collapsed during the Great Recession, shadow banks had to liquidate their holdings of securitized assets. By contrast, commercial banks increased securitized assets holdings because they had stable funding sources (He, Khang, and Krishnamurthy (2010)). Because of the liquidation, the market value of ABSs and MBSs plunged over the crisis. Agency MBSs were saved by the U.S. Federal Reserve's $1.25 trillion program to purchase agency MBSs, which commenced on January 5, 2009, and was completed on March 31, 2010. Nowadays, Agency MBSs account for $8.089 trillion in total $11.06 trillion securitized assets maybe because investors believe a government bailout will happen again when a crisis arrives.

2.1.1 Commercial Paper

Commercial paper includes ABCP, financial CP and corporate CP[29]. The maturity of CP is usually between 1 and 90 days with an average at about 30 days, although it can legally be up to 270 days. ABCP is relatively new compared to financial CP and corporate CP. It is issued by ABCP conduits which are SPVs sponsored by large financial institutions. The assets of ABCP conduits are collateral of ABCP and they are usually long-term MBSs and ABSs. Given the normal term structure of interest rates, ABCP conduits can earn profits by holding long-term securitized assets and issuing short-term ABCP as debt. The sponsoring financial institutions are mainly commercial banks and they usually provide guarantees to ABCP investors in case ABCP conduits default. In January 2007, commercial banks (BHCs) accounted for $903 billion or 74.8% of ABCP outstanding. According to Acharya, Schnabl, and Suarez (2013), regulatory arbitrage was another important motive that BHCs set up ABCP conduits. ABCP conduits are off-balance sheet financing for com-

[29] For a more detailed introduction about CP during the Great Recession, see Kacperczyk and Schnabl (2010).

Table 4: Annual U.S. Commercial Paper Outstanding ($ billions)

Date	ABCP	Financial CP	Corporate CP	Total
2003	680	528	134	1,341
2004	663	550	121	1,334
2005	763	623	142	1,529
2006	970	693	142	1,806
2007	1,059	772	175	2,005
2008	764	783	192	1,739
2009	558	597	148	1,303
2010	403	547	125	1,074
2011	370	543	167	1,081
2012	317	479	197	993
2013	275	544	216	1,034
2014	242	540	265	1,047
2015	231	522	275	1,028
2016	255	492	273	1,020
2017	242	468	285	996
2018	238	548	301	1,088

Source: Federal Reserve's H.8 statistical release.

mercial banks. Although BHCs need to satisfy capital requirements based on consolidated balance sheets, they could enjoy reduced regulatory capital if guarantees were skillfully structured before the Great Recession. Most losses of ABCP conduits were undertaken by the commercial banks instead of ABCP investors during the Great Recession. In June 2009, the Financial Accounting Standard Board (FASB) announced the Statements of Financial Accounting Standards (FAS) 166 and 167, amending existing accounting rules for the consolidation of securitization transactions. The United States banking agencies clarified in September 2009 that depository institutions (commercial banks) would have to hold normal regulatory capital against consolidated securitization transactions and ABCP conduits. Hence, we can see that the ABCP outstanding continues to decline after 2009 in Table 4.

Corporate CP is issued by large non-financial corporations. It has no collateral, so only corporations with good reputations can issue it. Compared to long-term bonds, corporate CP has fewer issue costs. It also usually has a backup (credit) line from commercial banks in case corporations cannot reissue their CP in crisis times. Besides seeking loans from commercial banks, corporations can also issue long-term bonds to replace the CP that they have difficulties reissuing. For example, CP is an important source of financing for Coca Cola, representing about 30% of their liabilities in 2007. During the Great Recession, Coca Cola switched to alternative long-term financing, mostly as a response to the reality that it could not reissue enough CP anymore. On March 3, 2009, Coca Cola announced that it had sold $\$0.9$ billion of five-year and $\$1.35$ billion of ten-year notes to repay its maturing CP. In table 2, we can see individual investors held much more corporate bonds during the Great Recession (2008).

Financial CP is issued by large financial institutions. It also has no collateral. The main issuers of financial CP are foreign financial institutions, accounting for $\$455$ billion of total $\$772$ billion financial CP outstanding in 2007. Foreign financial institutions usually set up U.S. subsidiaries to issue financial CP in the U.S. market. Other main issuers of financial CP are captive finance companies. Captive finance companies are financial subsidiaries of manufacturers, with the purpose of providing financing for the manufacturer. Others are shadow banks in the U.S. banking sector. They could be commercial bank-related or independent. Commercial banks cannot legally issue financial CP directly, but their BHCs can set up shadow banking subsidiaries to issue it. As an example of independent shadow banks, Lehman Brothers was a main issuer of financial CP and its bankruptcy triggered the following run on the financial CP market. Hence, most issuers of financial CP are independent shadow banks and it is the reason why I choose financial CP as the proxy for shadow banking financing instruments.

2.1.2 Tri-Party Repos

Repurchase Agreements have a similar process like collateralized borrowings, but investors have more controls over the collateral. The collateral is exempted from the automatic stay, so an investor in a repo can unilaterally enforce the termination provisions of the agreement as a result of a bankruptcy filing by the counter-party. Hence, investors have fewer risks when purchasing repos than when lending covered by collateral. In the tri-party repo market, a third party called a clearing bank acts as an intermediary and alleviates the administrative burden between two parties engaging in a repo. Dealers issue repos in the tri-party repo market using their securitized asset holdings as collateral. The largest dealers are primary dealers. Primary dealers are dealer banks that are authorized to trade directly with the New York Fed. Most tri-party repos are overnight.

Table 5: Annual U.S. Tri-Party Repos Outstanding ($ billions)

Year	Tri-Party Repos	GCF	Net Tri-Party Repos
2010	1,717	333	1,384
2011	1,871	306	1,565
2012	2,064	293	1,772
2013	1,932	257	1,675
2014	1,781	202	1,579
2015	1,801	221	1,580
2016	1,788	179	1,609
2017	1,958	123	1,835
2018	2,103	134	1,969

Source: Federal Reserve Bank of New York.

General collateral financing (GCF) in Table 5 are repos that trade between dealer banks. Because the FTQ circle model in this paper only considers the funds that flow from outside into the shadow banking system, net repos outstanding without GCF should be used in my study. Unfortunately, data before 2010 is unavailable.

2.1.3 Agency Debentures

Agency debentures are agency debt issued by GSEs. GSEs includes Fannie Mae, Freddie Mac, Farm Credit, Federal Home Loan Bank, Farmer Mac, and Tennessee Valley Authority. Agency debentures have no collateral, but GSEs have implicit government backup. From Table 6 we can see that short-term debt plunged, but the long-term debt remained relatively stable during the Great Recession[30].

[30] The peak of short-term agency debentures was $1.124 trillion outstanding in 2008, and the volume fell to $652 billion in 2009, since runs on GSEs, the issuer of agency debentures, happened in the last quarter of 2008. Agency debentures in Table 6 use the last quarter value in each year as annual data.

Table 6: **Annual U.S. Agency Debentures Outstanding ($ billions)**

Year	Short-Term	Long-Term	Total
2006	518	2,114	2,632
2007	832	2,074	2,906
2008	1,124	2,085	3,208
2009	652	2,074	2,726
2010	567	1,971	2,538
2011	517	1,810	2,327
2012	460	1,636	2,096
2013	533	1,525	2,058
2014	636	1,393	2,029
2015	718	1,278	1,995
2016	552	1,420	1,972
2017	529	1,406	1,935
2018	544	1,322	1,865

Source: Securities Industry and Financial Markets Association (SIFMA).

2.2 Great Recession

In this section, I review how CP outstanding and deposits changed over the Great Recession. Figure 2 shows the weekly CP outstanding, total deposits and cash at commercial banks from Dec. 12, 2001, through Nov. 29, 2017. The gray-shaded area in Figure 2 is the time period of the Great Recession. We can see the CP market had two prominent collapses during the Great Recession. I label them as ABCP market collapse and Lehman's Bankruptcy. The increase in deposits accompanied by the ABCP market collapse was not significant. Only a fraction of funds flew from ABCP into deposits directly. The others flew into financial CP, corporate CP, repos, etc. According to Figure 3, the ABCP market collapse happened on August 9, 2007. Financial CP and corporate CP still increased after the ABCP market collapse. The financial CP market collapse happened after the bankruptcy of Lehman Brothers on September 15, 2008, because Lehman Brothers was a main issuer of financial CP. No prominent collapse happened in corporate CP market like other two CP markets during the Great Recession. The bankruptcy of Lehman Brothers also triggered runs on the repo market and MMMFs. Lehman Brothers was a primary dealer bank in the tri-party repo market, and after knowing the portfolio of MMMFs had financial CP and repos from Lehman

Figure 2: CP Outstanding, Deposits and Cash at Commercial Banks

The figure shows the weekly CP outstanding, total deposits and cash at commercial banks from Dec. 12, 2001, through Nov. 29, 2017. The gray-shaded area is the time period of the Great Recession (from Aug. 1, 2007, to Jun. 24, 2009). The ABCP market collapse was Aug. 9, 2007. Lehman's bankruptcy was Sep. 15, 2008. Source: Federal Reserve's H.8 statistical release and CP release.

Brothers, MMMFs investors also withdrew their money from MMMFs. Hence, we observe an unprecedented steep jump in deposits accompanied by the bankruptcy of Lehman Brothers. Investors transferred their funds from shadow banks (CP and repos) to commercial banks (deposits).

From Figure 2, the cash[31] holdings of commercial banks shows that commercial banks had a relatively constant cash level before Lehman's bankruptcy. Commercial banks always tried to keep their cash at the level although their deposits continuously increased. The cash target did not change even after the ABCP market collapse. It means commercial banks still did not keep the

[31] Cash includes reserves.

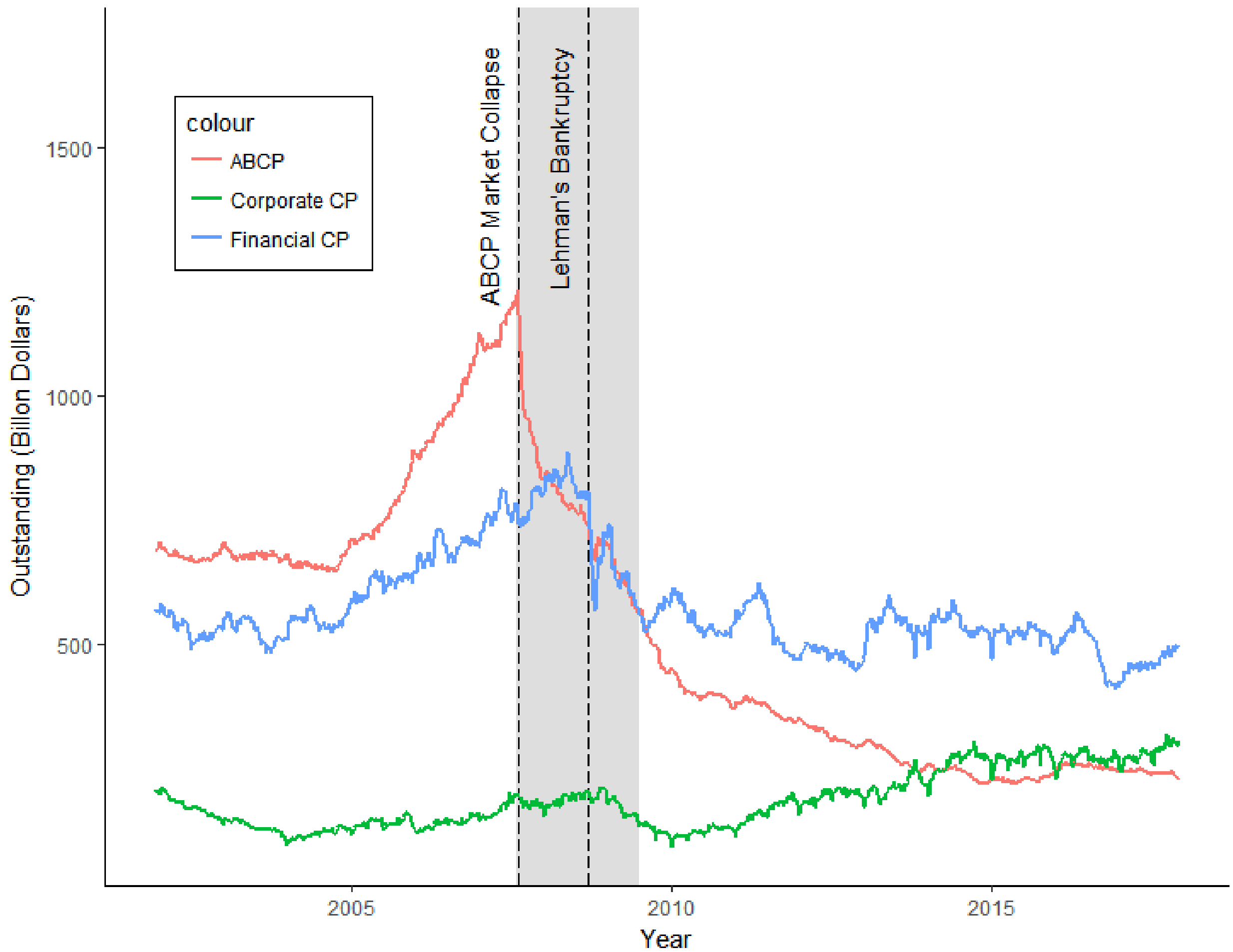

Figure 3: ABCP, Financial CP and Corporate CP Outstanding

The figure shows ABCP, Financial CP and Corporate CP Outstanding from Dec. 12, 2001, through Nov. 29, 2017. The gray-shaded area is the time period of the Great Recession (from Aug. 1, 2007, to Jun. 24, 2009). The ABCP market collapse was Aug. 9, 2007. Lehman's bankruptcy was Sep. 15, 2008. Source: Federal Reserve's CP release.

increment of deposits as extra cash on hand after the beginning of the Great Recession. Things changed after Lehman's bankruptcy. Commercial banks kept almost all the increment of deposits as extra cash on hand. Hence, the liquidity backup from commercial banks to shadow banks likely broke down after Lehman's bankruptcy.

It is worth mentioning that CP outstanding should have been much lower if unprecedented government bailouts did not happen during the Great Recession. Runs on MMMFs stopped on September 19, 2008, three days after it started, when the U.S. government announced that it would provide deposit insurance to investments in MMMFs. Although the MMMF outstanding stopped dropping, MMMFs still adjusted their portfolios by holding more T-Bills and deposits, and less CP and repos. For the first time ever, the Federal Reserve decided to purchase CP directly like investors. By early January 2009, the Federal Reserve was the single largest purchaser of CP and owned CP worth $\$357$ billion, or 22.4% of the market, through a variety of lending facilities.

3 Empirical Evidence: the FTQ Circle

From Section 2, we know that investors withdraw funds from commercial banks or shadow banks is actually the decrease in commercial or shadow banking financing instruments. Hence, to test the FTQ circle empirically, we first need to find empirical proxies for commercial and shadow banking financing instruments. For commercial banking financing instruments, it is easy because deposits are the only ones. For shadow banking financing instruments, we need to find an empirical counterparty that only shadow banks can issue to raise funds, and what is more, the issuing shadow banks are independent. It is especially difficult given that BHCs controlled much more shadow banks after the Great Recession. This paper chooses financial CP outstanding as the proxy for shadow banking financing instruments because only shadow banks can legally issue financial CP and main issuers are independent foreign financial institutions.

According to Figure 4, foreign financial institutions have accounted for an increasing share of financial CP outstanding over time. The financial CP outstanding issued by U.S.-owned financial institutions falls from more than 60% in 2002 to less than 20% in 2017. Although I do not collect data regarding how much financial CP outstanding issued by U.S. financial institutions are from independent shadow banks, the volume is not small, especially before the Great Recession. Captive finance companies, subsidiaries of non-financial large corporations, are main financial CP U.S. issuers. They are independent shadow banks. In addition, before the Great Recession, independent dealer banks such as Lehman Brothers were also main financial CP issuers. Hence, most financial CP issuers have no relation with U.S. BHCs and they are competitors by offering similar fixed-income products for investors in the FTQ circle. Deposits have lower interest rates and fewer

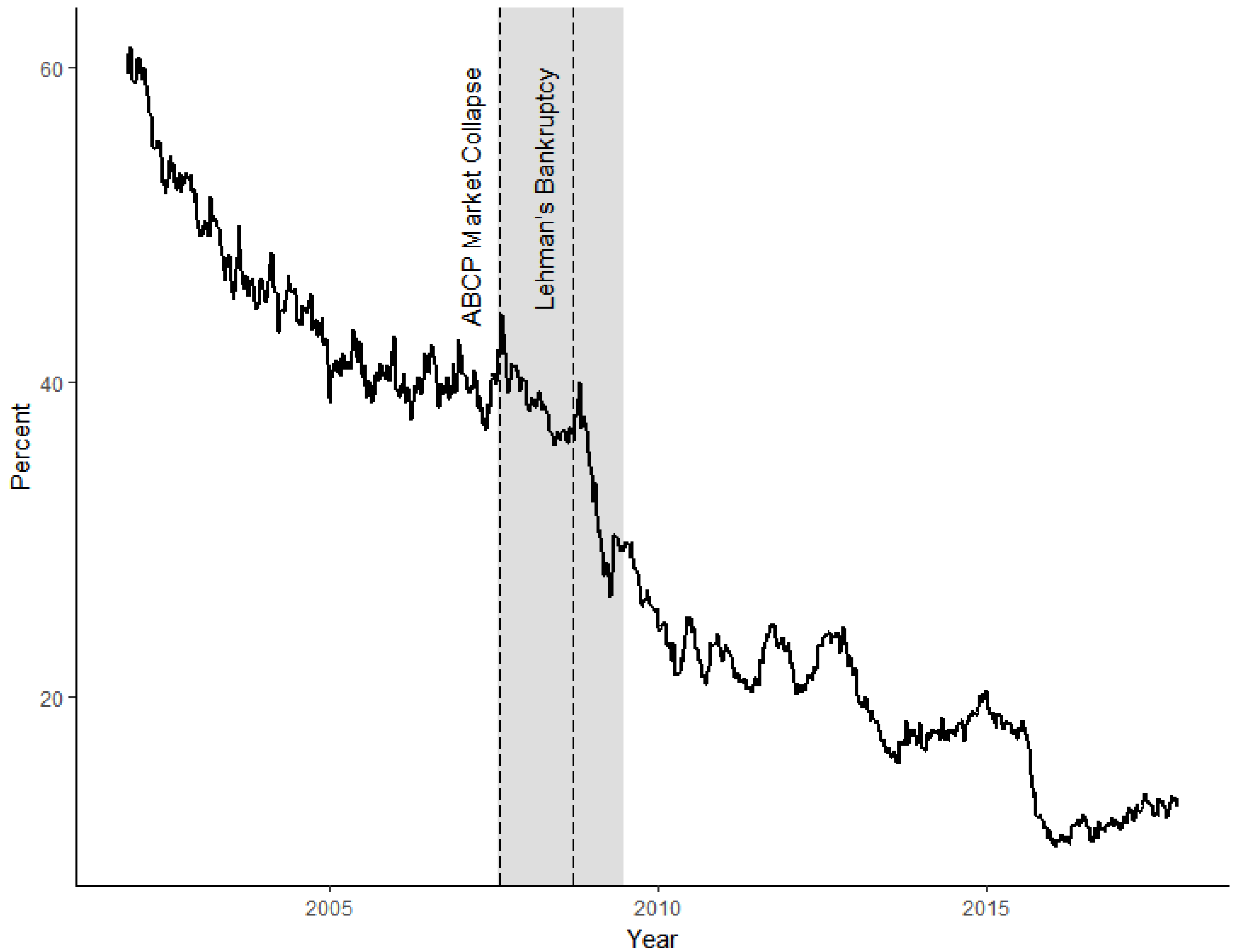

Figure 4: The Percentage of Financial CP Outstanding from U.S. Financial Institutions

The figure shows the percentage of financial CP outstanding that is issued by the U.S. owned financial institutions from Dec. 12, 2001, through Nov. 29, 2017. The gray-shaded area is the time period of the Great Recession (from Aug. 1, 2007, to Jun. 24, 2009). The ABCP market collapse was Aug. 9, 2007. Lehman's bankruptcy was Sep. 15, 2008. Source: Federal Reserve's CP release.

risks than financial CP. Although there always exists some financial CP issued by shadow banking subsidiaries of BHCs, it is just like the large time deposits in total deposits[32]. They do not change qualitative results in empirical tests.

Another difficulty in empirical tests comes from the frequency of data. In principle, the blue links ②, ③, and ④ in the FTQ circle occur in sequence. In reality, few investors hold plenty of cash on hand for some days, and most money transfers in investors' portfolios are executed elec-

[32]The large time deposits outstanding decreased over the Great Recession like shadow banking financing instruments because they are uncovered.

tronically and instantaneously, so it is difficult to observe the time-lag between the links ② and ③. Given weekly data used in this paper, we can think the substitution of deposits for financial CP happens within each week when investors are more risk-sensitive. Hence, the negative correlation between the change of deposits and that of financial CP outstanding is weekly concurrent. The interest of this paper is not the time-lag between the links ② and ③ but the observation of subsequent liquidity backup from commercial banks to shadow banks. According to the FTQ circle, I need high-frequency data to observe the link ④ that happens later after an increase in deposits, but not too late for shadow banks to rebuild the liquidity. Given that the highest frequency observation I could get from the data is weekly, the shadow banking financing instruments I pick to test should have the average maturity above at least one week. Repos are not feasible because they are mostly overnight. The link ④ in the FTQ circle may happen in a day. The liquidity backup from commercial banks in a week may be too late for repos. However, financial CP has the average maturity as about 30 days. Hence, the weekly data is enough to observe the link ④ in the FTQ circle if it really exists. In addition, the timely liquidity backup is effective for shadow banks to rebuild the liquidity.

After choosing the empirical proxies, we can simplify the FTQ circle into two predictions that we need to test.

- **Prediction 1**: In each week, there exists a concurrent correlation between the change of deposits and that of financial CP outstanding all the time. The concurrent correlation is negative as shown by the links ② and ③ in the FTQ circle.

- **Prediction 2**: In normal times, there exists a dynamic correlation between deposits and financial CP outstanding inter-weekly. An increase in deposits leads to an increase in financial CP outstanding in the following several weeks as shown by the link ④ in the FTQ circle. In crisis times, the dynamic correlation breaks down.

3.1 Methods and Data

I collect my data regarding commercial banks from the Federal Reserve's H.8 statistical release. Although data from the Call Reports contain much more detailed information about commercial banks than H.8 data, the latter does offer the available highest frequency (weekly) look at commercial banks. I choose the H.8 data regarding all domestically chartered commercial banks from December 12, 2001, to November 29, 2017. Weekly data about financial CP are collected from Federal Reserve's CP release and matched to the H.8 data.

I separate my entire times series data into three windows: pre-crisis, crisis, and post-crisis. The cutoff dates to split the period of the Great Recession are chosen arbitrarily. I choose August 1, 2007, one week before the ABCP market collapse, as the beginning of the crisis and June 24, 2009, as the end of the crisis. In such a way, I have 100 data points for the crisis, and the financial CP collapse is about in the middle of the crisis[33]. To test two predictions based on the FTQ circle, I estimate a series of VARs, each using the data in the window pre-crisis, crisis, and post-crisis.

Because both time series of deposits and financial CP outstanding are non-stationary in all the three windows and they are not co-integrated, I normalize them as follows:

$$g_{\text{De},t} = \ln(\frac{\text{Deposit}_t}{\text{Deposit}_{t-1}}) * 100; \quad g_{\text{CP},t} = \ln(\frac{\text{Financial CP}_t}{\text{Financial CP}_{t-1}}) * 100.$$

Time series of $g_{\text{De},t}$ and $g_{\text{CP},t}$ are actually weekly growth rates and they are stationary in all the three windows[34]. Table 7 shows the summary statistics for time series of $g_{\text{De},t}$ and $g_{\text{CP},t}$. We can see the mean of the percentage change in deposits is highest in the crisis as 0.188, but the standard deviation does not increase from the pre-crisis to the crisis. Hence, deposits have a stable high

[33]There exists a tradeoff in choosing the window crisis. If the chosen crisis is too short, observations in the crisis may be too few to get significant regression coefficients. If the chosen crisis is too long, it may include excessive noise. According to the nonprofit National Bureau of Economic Research (the official arbiter of U.S. recessions), the Great Recession in the U.S. began in December 2007 and ended in June 2009. My choice begins four months before the official one so that it can include the ABCP market collapse. Qualitative results in this paper do not change if I use the official time window.

[34]In some literature, the growth rate of deposits is defined by $g_{\text{De},t} = 100*(\text{Deposit}_t - \text{Deposit}_{t-1})/\text{Deposit}_{t-1}$. For the small absolute value of $r_{\text{De},t} = \text{Deposit}_t/\text{Deposit}_{t-1}$, the two definitions are very close, because $\ln(1 + r_{\text{De},t}) \approx r_{\text{De},t}$. In this paper, I always use log-difference to calcultate growth rates, since it is symmetry, and consistent with the forecast model in Section 4. Qualitative results in this paper do not change if I use the alternative definition.

growth rate in the crisis. By contrast, the growth rate of financial CP outstanding has the lowest mean and the highest volatility in the crisis.

Table 7: Summary Statistics for Weekly Growth Rates of Deposits and Financial CP (Percent)

Window	Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Pre-Crisis	$g_{\text{De},t}$	294	0.132	1.062	-2.327	-0.595	0.864	3.241
	$g_{\text{CP},t}$	294	0.113	1.638	-6.023	-0.900	1.228	5.234
Crisis	$g_{\text{De},t}$	100	0.188	1.019	-2.094	-0.513	0.883	4.227
	$g_{\text{CP},t}$	100	-0.313	2.824	-11.769	-1.691	1.169	10.456
Post-Crisis	$g_{\text{De},t}$	440	0.118	0.745	-2.340	-0.392	0.631	2.216
	$g_{\text{CP},t}$	440	-0.031	2.148	-7.396	-1.330	1.403	11.980

From Figure 5 and Table 8, we can see time series of $g_{\text{De},t}$ and $g_{\text{CP},t}$ have negative correlation coefficients all the time. However, it is not sufficient to justify Prediction 1 because there may exist an endogeneity problem between the growth rate of deposits and that of financial CP outstanding. To solve the possible endogeneity problem, I use VAR models that include two endogenous variables ($g_{\text{De},t}$ and $g_{\text{CP},t}$). I always choose the lag order as 4 in my VAR models because lag 4 means 4 weeks, and given that the average maturity of financial CP is 30 days, the liquidity backup after 4 weeks may not be effective in helping even if it exists[35]. The fitted VAR(4) model I estimate in each time window has the following formula:

$$\begin{bmatrix} g_{\text{De},t} \\ g_{\text{CP},t} \end{bmatrix} = \begin{bmatrix} \phi_1^0 \\ \phi_2^0 \end{bmatrix} + \begin{bmatrix} \phi_{11}^1 & \phi_{12}^1 \\ \phi_{21}^1 & \phi_{22}^1 \end{bmatrix} \begin{bmatrix} g_{\text{De},t-1} \\ g_{\text{CP},t-1} \end{bmatrix} + \begin{bmatrix} \phi_{11}^2 & \phi_{12}^2 \\ \phi_{21}^2 & \phi_{22}^2 \end{bmatrix} \begin{bmatrix} g_{\text{De},t-2} \\ g_{\text{CP},t-2} \end{bmatrix}$$
$$+ \begin{bmatrix} \phi_{11}^3 & \phi_{12}^3 \\ \phi_{21}^3 & \phi_{22}^3 \end{bmatrix} \begin{bmatrix} g_{\text{De},t-3} \\ g_{\text{CP},t-3} \end{bmatrix} + \begin{bmatrix} \phi_{11}^4 & \phi_{12}^4 \\ \phi_{21}^4 & \phi_{22}^4 \end{bmatrix} \begin{bmatrix} g_{\text{De},t-4} \\ g_{\text{CP},t-4} \end{bmatrix} + \begin{bmatrix} a_{1t} \\ a_{2t} \end{bmatrix}.$$

Here, residuals $\begin{bmatrix} a_{1t} \\ a_{2t} \end{bmatrix}$ are a sequence of serially uncorrelated vectors with mean zero and co-

[35] According to information criteria (AIC and BIC), lag order 3 or 4 is usually optimal in the pre-crisis and the post-crisis, but lag order 1 or 2 is optimal in the crisis.

variance matrix $\Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{bmatrix}$ if the VAR(4) model is correctly fitted. We can calculate the correlation coefficient between residuals a_{1t} and a_{2t} using $\rho_{12} = \sigma_{12}/\sqrt{\sigma_{11} * \sigma_{22}}$. If Prediction 1 is true, then ρ_{12} is negative in all three time windows. To justify Prediction 2, we expect to find that some of ϕ_{21}^{1}, ϕ_{21}^{2}, ϕ_{21}^{3} and ϕ_{21}^{4} are significantly positive in the pre-crisis and the post-crisis, but not significant in the crisis.

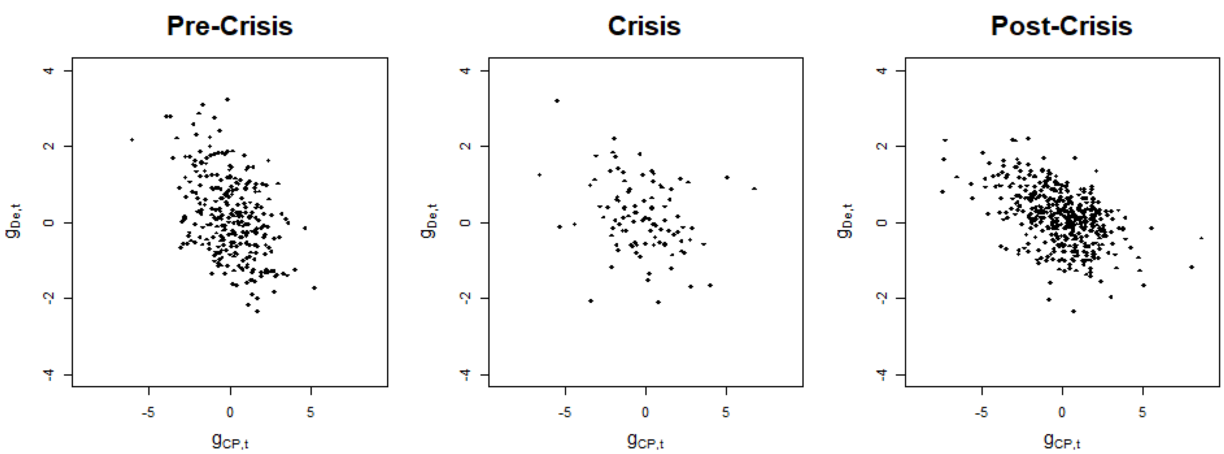

Figure 5: Concurrent Scatter Plots for Weekly Growth Rates of Deposits and Financial CP

Table 8: Concurrent Correlation Coefficients for Weekly Growth Rates of Deposits and Financial CP and t-Test

Window	Pre-Crisis	Crisis	Post-Crisis
Correlation Coefficient	−0.445	−0.276	−0.502
t-Value	−8.498	−2.847	−12.140
df	292	98	438
p-Value	5.0E-16	0.003	2.2E-16

3.2 Results

Table 9 summarizes the VAR(4) results in all the three time windows. Let's first look at the residuals $a_t = (a_{1t}, a_{2t})$. If the VAR(4) model is correctly fitted in any time window, residuals a_t should have no autocorrelation and no heteroskedasticity. In the pre-crisis, the p-value of Ljung-Box test

Table 9: VAR(4)s for Weekly Growth Rates of Deposits and Financial CP

	Pre-Crisis		*Crisis*		*Post-Crisis*	
	$g_{\text{CP},t}$	$g_{\text{De},t}$	$g_{\text{CP},t}$	$g_{\text{De},t}$	$g_{\text{CP},t}$	$g_{\text{De},t}$
$g_{\text{CP},t-1}$	0.028	−0.048	0.170	0.047	−0.166**	0.012
	(0.062)	(0.034)	(0.113)	(0.039)	(0.054)	(0.016)
$g_{\text{De},t-1}$	0.567***	−0.603***	−0.225	−0.093	−0.154	−0.191***
	(0.114)	(0.062)	(0.325)	(0.113)	(0.183)	(0.053)
$g_{\text{CP},t-2}$	0.115	−0.042	0.097	−0.050	0.104	−0.069***
	(0.062)	(0.034)	(0.114)	(0.040)	(0.055)	(0.016)
$g_{\text{De},t-2}$	0.709***	−0.468***	−0.616	0.026	0.751***	−0.439***
	(0.122)	(0.067)	(0.323)	(0.112)	(0.175)	(0.050)
$g_{\text{CP},t-3}$	0.044	−0.017	−0.105	0.004	−0.029	0.007
	(0.062)	(0.034)	(0.114)	(0.040)	(0.056)	(0.016)
$g_{\text{De},t-3}$	0.554***	−0.525***	−0.105	−0.164	0.342	−0.336***
	(0.128)	(0.069)	(0.327)	(0.114)	(0.180)	(0.052)
$g_{\text{CP},t-4}$	0.021	−0.048	0.039	0.024	0.149**	−0.031*
	(0.062)	(0.034)	(0.110)	(0.038)	(0.054)	(0.016)
$g_{\text{De},t-4}$	0.117	−0.033	0.277	0.190	0.197	0.197***
	(0.122)	(0.066)	(0.319)	(0.111)	(0.183)	(0.053)
const	−0.172	0.367***	−0.078	0.195	−0.153	0.207***
	(0.105)	(0.057)	(0.318)	(0.111)	(0.115)	(0.033)
Observations	290	290	96	96	436	436
R^2	0.157	0.406	0.122	0.156	0.104	0.378
Adjusted R^2	0.133	0.389	0.042	0.078	0.087	0.367
Σ	2.347	−0.385	7.843	−0.972	4.228	−0.577
	−0.385	0.696	−0.972	0.949	−0.577	0.350
ρ	1	−0.301	1	−0.356	1	−0.475
	−0.301	1	−0.356	1	−0.475	1
Granger Causality	0.171	1.5E-09	0.595	0.303	1.4E-05	2.3E-05
a_t Ljung-Box $Q_2(10)$	0.014		0.686		2.8E-05	
$\tilde{a}_t$ Ljung-Box $Q_2(10)$	0.087		0.118		2.2E-05	

Note: *p<0.05; **p<0.01; ***p<0.001

Granger Causality is the p-value of excluding the variable. a_t Ljung-Box test is a portmanteau test for autocorrelation in residuals. $\tilde{a}_t = a_t/\sigma_t$ are standardized residuals. $\tilde{a}_t$ Ljung-Box test is a portmanteau test for heteroskedasticity in residuals.

based on 10 lags of a_t is 0.014, so we can reject the null hypothesis that residuals a_t have no autocorrelation at 5% significance level. However, because commercial banks have an incentive to exaggerate their deposits when they report their financial statements quarterly, including seasonal dummy variables (from lag 1 to lag 13) can raise adjusted R^2 in equation $g_{\text{CP},t}$ from 0.133 up to 0.213 and that in equation $g_{\text{De},t}$ from 0.389 to 0.540. The p-value of Ljung-Box test based on 10 lags of a_t jumps up from 0.014 to 0.243. In addition, the p-value of Ljung-Box test based on 10 lags of standardized residuals $\tilde{a}_t = a_t/\sigma_t$ rises from 0.087 to 0.270. Hence, considering seasonal effects, the fitted model has no autocorrelation and no heteroskedasticity in the pre-crisis[36]. The VAR(4) may also be correctly fitted in the crisis given large enough p-values of Ljung-Box tests based on a_t and $\tilde{a}_t$. By contrast, the residuals a_t are not well-behaved in the post-crisis. There may exist missing variables that should be included in the model. Another possible reason is the model structure has changed for the time span of the post-crisis. The post-crisis has 440 data points across more than 8 years. I treat it as normal times in this section, but the dynamic correlation between deposits and financial CP outstanding still breaks down in some periods of the post-crisis[37]. Anyway, no crisis after 2009 is as prominent as the Great Recession. Hence, in this section, I ignore the possible structural change in the post-crisis. The correlation coefficients between a_{1t} and a_{2t} are -0.301, -0.356 and -0.475 in the three time windows. They further demonstrate that Prediction 1 is true all the time though they are larger than what we get in Table 8. The change of deposits and the change of financial CP outstanding are concurrently negatively correlated.

In the pre-crisis, except for the intercept, only coefficients of the growth rate of deposits are significant. For equation $g_{\text{CP},t}$, the coefficients of $g_{\text{De},t-1}$, $g_{\text{De},t-2}$ and $g_{\text{De},t-3}$ are significantly positive. Hence, an increase in deposits leads to an increase in financial CP outstanding in the following one to three weeks, and shadow banks have enough time to rebuild the liquidity. It is worth mentioning that the dynamic correlation is unidirectional. The change of financial CP is affected by the past movements of the change of deposits. However, past movements of the change of financial

[36]The estimation results of VAR(4) models with seasonal dummy variables are given if request. Qualitative results do not change.

[37]For details, see Section 4.

CP outstanding do not significantly affect the change of deposits, even though the two series have substantial concurrent negative correlation. From the Granger causality tests, we can also see that the change of deposits Granger causes that of financial CP outstanding, but the change of latter does not Granger cause that of deposits. Hence, commercial banks dominate the market in the pre-crisis.

In the crisis, no coefficient is significant at all. Actually, according to the F-test of the whole model (not reported in Table 9), two equations about $g_{\text{CP},t}$ and $g_{\text{De},t}$ are not significant. Hence, no dynamic correlation between deposits and financial CP outstanding exists. The liquidity backup shown by the link ④ in the FTQ circle breaks down.

In the post-crisis, the dynamic correlation between deposits and financial CP outstanding emerges again. For equation $g_{\text{CP},t}$, the coefficient of $g_{\text{De},t-2}$ is significantly positive. Hence, an increase in deposits leads to an increase in financial CP outstanding in the following two weeks. The dynamic correlation is not unidirectional anymore although the significant coefficients of the change of financial CP outstanding on the change of deposits are relatively small (-0.069 and -0.031).

In summary, Prediction 2 is also proved by the results of VAR(4) models.

3.3 Other Variables of Commercial Banks

In this subsection, I estimate VAR(4) models for some other variables of commercial banks and financial CP outstanding. On the liability side, besides deposits, large time deposits are also an interesting variable. They are uncovered by deposit insurance. During the Great Recession, the volume of large time deposits decreased like financial CP. Thus, I expect the concurrent negative correlation between large time deposits and financial CP outstanding still exists but weaker than deposits, given that commercial banks and independent shadow banks are competitors. However, commercial banks are not willing to use the increase in large time deposits as the liquidity backup to shadow banks because of the high risks. The dynamic correlation between large time deposits and financial CP outstanding does not exist all the time. On the asset side, I estimate VAR(4)

Table 10: VAR(4)s for Weekly Growth Rates of Large Time Deposits and Financial CP

	Pre-Crisis		*Crisis*		*Post-Crisis*	
	$g_{\text{CP},t}$	$g_{\text{LTDe},t}$	$g_{\text{CP},t}$	$g_{\text{LTDe},t}$	$g_{\text{CP},t}$	$g_{\text{LTDe},t}$
$g_{\text{CP},t-1}$	0.009	−0.013	0.245*	−0.045	−0.147**	0.037*
	(0.061)	(0.039)	(0.109)	(0.050)	(0.048)	(0.017)
$g_{\text{LTDe},t-1}$	0.144	−0.183**	0.242	0.115	−0.247	0.083
	(0.094)	(0.060)	(0.244)	(0.112)	(0.138)	(0.049)
$g_{\text{CP},t-2}$	0.043	0.031	0.083	−0.005	−0.016	−0.004
	(0.060)	(0.038)	(0.108)	(0.049)	(0.049)	(0.017)
$g_{\text{LTDe},t-2}$	0.236*	−0.157*	−0.660**	0.410***	0.221	0.067
	(0.094)	(0.061)	(0.235)	(0.108)	(0.138)	(0.049)
$g_{\text{CP},t-3}$	−0.036	0.031	−0.193	0.012	−0.078	−0.012
	(0.060)	(0.038)	(0.107)	(0.049)	(0.049)	(0.017)
$g_{\text{LTDe},t-3}$	0.219*	−0.150*	−0.327	−0.249*	0.003	0.050
	(0.095)	(0.061)	(0.238)	(0.109)	(0.138)	(0.049)
$g_{\text{CP},t-4}$	0.014	−0.023	0.078	0.038	0.141**	−0.022
	(0.060)	(0.039)	(0.107)	(0.049)	(0.048)	(0.017)
$g_{\text{LTDe},t-4}$	−0.202*	0.172**	0.583*	0.088	0.277*	0.077
	(0.095)	(0.061)	(0.247)	(0.113)	(0.137)	(0.049)
const	0.036	0.244***	−0.198	0.017	−0.016	−0.018
	(0.104)	(0.067)	(0.280)	(0.128)	(0.101)	(0.036)
Observations	290	290	96	96	436	436
R^2	0.075	0.127	0.179	0.260	0.068	0.041
Adjusted R^2	0.049	0.102	0.103	0.192	0.050	0.023
Σ	2.575	−0.321	7.338	−1.102	4.397	−0.247
	−0.321	1.061	−1.102	1.542	−0.247	0.551
ρ	1	−0.194	1	−0.328	1	−0.159
	−0.194	1	−0.328	1	−0.159	1

Note: *p<0.05; **p<0.01; ***p<0.001

Table 11: VAR(4)s for Weekly Growth Rates of Cash and Financial CP

	Pre-Crisis		*Crisis*		*Post-Crisis*	
	$g_{\text{CP},t}$	$g_{\text{Cash},t}$	$g_{\text{CP},t}$	$g_{\text{Cash},t}$	$g_{\text{CP},t}$	$g_{\text{Cash},t}$
$g_{\text{CP},t-1}$	0.009	0.009	0.227*	0.173	−0.140**	0.047
	(0.059)	(0.203)	(0.106)	(0.304)	(0.050)	(0.093)
$g_{\text{Cash},t-1}$	0.062***	−0.826***	0.010	−0.356***	−0.033	−0.277***
	(0.017)	(0.058)	(0.036)	(0.104)	(0.027)	(0.050)
$g_{\text{CP},t-2}$	−0.001	0.314	0.135	0.044	0.021	0.043
	(0.058)	(0.201)	(0.106)	(0.306)	(0.050)	(0.094)
$g_{\text{Cash},t-2}$	0.067***	−0.505***	−0.058	0.073	0.074**	−0.214***
	(0.020)	(0.067)	(0.038)	(0.109)	(0.027)	(0.050)
$g_{\text{CP},t-3}$	−0.038	−0.411*	−0.141	−0.309	−0.091	0.319***
	(0.059)	(0.203)	(0.106)	(0.305)	(0.050)	(0.093)
$g_{\text{Cash},t-3}$	0.100***	−0.586***	−0.013	0.042	−0.020	−0.147**
	(0.019)	(0.067)	(0.038)	(0.109)	(0.027)	(0.051)
$g_{\text{CP},t-4}$	0.090	−0.684***	0.047	−0.632*	0.126*	−0.072
	(0.059)	(0.204)	(0.105)	(0.303)	(0.050)	(0.093)
$g_{\text{Cash},t-4}$	0.068***	−0.248***	0.062	0.157	−0.011	0.095
	(0.017)	(0.058)	(0.036)	(0.104)	(0.026)	(0.049)
const	0.114	−0.066	−0.193	0.942	−0.026	0.270
	(0.093)	(0.321)	(0.304)	(0.877)	(0.101)	(0.188)
Observations	290	290	96	96	436	436
R^2	0.110	0.513	0.128	0.233	0.079	0.167
Adjusted R^2	0.085	0.500	0.048	0.163	0.061	0.151
Σ	2.478	−1.137	7.790	−1.806	4.345	−2.206
	−1.137	29.342	−1.806	64.612	−2.206	15.189
ρ	1	−0.133	1	−0.081	1	−0.272
	−0.133	1	−0.081	1	−0.272	1

Note: *p<0.05; **p<0.01; ***p<0.001

Table 12: VAR(4)s for Weekly Growth Rates of Liquid Assets and Financial CP

	Pre-Crisis		*Crisis*		*Post-Crisis*	
	$g_{\text{CP},t}$	$g_{\text{LAsset},t}$	$g_{\text{CP},t}$	$g_{\text{LAsset},t}$	$g_{\text{CP},t}$	$g_{\text{LAsset},t}$
$g_{\text{CP},t-1}$	0.015	0.072	0.253*	0.004	−0.140**	0.032
	(0.060)	(0.065)	(0.106)	(0.091)	(0.050)	(0.037)
$g_{\text{LAsset},t-1}$	0.108	−0.531***	0.205	−0.271*	−0.067	−0.279***
	(0.055)	(0.060)	(0.121)	(0.104)	(0.070)	(0.051)
$g_{\text{CP},t-2}$	−0.018	0.130*	0.135	0.001	0.037	−0.006
	(0.059)	(0.064)	(0.107)	(0.092)	(0.051)	(0.037)
$g_{\text{LAsset},t-2}$	0.082	−0.312***	−0.170	0.097	0.225**	−0.261***
	(0.059)	(0.064)	(0.121)	(0.104)	(0.070)	(0.051)
$g_{\text{CP},t-3}$	−0.032	−0.075	−0.167	−0.244**	−0.094	0.118**
	(0.060)	(0.065)	(0.106)	(0.092)	(0.050)	(0.037)
$g_{\text{LAsset},t-3}$	0.262***	−0.388***	−0.086	0.035	−0.029	−0.162**
	(0.059)	(0.064)	(0.120)	(0.103)	(0.071)	(0.051)
$g_{\text{CP},t-4}$	0.043	−0.044	0.093	−0.153	0.126*	−0.034
	(0.060)	(0.065)	(0.107)	(0.092)	(0.050)	(0.037)
$g_{\text{LAsset},t-4}$	0.099	−0.011	0.184	0.185	−0.018	0.073
	(0.056)	(0.061)	(0.119)	(0.102)	(0.068)	(0.049)
const	0.064	0.172	−0.231	0.243	−0.042	0.258***
	(0.096)	(0.104)	(0.299)	(0.258)	(0.104)	(0.075)
Observations	290	290	96	96	436	436
R^2	0.084	0.329	0.151	0.212	0.082	0.178
Adjusted R^2	0.058	0.310	0.073	0.139	0.064	0.162
Σ	2.552	−0.409	7.590	−0.415	4.331	−0.959
	−0.409	3.003	−0.415	5.622	−0.959	2.284
ρ	1	−0.148	1	−0.064	1	−0.305
	−0.148	1	−0.064	1	−0.305	1

Note: *p<0.05; **p<0.01; ***p<0.001

Table 13: VAR(4)s for Weekly Growth Rates of Assets and Financial CP

	Pre-Crisis		*Crisis*		*Post-Crisis*	
	$g_{\text{CP},t}$	$g_{\text{Asset},t}$	$g_{\text{CP},t}$	$g_{\text{Asset},t}$	$g_{\text{CP},t}$	$g_{\text{Asset},t}$
$g_{\text{CP},t-1}$	0.003	0.010	0.216*	0.012	−0.154**	0.014
	(0.061)	(0.023)	(0.106)	(0.028)	(0.052)	(0.012)
$g_{\text{Asset},t-1}$	0.419*	−0.412***	−0.049	−0.095	−0.426	−0.223***
	(0.165)	(0.061)	(0.416)	(0.111)	(0.224)	(0.051)
$g_{\text{CP},t-2}$	0.012	0.027	0.098	−0.003	0.064	−0.024*
	(0.061)	(0.023)	(0.107)	(0.029)	(0.052)	(0.012)
$g_{\text{Asset},t-2}$	0.515**	−0.195**	−1.111**	0.295**	0.889***	−0.295***
	(0.173)	(0.064)	(0.417)	(0.111)	(0.219)	(0.050)
$g_{\text{CP},t-3}$	−0.040	0.029	−0.129	−0.002	−0.072	0.025*
	(0.061)	(0.023)	(0.106)	(0.028)	(0.052)	(0.012)
$g_{\text{Asset},t-3}$	0.583***	−0.267***	−0.023	0.060	0.130	−0.274***
	(0.173)	(0.064)	(0.423)	(0.113)	(0.222)	(0.050)
$g_{\text{CP},t-4}$	0.036	−0.018	0.103	−0.0002	0.153**	−0.021
	(0.061)	(0.023)	(0.104)	(0.028)	(0.051)	(0.011)
$g_{\text{Asset},t-4}$	0.178	0.053	1.228**	0.100	0.191	0.165**
	(0.166)	(0.061)	(0.419)	(0.112)	(0.222)	(0.050)
const	−0.141	0.266***	−0.196	0.092	−0.076	0.119***
	(0.118)	(0.044)	(0.304)	(0.081)	(0.107)	(0.024)
Observations	290	290	96	96	436	436
R^2	0.067	0.243	0.189	0.133	0.108	0.268
Adjusted R^2	0.040	0.222	0.115	0.053	0.091	0.254
Σ	2.598	−0.229	7.244	−0.566	4.208	−0.360
	−0.229	0.357	−0.566	0.518	−0.360	0.216
ρ	1	−0.238	1	−0.292	1	−0.378
	−0.238	1	−0.292	1	−0.378	1

Note: *p<0.05; **p<0.01; ***p<0.001

models for cash, liquid assets and (total) assets with financial CP outstanding respectively[38]. When investors make deposits from commercial banks, on one hand, deposits are the debt of commercial banks. On the other hand, deposits are the cash of commercial banks if they keep the cash on hand. If I replace deposits with cash in the VAR(4) models, I should have the same qualitative results as Table 9. It means in a week, when there is an increase in deposits, commercial banks would keep the deposits as cash on hand but not lend them. In the following weeks, the cash goes to shadow banks if no crisis happens. If within one week, cash does not increase when there is an increase in deposits, my story is not valid even though the fact of two predictions exists in deposits. I calculate the growth rates as follows:

$$g_{\text{LTDe},t} = \ln(\frac{\text{Large Time Deposit}_t}{\text{Large Time Deposit}_{t-1}}) * 100; \quad g_{\text{Cash},t} = \frac{\text{Cash}_t}{\text{Cash}_{t-1}} * 100;$$

$$g_{\text{LAsset},t} = \ln(\frac{\text{Liquid Asset}_t}{\text{Liquid Asset}_{t-1}}) * 100; \quad g_{\text{Asset},t} = \frac{\text{Asset}_t}{\text{Asset}_{t-1}} * 100;$$

Table 10 shows the regression results for large time deposits. As we expected, the concurrent correlation between the change of large time deposits and that of financial CP outstanding is still negative all the time, although they are weaker than the case of deposits. The dynamic correlation is more subtle. In the crisis, an increase in large time deposits can even lead to a decrease in financial CP outstanding. It could be the liquidity spirals (Brunnermeier and Pedersen (2008)). In normal times, we can see the change of commercial banks' attitudes towards large time deposits. In the pre-crisis, liquidity backup from large time deposits happens in two or three weeks, but in the post-crisis, it only happens in four weeks. Commercial banks are more prudent to offer liquidity backup that comes from the increase in large time deposits. After the Great Recession, commercial banks realize that large time deposits possess more liquidity risks than they thought before.

From Table 11 and Table 12, we can see the results for cash and liquid assets are similar to the case of deposits in normal times. Regression results (not reported in the paper) also show that the change of cash and that of deposits have strong positive concurrent correlation within one

[38]Liquid assets include cash and securities.

week. Hence, within one week, commercial banks keep most increment of deposits as cash on hand. Things change in the crisis. Not only $g_{\text{Cash},t}$ and $g_{\text{LAsset},t}$ do not Granger cause $g_{\text{CP},t}$, but also absolute values of correlation coefficients of residuals are relatively small with -0.081 from residuals of $g_{\text{Cash},t}$ and $g_{\text{CP},t}$, and -0.064 from residuals of $g_{\text{LAsset},t}$ and $g_{\text{CP},t}$. For (total) assets, the correlation coefficient of residuals of $g_{\text{Asset},t}$ and $g_{\text{CP},t}$ is -0.292, and it is nearly as low as the case of deposits. Within one week, which is a relatively short term, when there is a decrease in financial CP outstanding, there is an increase in deposits, and total assets also have to keep up with the corresponding change of deposits because of the accounting equation. However, commercial banks may no longer keep the increase in deposits as cash or liquid asset on hand within one week given the relatively insignificant concurrent correlations shown before.

3.4 Robustness Tests

To simplify the analysis, I only include two endogenous variables in VAR(4) models before. Although the residuals are well-behaved, potentially omitted variables are worth further studies in case I ignore some possible crucial relations. In this subsection, I estimate VAR(4) models with three endogenous variables: the growth rate of deposits ($g_{\text{De},t}$), the growth rate of financial CP outstanding ($g_{\text{CP},t}$) and one of the potentially omitted variables. The potentially omitted variables considered in this paper are about interest rates. If deposits and financial CP outstanding are sales quantities of commercial and shadow banking financing products, interest rates are prices. Because different commercial banks have different interest rates, and there are different kinds of deposits, it is difficult to find a proxy for interest rates of total deposits. I first consider the 3-month T-Bill rate as the potentially omitted variable. T-Bills are similar to covered deposits in that they are default risk-free fixed-income products. If commercial banks match the interest rates of their deposits against the T-Bill rate, an increase in the T-Bill rate could lead to an increase in deposits. In weekly data, T-Bills and deposits are more likely substitutes. Hence, I expect an increase in the T-Bill rate to lead to a decrease in deposits. Next, the spread (Paper-TBill) between the 3-month AA-rated financial CP rate and the 3-month T-Bill rate could possibly explain the change of financial CP

Table 14: Robustness Tests for Omitted Variables

	Potentially Omitted Variable (top row)	*Pre-Crisis* Granger	*Pre-Crisis* Instant	*Crisis* Granger	*Crisis* Instant	*Post-Crisis* Granger	*Post-Crisis* Instant
(1)	$\Delta_{\text{T-Bill},t}$	0.753	0.858	**2.397**	5.234	1.558	4.074
		(0.645)	(0.651)	(0.017)	(0.073)	(0.133)	(0.130)
	$g_{\text{De},t}$	**6.893**	**23.799**	1.339	**13.540**	**3.437**	**82.149**
		(8.3E-09)	(6.8E-06)	(0.225)	(0.001)	(0.001)	(2.2E-16)
(2)	$\Delta_{\text{Paper-TBill},t}$	0.630	0.843	**2.444**	**10.507**	0.264	0.006
		(0.753)	(0.656)	(0.015)	(0.005)	(0.977)	(0.997)
	$g_{\text{De},t}$	**8.057**	**24.525**	1.113	**8.040**	**4.157**	**80.412**
		(1.6E-10)	(4.7E-06)	(0.355)	(0.018)	(6.4E-05)	(2.2E-16)
(3)	$\Delta_{\text{Libor-OIS},t}$	**2.751**	1.860	**2.806**	**15.928**	0.579	3.384
		(0.005)	(0.395)	(0.005)	(3.5E-04)	(0.796)	(0.184)
	$g_{\text{De},t}$	**6.694**	**20.659**	0.756	**18.705**	**3.752**	**82.330**
		(1.6E-08)	(3.3E-05)	(0.642)	(8.7E-05)	(2.4E-04)	(2.2E-16)
(4)	$\Delta_{\text{OIS-TBill},t}$	1.132	1.034	**3.169**	3.655	0.757	1.902
		(0.339)	(0.596)	(0.002)	(0.161)	(0.641)	(0.386)
	$g_{\text{De},t}$	**7.220**	**24.069**	1.397	**10.098**	**3.562**	**81.879**
		(2.8E-09)	(5.9E-06)	(0.198)	(0.006)	(4.3E-04)	(2.2E-16)

Granger and Instantaneous causality tests for VAR(4)s with three endogenous variables: the growth rate of deposits ($g_{\text{De},t}$), the growth rate of financial CP outstanding ($g_{\text{CP},t}$) and one of the potentially omitted variables. The potential omitted variables are (1) $\Delta_{\text{T-Bill},t}$: the weekly change in the 3-month T-Bill rate; (2) $\Delta_{\text{Paper-TBill},t}$: the weekly change in the spread between the 3-month AA-rated financial CP rate and the 3-month T-Bill rate; (3) $\Delta_{\text{Libor-OIS},t}$: the weekly change in spread between the 3-month London inter-bank offered rate and the 3-month overnight indexed swap rate; (4) $\Delta_{\text{OIS-TBill},t}$: the weekly change in the spread between the 3-month overnight indexed swap rate and the 3-month T-Bill rate. The table reports the F-Test statistics and p-values (in parentheses) testing the null that the variable on the left side does not Granger cause the other two variables in Granger columns. In addition, it also reports the χ^2 statistics and p-values (in parentheses) testing the null that the variable on the left side does not instantaneously cause the other two variables in Instant columns. All statistics that are significant at the 5% significance level are in bold.

outstanding. An increase in the Paper-TBill spread means not only a higher return rate but also higher liquidity and potential credit risks in the investment of financial CP. If investors perceive the return more than risks, then a positive concurrent or dynamic correlation may exist between the change of spread and $g_{\text{CP},t}$. In the other case, if the large spread is offered by shadow banks when they have difficulties in rolling over their debt, then it reflects more about the liquidity and potential credit risks.

In addition to the T-Bill rate and the Paper-TBill spread, risks in the whole banking sector are also crucial to the transfer of funds between deposits and financial CP. Intuitively, when the risks increase, investors prefer to invest more in deposits and less in financial CP, and vice versa. In most of the literature, the spread (a.k.a. TED spread) between the 3-month London inter-bank offered (henceforth, Libor) rate and the 3-month T-Bill rate is used as the proxy for the risks. In this paper, I further subdivide the TED spread into two parts: (1) the spread (Libor-OIS) between the 3-month Libor rate and the 3-month overnight indexed swap (henceforth, OIS) rate which is a proxy for credit risks; (2) the spread (OIS-TBill) between 3-month OIS rate and the 3-month T-Bill rate which is a proxy for liquidity risks.

In order to save space, I first report Granger and Instantaneous causality tests for VAR(4)s that include one more potentially omitted variable respectively in Table 14. If an omitted variable indeed significantly influences $g_{\text{De},t}$ and $g_{\text{CP},t}$, I report detailed results of regressions including the variable next. Statistics and p-values (in parentheses) testing the null that the variable on the left side does not Granger or instantaneously cause the other two variables are shown in Table 14[39]. The Granger causality tests check the significance of dynamic correlations, and the Instantaneous causality tests check that of concurrent correlations. From Table 14, we can see the concurrent correlation between the growth rate of deposits and the growth rate of financial CP outstanding in Prediction 1 always exists, even if I include one of the potentially omitted variables in the VAR(4) models[40]. Besides, the dynamic correlation between the growth rate of deposits and the growth

[39] I also test the effective federal funds rate, which is a proxy for the interest rate of deposits, to see if it is a potentially omitted variable. However, it is insignificant all the time and has almost no effect on deposits and financial CP outstanding. I drop it to save space.

[40] In this paper, I use first differences but not log-difference growth rates for all interest rates because some interest

rate of financial CP outstanding exists in normal times but breaks down in the crisis like Prediction 2 after I consider the potentially omitted variables.

Except for the Libor-OIS spread, no potentially omitted variable has significant dynamic or concurrent correlations with $g_{\text{De},t}$ and $g_{\text{CP},t}$ in normal times, but they are indeed worth being included in the models when the crisis happens. In normal times, the prices of deposits and financial CP, and the liquidity risks in the banking sector are totally endogenously decided by $g_{\text{De},t}$ and $g_{\text{CP},t}$. The credit risks in the banking sector (Libor-OIS spread) have significant dynamic explanatory power in the pre-crisis, but the power disappears in the post-crisis. By contrast, the potentially omitted variables are exogenously decided in the crisis. From Figure 6, we can see that spreads widen in the crisis, and it is very likely unexpected to commercial banks and shadow banks. Hence, all potentially omitted variables have explanatory power in the crisis.

Table 15 shows the estimation results of VAR(4) that includes the Libor-OIS spread in the pre-crisis. As we expected, an increase in the credit risks of the banking sector leads to an increase in deposits and a decrease in financial CP outstanding in two weeks. The results of VAR(4)s include each potentially omitted variable in the crisis are reported in Table 16, 17, 18, and 19 respectively. During the Great Recession, $g_{\text{De},t}$ and $\Delta_{\text{T-Bill},t}$ are concurrently negatively correlated, and an increase in T-Bill rates leads to an increase in financial CP outstanding and a decrease in deposits, since deposits and T-Bills are substitutes. $g_{\text{CP},t}$ and $\Delta_{\text{Paper-TBill},t}$ are concurrently negatively correlated, and an increase in Paper-TBill spread leads to a decrease in financial CP outstanding. It proves that in the crisis, shadow banks have difficulties to reissue their financial CP even if they offer high additional interest rates. Investors perceive the high additional return of financial CP as high risks. Finally, investors transfer their funds from financial CP to deposits when the banking sector has increases in credit risks (Libor-OIS spread) and liquidity risks (OIS-TBill spread) in the crisis. As to concurrent correlations, $\Delta_{\text{Libor-OIS},t}$ is negatively correlated with $g_{\text{CP},t}$ and positively correlated with $g_{\text{De},t}$, but $\Delta_{\text{OIS-TBill},t}$ is only positively correlated with $g_{\text{De},t}$. Hence, investors do not think liquidity risks have an instant negative influence on financial CP like credit risks.

rates are negative. Qualitative results do not change if I first add a constant value to interest rates and then transform them into log-difference growth rates.

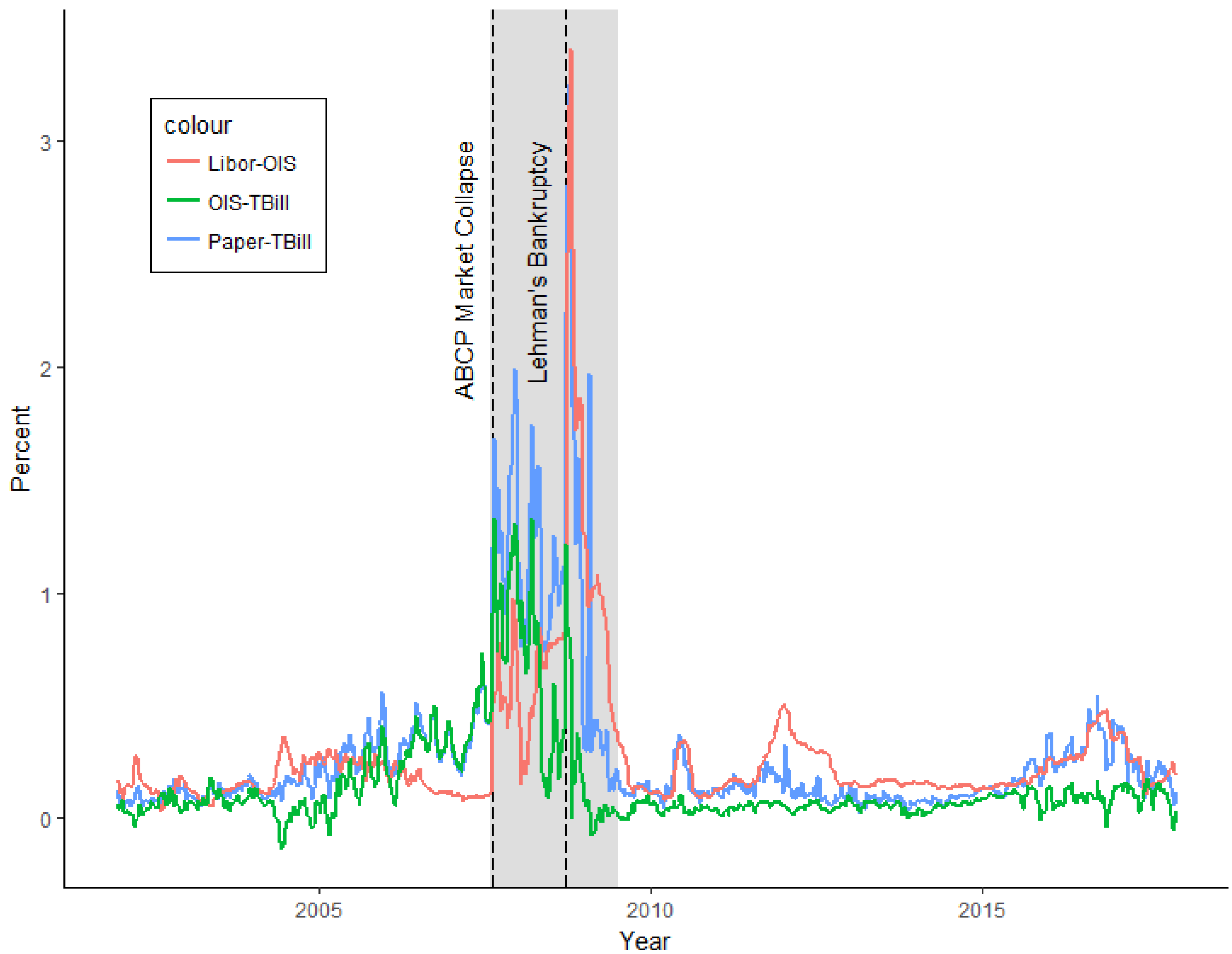

Figure 6: The Spreads

The figure shows the spreads from Dec. 12, 2001, through Nov. 29, 2017. Paper-TBill: the spread between the 3-month AA-rated financial CP rates and the 3-month T-Bill rates. Libor-OIS: the spread between the 3-month London inter-bank offered rates and the 3-month overnight indexed swap rates. OIS-TBill: the spread between the 3-month overnight indexed swap rates and the 3-month T-Bill rates. The gray-shaded area is the time period of the Great Recession (from Aug. 1, 2007, to Jun. 24, 2009). The ABCP market collapse was Aug. 9, 2007. Lehman's bankruptcy was Sep. 15, 2008. Source: Federal Reserve's CP release, Bloomberg, U.S. Treasury.

Table 15: VAR(4) Includes the Libor-OIS Spread in the Pre-Crisis

	Pre-Crisis		
	$g_{\text{CP},t}$	$g_{\text{De},t}$	$\Delta_{\text{Libor-OIS},t}$
$g_{\text{CP},t-1}$	0.019	−0.035	−0.001
	(0.063)	(0.034)	(0.001)
$g_{\text{De},t-1}$	0.593***	−0.635***	−0.003*
	(0.116)	(0.062)	(0.001)
$\Delta_{\text{Libor-OIS},t-1}$	−3.271	2.329	0.299***
	(5.293)	(2.840)	(0.058)
$g_{\text{CP},t-2}$	0.092	−0.027	0.0001
	(0.063)	(0.034)	(0.001)
$g_{\text{De},t-2}$	0.717***	−0.493***	−0.001
	(0.127)	(0.068)	(0.001)
$\Delta_{\text{Libor-OIS},t-2}$	−13.449*	8.093**	−0.039
	(5.486)	(2.944)	(0.061)
$g_{\text{CP},t-3}$	0.029	−0.005	0.0001
	(0.062)	(0.033)	(0.001)
$g_{\text{De},t-3}$	0.539***	−0.527***	0.001
	(0.132)	(0.071)	(0.001)
$\Delta_{\text{Libor-OIS},t-3}$	2.372	4.006	−0.165**
	(5.566)	(2.987)	(0.061)
$g_{\text{CP},t-4}$	0.025	−0.047	0.001*
	(0.062)	(0.033)	(0.001)
$g_{\text{De},t-4}$	0.123	−0.035	0.001
	(0.123)	(0.066)	(0.001)
$\Delta_{\text{Libor-OIS},t-4}$	−5.027	1.455	−0.133*
	(5.360)	(2.876)	(0.059)
const	−0.176	0.375***	0.00004
	(0.106)	(0.057)	(0.001)
Observations	290	290	290
R^2	0.183	0.441	0.217
Adjusted R^2	0.148	0.417	0.183
	1	−0.275	−0.072
ρ	−0.275	1	−0.015
	−0.072	−0.015	1

Note: *p<0.05; **p<0.01; ***p<0.001

Table 16: VAR(4) Includes the T-Bill Rate in the Crisis

	Crisis		
	$g_{\text{CP},t}$	$g_{\text{De},t}$	$\Delta_{\text{T-Bill},t}$
$g_{\text{CP},t-1}$	0.166	0.054	−0.014
	(0.114)	(0.039)	(0.009)
$g_{\text{De},t-1}$	−0.376	−0.102	−0.017
	(0.343)	(0.116)	(0.026)
$\Delta_{\text{T-Bill},t-1}$	0.591	0.416	−0.057
	(1.424)	(0.481)	(0.107)
$g_{\text{CP},t-2}$	0.139	−0.035	−0.008
	(0.116)	(0.039)	(0.009)
$g_{\text{De},t-2}$	−0.424	−0.047	-0.057^{*}
	(0.340)	(0.115)	(0.025)
$\Delta_{\text{T-Bill},t-2}$	3.532^{*}	-1.351^{**}	−0.153
	(1.393)	(0.471)	(0.104)
$g_{\text{CP},t-3}$	−0.094	0.002	−0.005
	(0.114)	(0.038)	(0.009)
$g_{\text{De},t-3}$	−0.063	−0.145	−0.005
	(0.332)	(0.112)	(0.025)
$\Delta_{\text{T-Bill},t-3}$	−1.413	−0.463	0.052
	(1.453)	(0.491)	(0.109)
$g_{\text{CP},t-4}$	0.063	0.003	0.004
	(0.110)	(0.037)	(0.008)
$g_{\text{De},t-4}$	0.420	0.104	−0.022
	(0.323)	(0.109)	(0.024)
$\Delta_{\text{T-Bill},t-4}$	0.187	−0.947	−0.083
	(1.473)	(0.498)	(0.110)
const	0.029	0.110	−0.033
	(0.326)	(0.110)	(0.024)
Observations	96	96	96
R^2	0.196	0.270	0.127
Adjusted R^2	0.079	0.165	0.0003
	1	−0.337	0.026
ρ	−0.337	1	−0.233
	0.026	−0.233	1

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 17: VAR(4) Includes the Paper-TBill Spread in the Crisis

	Crisis		
	$g_{\text{CP},t}$	$g_{\text{De},t}$	$\Delta_{\text{Paper-TBill},t}$
$g_{\text{CP},t-1}$	0.004	0.087*	0.020
	(0.118)	(0.044)	(0.015)
$g_{\text{De},t-1}$	−0.104	−0.111	0.064
	(0.306)	(0.113)	(0.039)
$\Delta_{\text{Paper-TBill},t-1}$	−2.324*	0.657	−0.068
	(0.895)	(0.332)	(0.114)
$g_{\text{CP},t-2}$	0.048	−0.041	−0.008
	(0.120)	(0.045)	(0.015)
$g_{\text{De},t-2}$	−0.496	−0.012	0.049
	(0.306)	(0.113)	(0.039)
$\Delta_{\text{Paper-TBill},t-2}$	−3.034**	0.470	−0.055
	(0.899)	(0.333)	(0.114)
$g_{\text{CP},t-3}$	−0.077	0.008	0.032*
	(0.114)	(0.042)	(0.014)
$g_{\text{De},t-3}$	−0.024	−0.183	0.014
	(0.306)	(0.113)	(0.039)
$\Delta_{\text{Paper-TBill},t-3}$	−1.163	0.286	0.108
	(0.947)	(0.352)	(0.120)
$g_{\text{CP},t-4}$	0.135	0.006	−0.002
	(0.110)	(0.041)	(0.014)
$g_{\text{De},t-4}$	0.436	0.168	0.027
	(0.300)	(0.111)	(0.038)
$\Delta_{\text{Paper-TBill},t-4}$	0.690	0.087	−0.023
	(0.914)	(0.339)	(0.116)
const	−0.236	0.234*	−0.034
	(0.302)	(0.112)	(0.038)
Observations	96	96	96
R^2	0.276	0.208	0.130
Adjusted R^2	0.171	0.093	0.004
	1	−0.301	−0.349
ρ	−0.301	1	0.077
	−0.349	0.077	1

Note: *p<0.05; **p<0.01; ***p<0.001

Table 18: VAR(4) Includes the Libor-OIS Spread in the Crisis

	Crisis		
	$g_{\text{CP},t}$	$g_{\text{De},t}$	$\Delta_{\text{Libor-OIS},t}$
$g_{\text{CP},t-1}$	0.081	0.051	-0.016^{*}
	(0.111)	(0.041)	(0.007)
$g_{\text{De},t-1}$	0.371	-0.225	0.003
	(0.336)	(0.125)	(0.020)
$\Delta_{\text{Libor-OIS},t-1}$	-6.873^{**}	1.754^{*}	0.462^{***}
	(2.065)	(0.770)	(0.122)
$g_{\text{CP},t-2}$	-0.020	-0.023	0.00001
	(0.119)	(0.044)	(0.007)
$g_{\text{De},t-2}$	-0.128	-0.033	0.008
	(0.337)	(0.126)	(0.020)
$\Delta_{\text{Libor-OIS},t-2}$	-2.745	-0.087	0.025
	(2.214)	(0.825)	(0.131)
$g_{\text{CP},t-3}$	-0.121	0.007	0.009
	(0.119)	(0.044)	(0.007)
$g_{\text{De},t-3}$	-0.171	-0.135	-0.001
	(0.332)	(0.124)	(0.020)
$\Delta_{\text{Libor-OIS},t-3}$	3.360	-0.962	-0.220
	(2.206)	(0.822)	(0.130)
$g_{\text{CP},t-4}$	0.212	-0.008	0.001
	(0.115)	(0.043)	(0.007)
$g_{\text{De},t-4}$	0.270	0.174	0.028
	(0.312)	(0.116)	(0.018)
$\Delta_{\text{Libor-OIS},t-4}$	0.716	0.578	-0.053
	(1.952)	(0.728)	(0.115)
const	-0.304	0.234^{*}	-0.009
	(0.311)	(0.116)	(0.018)
Observations	96	96	96
R^2	0.291	0.217	0.415
Adjusted R^2	0.189	0.104	0.330
	1	-0.294	-0.186
ρ	-0.294	1	0.442
	-0.186	0.442	1

Note: *p<0.05; **p<0.01; ***p<0.001

Table 19: VAR(4) Includes the OIS-TBill Spread in the Crisis

	Crisis		
	$g_{\text{CP},t}$	$g_{\text{De},t}$	$\Delta_{\text{OIS-TBill},t}$
$g_{\text{CP},t-1}$	0.123	0.076*	0.009
	(0.112)	(0.038)	(0.007)
$g_{\text{De},t-1}$	−0.251	−0.117	0.005
	(0.333)	(0.113)	(0.020)
$\Delta_{\text{OIS-TBill},t-1}$	−2.346	−0.379	−0.103
	(1.689)	(0.576)	(0.103)
$g_{\text{CP},t-2}$	0.108	−0.026	0.009
	(0.115)	(0.039)	(0.007)
$g_{\text{De},t-2}$	−0.385	−0.037	0.046*
	(0.329)	(0.112)	(0.020)
$\Delta_{\text{OIS-TBill},t-2}$	−5.386**	1.901**	−0.142
	(1.664)	(0.567)	(0.102)
$g_{\text{CP},t-3}$	−0.081	0.004	0.005
	(0.113)	(0.038)	(0.007)
$g_{\text{De},t-3}$	−0.076	−0.124	−0.017
	(0.321)	(0.109)	(0.020)
$\Delta_{\text{OIS-TBill},t-3}$	−0.231	0.952	0.099
	(1.768)	(0.603)	(0.108)
$g_{\text{CP},t-4}$	0.128	−0.008	−0.0002
	(0.109)	(0.037)	(0.007)
$g_{\text{De},t-4}$	0.465	0.106	−0.003
	(0.310)	(0.106)	(0.019)
$\Delta_{\text{OIS-TBill},t-4}$	−1.938	1.238*	−0.118
	(1.784)	(0.608)	(0.109)
const	−0.197	0.243*	−0.015
	(0.308)	(0.105)	(0.019)
Observations	96	96	96
R^2	0.239	0.297	0.173
Adjusted R^2	0.129	0.196	0.053
	1	−0.290	−0.057
ρ	−0.290	1	0.199
	−0.057	0.199	1

Note: *p<0.05; **p<0.01; ***p<0.001

4 The Forecast Model: When Liquidity Backup Breaks Down

In Section 3, I mark out the time window of the Great Recession as the crisis in advance. The VAR(4) model for $g_{\text{De},t}$ and $g_{\text{CP},t}$ is not significant in the crisis. Although the crisis set has 100 data points, it still could be too small to have significant results. In this section, I do not presume the crisis times but let the data reveal them according to the FTQ circle. If my FTQ circle model is correct, when the liquidity backup of the blue link ④ breaks down, it is the time that markets have a crisis. How to find the specific time that the liquidity backup from commercial banks to shadow banks breaks down? The dynamic correlation between $g_{\text{De},t}$ and $g_{\text{CP},t}$ stemming from the blue link ④ can help improve the prediction of future financial CP outstanding in normal times. An increase in deposits leads to an increase in financial CP outstanding. Hence, to predict future financial CP outstanding, including the past value of deposits is more accurate than using the past value of financial CP outstanding alone. If including the past value of deposits cannot substantially increase the accuracy of the prediction of financial CP outstanding, it means the dynamic correlation breaks down, and it is the crisis time. I expect that the data will reveal the liquidity backup breaks down during the most time of the Great Recession beforehand, or the FTQ circle model may be wrong.

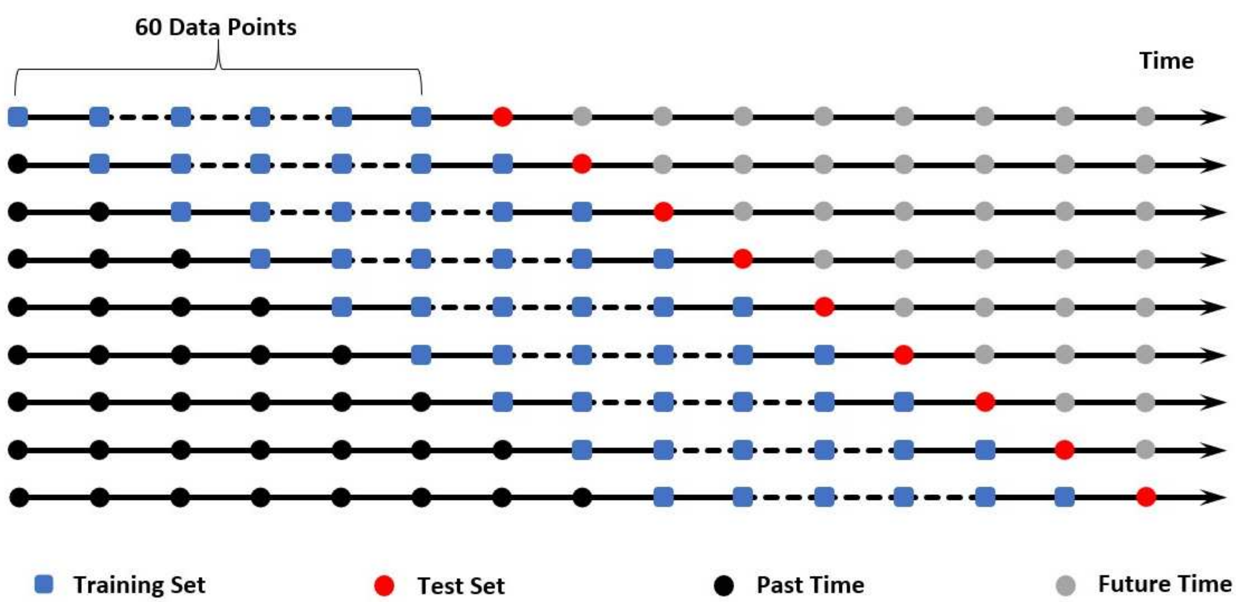

Figure 7: One-Step Forward-Chaining Cross-Validation

The time span I use to make predictions is longer than that I use to estimate the VAR(4) models in Section 3. I collect weekly data regarding deposits and financial CP outstanding from January 3, 2001, to January 16, 2019. Totally, there are 942 observations. Figure 7 shows the one-step forward-chaining cross-validation method I use to compare the prediction accuracy of different models. Each training set (blue squares) has 60 data points, and the corresponding test set (red circle) is the next observation after the training set. Hence, each model has to be estimated in total 882 training sets respectively, and the 882 fitted models are used to predict the 882 test sets. Finally, we have time series of 882 squared errors from the difference between the true value and the predicted value in test sets for each model, and they are the measure to judge the prediction accuracy of different models.

I set the size of training sets as fixed 60 data points even if there exist more historical data when we predict relatively recent test sets. Although including more data points in training sets can help estimate the yearly seasonality, the time series of squared errors will have a decreasing trend because more recent test sets have more data points in their corresponding training sets. To give a fair condition for each group of the training set and test set, I assume the 60 weeks Markov property. Given 60 weeks in each training set, I ignore the yearly seasonality. However, it does not undermine the analysis in this section because the goal of this section is not to find a model that can best predict weekly financial CP outstanding but justify including past deposits can improve the prediction in normal times.

For univariate models with only financial CP outstanding, a simple random walk with drift model regarding the log value can give a good prediction according to the mean squared error (henceforth, MSE) in test sets. Hence, the univariate model I use to predict financial CP outstanding is:

$$\text{Univariate Model:} \quad \ln(\text{Financial CP}_{t+1}) = d + \ln(\text{Financial CP}_t) + \epsilon_t$$

where ϵ_t is a normal i.i.d. error and financial CP outstanding is in million dollars. It is the same as we usually assume the price of a stock follows the geometric Brownian motion. Complicated univariate models like ARIMA-GARCH models or artificial neural networks models cannot substantially reduce the MSE. The multivariate model including deposits I use to predict financial CP outstanding is:

$$\text{Multivariate Model:} \quad \begin{cases} \ln(\text{Financial CP}_{t+1}) = d_1 + \ln(\text{Financial CP}_t) + \epsilon_{1t} + \\ \beta[\ln(\widehat{\text{Deposits}}_{t+1}) - \ln(\text{Deposits}_t)] \\ (1-\gamma_1 L^{13})[\ln(\text{Deposits}_{t+1}) - \ln(\text{Deposits}_t)] = d_2 + (1-\gamma_2 L^{13})\epsilon_{2t} \end{cases}$$

where ϵ_{1t} and ϵ_{2t} are normal i.i.d. errors, and deposits and financial CP outstanding are in million dollars. Compared to the univariate model, financial CP outstanding depends on not only the drift and its value in last week but also the predicted deposits ($\widehat{\text{Deposits}}_{t+1}$). The predicted deposits ($\widehat{\text{Deposits}}_{t+1}$) are estimated by a seasonal random walk with drift model. The quarterly (13 weeks) seasonality exists in deposits because commercial banks tend to exaggerate their deposits when they report their financial statements every quarter[41]. It is the reason I cannot use the VAR model to predict financial CP outstanding. Even seasonal VAR models cannot capture the seasonality in deposits like the univariate seasonal model for deposits. Admittedly, the seasonal random walk with drift model is not the best model to predict deposits. However, to achieve the goal in this section, it is enough and straightforward. I only need to test if including deposits and keeping all other things unchanged in the univariate model of financial CP outstanding can improve the prediction accuracy in normal times.

Figure 8 shows 40 weeks moving averages of squared errors for univariate and multivariate models. To make the MSE more readable, the squared error in Figure 8 is calculated as follows:

$$\text{Squared Error} = (\ln(\text{Financial CP}) - \ln(\widehat{\text{Financial}}\text{ CP}))^2 * 10000$$

where financial CP outstanding from test sets is in million dollars. Except for the four gray-shaded columns, the multivariate model has fewer MSEs than the univariate model as we expected, which means there exists a dynamic correlation between deposits and financial CP outstanding. The liq-

[41]Financial CP outstanding does not have quarterly seasonality alone.

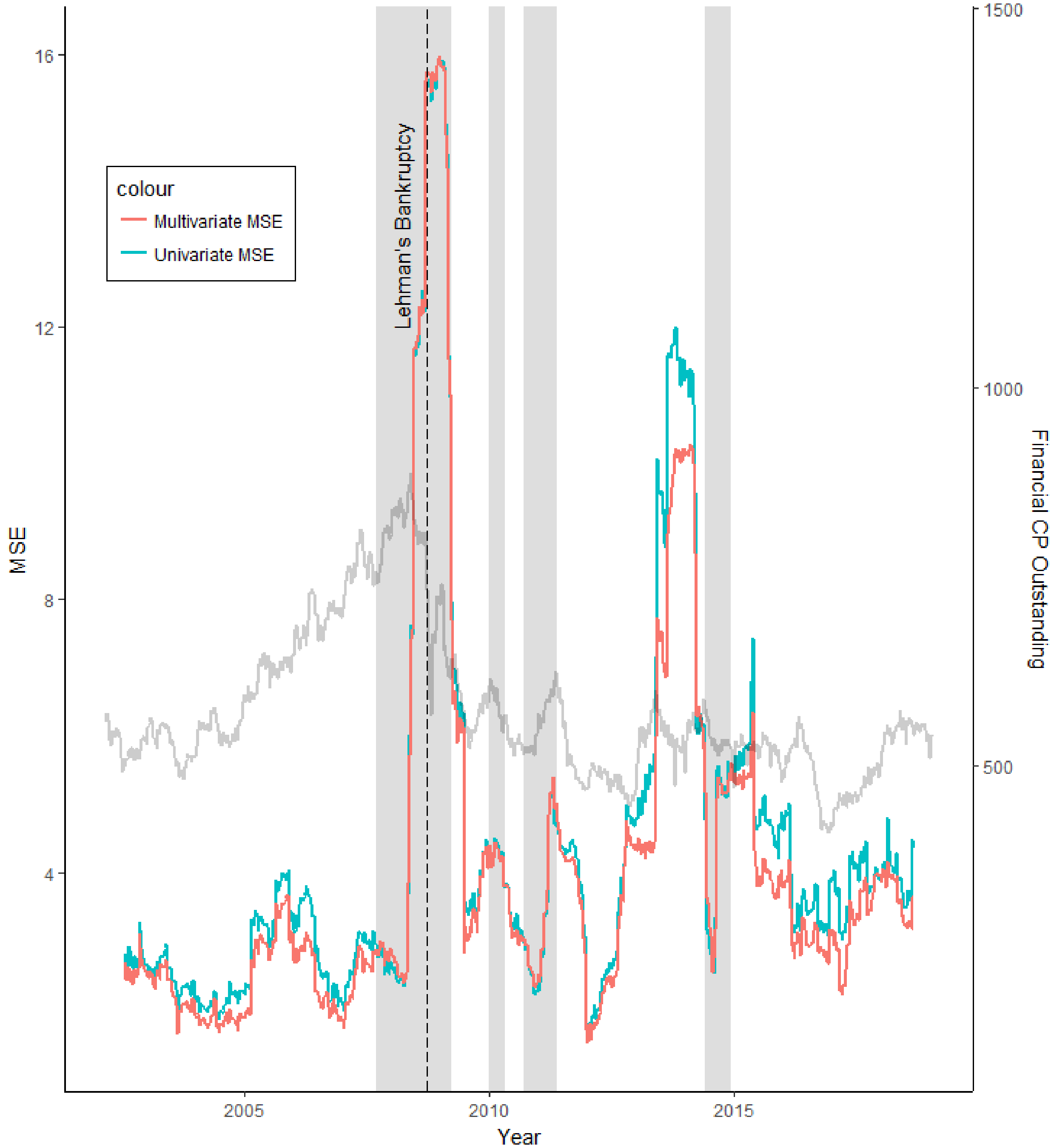

Figure 8: 40 Weeks Moving Averages of Squared Errors for Univariate and Multivariate Models

The figure shows 40 weeks moving averages of squared errors for univariate and multivariate models. The gray-shaded areas are the time periods when the multivariate MSE is larger the univariate MSE and therefore, the possible crisis times. The first gray column is from Sep. 2007 to Apr. 2009 (the Great Recession). The second and third gray columns are from Jan. 2010 to Apr. 2010 and from Sep. 2010 to May 2011, respectively (the European debt crisis). The fourth gray column is from Jun. 2014 to Nov. 2014 (2014 Oil price crash). Lehman's bankruptcy was Sep. 15, 2008. The gray line in the background is financial CP outstanding (billion dollars) for reference only.

uidity backup was broken from September 2007 to April 2009 first time as shown by the first gray column. It is almost the generally accepted time period of the Great Recession. The second and third gray columns are from January 2010 to April 2010 and from September 2010 to May 2011, respectively. We know the European sovereign debt crisis peaked between 2010 to 2011. Foreign financial institutions account for more than 75% of total financial CP outstanding after 2010 (Figure 4), and most of them are headquartered in Europe, so it is not hard to understand that U.S. commercial banks stop the liquidity backup from increased deposits to European financial institutions during the European debt crisis. According to my forecast model, there exists a mitigation gap between the second and third gray columns. Further studies need to check if the crisis truly mitigates between April 2010 to September 2010. The last gray column in Figure 8 is between June 2014 to November 2014. Crude oil prices (Brent or WTI) plunged more than 50% in this period. The more detailed reasons behind the breakdown of liquidity backup are still worth further studies.

The model in this section is not for the financial crisis forecast. Commercial banks change their strategies about the change of deposits when they realize a crisis is coming. Somehow, they can forecast the arrival of a potential crisis using their risk management models. In addition, the breakdown of liquidity backup does not necessarily result in the collapse of financial CP. We only observe the prominent collapse following the Lehman's Bankruptcy. Liquidity backup is a guarantee for investors' confidence. When it breaks down, a trigger such as a large impact of credit risks may set off the collapse of financial CP.

5 Concluding Remarks

During the Great Recession, not all funds flew out from the banking system. Deposits increased, but the volumes of all other short-term financing instruments decreased. Commercial banks that relied more heavily on core deposit and equity capital financing can still lend and purchase securitized assets compared to other banks. After the bankruptcy of Lehman Brothers, commercial banks kept the unprecedentedly increased deposits as cash on hand, which could be crucial liquidity backup for shadow banks (see Table 2). It may come from the counter-party risks or the first time ever interest on reserves offered by Federal Reserves. Or sometimes, commercial banks would rather squeeze their credit and acquire securitized assets at fire-sale price liquidated by shadow banks than offer liquidity backup to high risky counter-parties (Acharya, Shin, and Yorulmazer (2010)). Although there were unprecedented government bailouts after Lehman's bankruptcy, securitized assets have already been priced at extremely risk-averse preference from fixed-income investors. Using their securitized assets as collateral, shadow banks cannot raise enough funds like the time when securitized assets are in nearly risk-neutral pricing. No liquidity can arbitrage securitized assets back to nearly risk-neutral pricing, and even if any, it takes a too long time to go back, and survival could be a problem.

After the Great Recession, BHCs were potential winners and owned more and more shadow banking subsidiaries. Although the number of independent shadow banks decreased, we have the internal FTQ circle in BHCs. BHCs can enjoy the synergy by holding commercial banks and shadow banks together. However, deposits may not be enough for some BHCs to resist the next crisis. Funds will transfer from some BHCs to some other BHCs, and regulations should be able to stimulate BHCs with rich liquidity to help BHCs in trouble but not stand by and profit from the trouble. This paper also proposes that regulations should be concerned with not only sufficient capital but also sufficient core deposits.

Nowadays, new kinds of shadow banks spring up. It is important to differentiate between pure dis-intermediation and banking activities. For example, peer-to-peer lending is pure dis-intermediation if the lending platform only channels funds from lenders to borrowers, and all risks transfer from borrowers to lenders. However, lending platforms usually have their own liquidity management and sometimes offer guarantees to investors for protection. The credit risk retention can stimulate platforms to monitor borrowers, but it also brings about the liquidity risks given that lending platforms are not pure platforms anymore. Another example of new rising shadow banks is the mortgage lending company. Some mortgage lenders are ultimately funded by agency

MBSs. During the Great Recession, agency MBSs were saved by government bailouts. Agency MBS investors may expect the implicit bailouts will happen again, so agency MBSs dominate the securitized asset market today (Table 3). If agency MBSs suffer runs in the future, mortgage lenders that rely on the agency MBS financing will suffer liquidity problems too. Even if the government saves the agency MBSs again, taxpayers will undertake the final cost.

The FTQ circle model in this paper also gives wisdom in international finance. When a country raises capital internationally, it can still have sufficient capital when normal fluctuation in the economy of the country happens. The capital outflow is offset by the inflow from the liquidity backup. However, when a severe crisis happens inside the country, the liquidity problem may break out. In reality, European financial institutions issue financial CP in the United States, and the liquidity backup broke down during the European debt crisis.

Finally, there is one caveat: this paper only considers the liquidity risks and therefore, the liability side of financial institutions. Most financial institutions failed in the Great Recession because of their holdings of MBSs, especially subprime MBSs. When the prices of their assets (mostly MBSs) declined, financial institutions could be insolvent even with no liquidity problem. The neglected credit risks and bubbles in prices of collateral (mostly real estate) largely account for the price decline of securitized assets. Liquidity risks also play a role in explaining the price decline. As the story in this paper, when the liquidity backup from commercial banks broke down, shadow banks could not roll over their debt and had to liquidate their securitized assets. The liquidation leads to the further price decline of MBSs. Excluding the neglected credit risks and bubbles, MBSs are priced from nearly risk-neutral to extremely risk-averse valuation because extremely risk-averse investors dominate the markets. It is hard to say that the failed financial institutions hold a large number of MBSs intentionally or they cannot resell the MBSs they issued or underwrote. From a risk-neutral perspective, their holdings of MBSs may be correct, but they cannot survive into the time when markets are full of liquidity and dominated by nearly risk-neutral arbitragers again.

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