Monetary Policy and Bank Risk-Taking

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Abstract

Taking risk is an integral part of the banking business, they had to try managing risk since the emergence of the bank industry. In the wave of the recent global financial crisis, when researchers and policymakers start to study its causes, the topic of the effect of monetary policy on bank's risk-taking incentives has been brought to the forefront of the economic policy debate, because it has been widely agreed that monetary policy contributes to the recent financial crisis build-up, via the excessive risk taking in financial sectors. Hence, this thesis is broadly related to the relationship between monetary policy and the bank's risk-taking. It explains in detail the different effects of conventional and unconventional monetary policy on bank risk-taking behavior in different periods.

The second chapter identifies the impact of the monetary policy on the behaviour of banks risk taking in theoretical foundation with different assumptions in different market structures. In our model, monetary policy may affect banks' perceptions of risk taking, and their attitude to risk taking in three forces: the values effect, the search for yield effect, and the risk taking channel effect. We analyse several cases in which with different market structures, a reasonable bank monitoring cost functions and different loan demand functions exist. By letting banks maximize their profits and achieve the equilibrium, we have different theoretical results of our models, with the assumption of unlimited liability for the bank, and with the assumption of limited liability for the bank in the case of failure. We combine the convex monitoring cost function with a linear loan demand function, a concave loan demand function, and a piecewise loan demand function, and achieve three different results under each assumption. And

finally, we have six propositions about the effect of monetary policy on bank risk taking. In most cases, the results indicate the low interest rate will spur bank risk taking.

Chapter 3 investigates the relationship between short-term low interest rates and bank risk-taking in the U.S. banking system, by using a unique quarterly dataset that includes balance sheet information for listed top 30 banks in the U.S. over the period from 2000 to 2017. In this chapter, we apply a Generalised Method of Moments (GMM) to address the dynamic effect. We find evidence that low interest rates will contribute to the increase of bank risk-taking. Moreover, this effect of monetary policy on bank risk-taking is stronger after the financial crisis, and weaker before the financial crisis. We also discuss the different effects of short term interest rates on risk-taking by banks with different characteristics, such as, the capacity of the bank's capitalization, and bank's equity ratio. The result indicates that the effect of short-term interest rates on bank risk-taking is less pronounced for poorly capitalized banks; the effect of short-term interest rates on bank risk-taking is also stronger for the banks financed with a higher portion of equity. Finally, season will change bank risk taking behavior as well, and power is especially strong at the period of pre-crisis.

In chapter 4, by using U.S. individual bank's balance sheet data, we analyze whether and how the Federal Reserve's LSAPs, referred to as QE, affected bank lending standards, and especially the bank risk-taking behavior. The results indicate that all three waves of quantitative easing, QE1, QE2, and QE3 had significant effects on lowing bank lending standards, which means, because of QE, it leads banks to issue relatively more risky loans with lower lending standards. We also compare the effect between the unconventional monetary policy instrument, QE, and the conventional

monetary policy instrument, short-term interest rate, in the model. The results show that because the United States' short term interest rate has been lowered to zero lower bound, although it still has an effect on the bank risk taking behavior, but it will keep relatively constant. And in this case, we can carefully say that quantitative easing is a more effective tool to stimulate the economy by replacing the role of monetary policy rate during this period.

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List of Abbreviations

CAR	Capital Assets Ratio
CPI	Consumer Prices Index
ECB	European Central Bank
DID	Difference-In-Difference
FDHLMCV	Federal Home Loan Mortgage Corporation
FFIEC	Federal Financial Institutions Examination Council
FHLMC	Federal Home Loan Mortgage Corp
FOMC	Federal Open Market Committee
FNMA	Federal National Mortgage Association
GDP	Gross domestic products
GMM	Generalised Method of Moments
GSEs	Government-Sponsored Enterprises
LASPs	Large-Scale Assets Purchases
MBS	Mortgage-backed securities
NPL	Non-Performing Loan
OLS	Ordinary Least Squares
OMT	Outright Monetary Transactions
QE	Quantitative Easing
REMICS	Real Estate Mortgage Investment Conduits
ROA	Return on Assets
U.K.	United Kindom
U.S.	United States
VAR	Vector Autoregression

Chapter 1

Introduction

1.1 Background and Motivation of the Research

The 2007-2008 financial crisis, starting between banks in the summer of 2007, is referred to as the worst economic disaster since the Great Depression of 1929. It results in a substantial negative influence on the economic growth around the world, e.g., the collapse of large financial institutions, downturns in stock markets, etc. In the wave of this global financial crisis, when researchers and policymakers start to study its causes, the topic of the effect of monetary policy on bank's risk-taking incentives has been brought to the forefront of the economic policy debate, because it has been widely agreed that monetary policy contributes to the recent financial crisis build-up, via the excessive risk taking in financial sectors. Hence, this thesis is broadly related to the relationship between monetary policy and bank's risk-taking. It explains in detail that the different effects of conventional and unconventional monetary policy on bank risk-taking behavior in different periods.

Traditionally, the priority of monetary policy is to ensure price stability in the market for goods and services and tame business cycles. It should not be used to address the instability in the financial market, because the potential trade-off of financial stability is presumed as a less relevant issue (Woodford, 2012). However, after the whole world witnesses the collapse of some major financial institutions during the financial crisis, it has received wide attention from both academia and policymakers, and they start to recognize that the stability of financial systems should be at the forefront of policy. That is because the run-up to the global financial crisis of 2007 to 2008 is marked by excessive risk taking in the financial sectors, and the banking sector in particular. As a result of this accumulation of risks, it leads to severe systemic problems and the eventual collapse of many financial institutions, when the crisis finally occurred. Hence the topic of bank risk-taking incentives takes an essential and important role in the stability of the financial system. And a better understanding of the banks' appetite for risk taking is an indispensable way to help the banks, as well as the worst affected countries in the recent financial crisis, to avoid significant welfare losses in the future.

Researchers have shown lots of interest and evidence to link the bank's attitude of risk-taking with banks' ownership structures (see, e.g., Saunders et al. (1990)), banking competition (see, e.g., Keeley (1990)), bank's deposit insurance (see, e.g., Hovakimian and Kane (2000)), government bailout policies (see, e.g., Gropp et al. (2011)), and the compensation of bank managers (see, e.g., DeYoung et al. (2012)). Due to the recent financial crisis, researchers put more attention on monetary policy which is widely regarded as a new potential risk-taking channel that can drive the bank's incentives to take on risk. This thesis seeks to enhance our understanding of selected topics of such, and attempt to contribute to the ongoing debate on the effects of monetary policy on banks' risk-taking incentives by adopting both theoretical and empirical models.

Concerning the monetary policy, this thesis exams the separate effects of conventional monetary policy and unconventional monetary policy on bank risk-taking. That is because, the wake of the latest financial crisis has a huge influence on the traditional monetary policy, which worked very well previously. Before the 2007-2008 financial crisis, the interest rates, as a traditional monetary policy instrument, are an effective tool used by central banks to shape monetary policy, for example, keeping the inflation rate around the target level, stimulate economic growth, or maintaining unemployment rate at an acceptable level. However, after the recent financial crisis, central banks in lots of developed economies around the world lower their monetary policy rates effectively to the zero lower bound, because of the recession in both financial markets and of the real economy. As a result, the zero lower bound of interest rates reduces the ability of central banks to stimulate economic growth and other economic activities. To solve this situation, lots of central banks begin to undertake various unconventional monetary policies instead, including large-scale assets purchases (LSAPs), colloquially referred to as "Quantitative Easing" or QE. Even nearly a decade after the financial crisis, those central banks in developed countries continue to resort a lot to QE to stimulate the economy, particularly to provide the monetary stimulus, for example, reducing the long-term interest rate (nominal interest rates on long-maturity bonds), which has been widely accepted (Gagnon et al, 2011; Christensen and Rudebusch, 2012; Eser and Schwaab, 2016, etc.).

For example, in late 2008, United States, to push down bond yields and provide additional monetary policy stimulus to the economy, the Federal Reserve Bank began to purchase longer term securities, because the zero lower bound target policy rate gave a deteriorating outlook for the economic growth and a perceived threat of price deflation (Christensen and Rudebusch, 2012). Nearly at the same time, in the early spring 2009, United Kingdom, to increase nominal economic activity, the Bank of England announced plans to purchase government bonds, due to the weak UK economic growth and a low medium-term inflation rate, which were both caused by the policy interest rate had been lowered to its effective zero lower bound.

How does the monetary policy influence banks' appetite for risk taking? Low interest rates can lead banks to take on more risk for several reasons. First, low interest rates can affect valuations, incomes, and cash flows. All these factors in turn can influence how banks measure risk (Adrian and Shin, 2009; Borio and Zhu, 2008). Second, a low interest rate means low returns on general investments, such as government risk free securities, and it also means a low inducement to some investors. It may increase the incentives for banks and other financial institutions to search for some high growing (more risk) investments, with the aim of getting some higher target of return (Brunnermeier, 2001 and Rajan, 2005). Thirdly, low interest rate may reduce the degree of risk aversion of banks and other institutions, which can also induce the financial imbalance.

Based on the different choices of monetary policy instruments by the central banks, this thesis will investigate how the conventional monetary policy affect the bank risk-taking in a theoretical framework and an empirical methodology. Meanwhile, it will also exam the bank risk taking channel under an unconventional monetary policy conditional, and compare those effects with the conventional monetary policy effects.

1.2 Contributions of the Study

In this thesis, Chapter 2 and Chapter 3 mainly focus on the effect of conventional monetary policy on bank risk-taking attitude, while Chapter 4 studies the banks' appetite for risk taking under an unconventional monetary policy conditional.

Chapter 2 analyses one of the main causes of the recent financial crisis from a bank risk taking perspective. Meanwhile, studying this topic will also complement the current theory. The macroeconomics models have generally looked more at the quantity (volume) of credit rather than the credit's quality (risk), such as the impact of short term interest rates on the aggregate volume of credit in economy (Bernanke and Blinder (1992), Kashyap and Stein (2000), Jiménez, Ongena, Peydro and Saurina, 2012). The papers which thought about risk, have mainly studied how the monetary policy rate changes the level of risk on the borrowers' side, rather than the side of financial institutions' risk attitude (Gertler and Gilchrist, 1991, Bernanke, Gertler and Gilchrist, 1994). Secondly, about how the monetary policy affects bank risk taking, we explain three effects in this chapter: the value effect, the search-for-yield effect, and the risk-taking-channel effect. Thirdly, we extended the combinations of banks monitoring cost function and firms loan demand function in the theoretical models. We also extend the assumptions, to compare the case which includes the assumption of limited liability for banks and the case which excludes the assumption of limited liability for banks.

The third chapter is an empirical work adopting a unique model from chapter 2 and database including balance sheet information for listed top banks in the U.S. over the period 2000 to 2017, to check the effect of U.S. monetary policy on their listed top banks' risk taking behavior. It contributes to the literature from the following few aspects. Firstly, in this chapter, the listed top 30 U.S. banks have been chosen as the target banks to investigate the large banks' appetite for risk taking, because it is where the recent financial crisis happened, and the top banks would deliver representative outcomes. Secondly, this chapter compares the effect of other factors on bank risk taking attitude, such as bank's size, time, and how the bank is financed, etc. Thirdly, we apply a Generalised Method of Moments (GMM) to address the dynamic effect. Last but not lease, the last contribution benefits from the up-to-date data.

The fourth chapter uses U.S. banks Call Report data to document the effect of large-scale asset purchase programs (LSAPs) on banks' lending standards and risk taking. The contribution of this research is threefold. Firstly, our findings in this chapter contribute to the growing literature which is about the effect on LASPs on economic activities, especially the understanding of how unconventional monetary policy affects risk-taking behavior in the banking sector. It is very important to show that QE can affect the availability of credit, meanwhile, it also leads banks to issue relatively more risky loans by lowering their lending standards. Secondly, this chapter investigates the general risk taking behavior of all the banks in the U.S. market, including more than 150,000 observations, which shows a broad view of banks' appetite for risk taking under an unconventional monetary policy conditional. Thirdly, this chapter also compares the effects of QE and short term interest rates in the same period, and discusses how their effect on bank risk taking shifts.

1.3 The Structure of the Thesis

The thesis is organized into five chapters, and the main body of the thesis presents three independent essays. The first essay theoretically assesses the topics of interest, the next two essays use empirical methodologies, with Chapters 1 and 2 being closely linked. The rest of this thesis is structured as follow:

Chapter 2: The Effect of Monetary Policy on Bank Risk-Taking

This chapter identifies the impact of the monetary policy on the behaviour of banks risk taking in theoretical foundation with different assumptions in different market structures. In our model, monetary policy may affect banks' perceptions of risk taking, and their attitude to risk taking in three forces: the value effect, the search-for-yield effect, and the risk-taking-channel effect. We analyse several cases in which with different market structures, a reasonable bank monitoring cost functions and different loan demand functions exist. By letting banks maximize their profits and achieve the equilibrium, we have different theoretical results of our models, with the assumption of unlimited liability for the bank, and with the assumption of limited liability for the bank in the case of failure. We combine the convex monitoring cost function with a linear loan demand function, a concave loan demand function, and a piecewise loan demand function, and achieve three different results under each assumption. And finally, we have six propositions about the effect of monetary policy on bank risk taking. In most cases, the results indicate the low interest rate will spur bank risk taking.

Chapter 3: Monetary Policy and Bank Risk-Taking: Evidence from the United States

This chapter investigates the relationship between short-term low interest rates and bank risk-taking in the U.S. banking system, by using unique quarterly data that includes balance sheet information for listed top 30 banks in the U.S. over the period from 2000 to 2017. In this chapter, we apply a Generalised Method of Moments (GMM) to address the dynamic effect. This chapter finds evidence that low interest rates will contribute to the increase of bank risk-taking. Moreover, this effect of monetary policy on bank risk-taking is stronger after the financial crisis, and weaker before the financial crisis. We also discuss the different effects of short term interest rates on risk-taking by banks with different characteristics, such as the capacity of a bank's capitalization, and bank's equity ratio. The result indicates that the effect monetary of policy on bank risk-taking is positive correlated with the size of bank's capitalization and bank's equity ratio. These results are consistent with the evidence collected from Chapter 2.

Chapter 4: The Effect of Quantitative Easing on Bank Risk-Taking: Evidence from the Federal Reserve's LSAPs

In this chapter, by using U.S. individual bank's balance sheet data, we analyze whether and how the Federal Reserve's LSAPs, referred to as QE, affected bank lending standards, and especially the bank risk-taking behavior. The results indicate that all three waves of quantitative easing, QE1, QE2, and QE3 had significant effects on lowing bank lending standards, which means, because of QE, it leads banks to issue relatively more risky loans with lower lending standards. We also compare the effect between the unconventional monetary policy instrument, QE, and the conventional monetary policy instrument, short-term interest rate, in the model. The results show that because the United States' short term interest rate has been lowered to the zero lower bound, although it still has an effect on the bank risk taking behavior, but it will keep relatively constant. And in this case, the quantitative easing generally replaces the role of monetary policy rate during this period.

Chapter 5: Conclusion

This chapter delivers the general conclusion of the thesis and discusses some policy suggestions as well.

Chapter 2

The Effect of Monetary Policy on Bank Risk-Taking

2.1 Introduction and Three Effects

Taking risk is an integral part of the banking business, they had to try managing risk since the emergence of the bank industry. Until now, avoiding excessive risk exposures is still one of the principal rules for bank risk management. The run-up to the global financial crisis of 2007 to 2008 was marked by what became known as excessive risk taking in the financial sectors, and the banking sector in particular. As a result of this accumulation of risks, it led to severe systemic problems and the eventual collapse of many financial institutions, when the crisis finally occurred. Thereafter the whole world witnessed the collapse of some major financial institutions during the financial crisis, it also helped the policy-makers to recognize that the stability of financial systems should be at the forefront of policy. Hence a better understanding of the causes of bank failures, especially the aspect of bank risk-taking, is an essential way to help the banks, as well as the worst affected countries, to avoid the significant welfare losses in the future.

The main attention of most researchers, before the crisis, was on the impact of monetary policy on credit quantity in both macroeconomic theoretical models and empirical models (such as the literature on the bank lending channels), rather than the impact of monetary policy on bank risk taking (e.g. Bernanke and Blinder, 1992; Kashyap and Stein, 2000, et al.). Following the crisis, increasingly more economists, policymakers and bankers debated whether a low interest rate spurs risk-taking by banks. According to Jiménez *et al* (2014), from the start of the recent crisis, the market commentators argued that during the long period of quite low interest rate, bank had softened their lending standards and taken on excessive risk. Meanwhile, some other researchers (see, Taylor 2009, Allen and Carletti, 2010, Acharya and Richardson, 2009 and Rajan, 2012) held the opinion that low long-term interest rates and other factors were the cause of the current financial crisis. Despite that, at the same time, investors, firms, and other market participants still requested central banks to reduce the monetary policy rate to improve their financial situation, which made the whole financial market even worse.

Although it is not difficult to recognize that the low interest rate was not the main cause of the recent crisis, there is still no doubt that a low interest rate can contribute to the building up of the crisis. According to Altunbas et al. (2010), there are mainly two ways in which a low interest rate may have an influence on bank risk taking. First, low interest rates can affect valuations, incomes, and cash flows. All these factors in turn can influence how banks measure risk (Adrian and Shin, 2009; Borio and Zhu, 2008). We call these the value effect. Second, a low interest rate means low returns on general investments, such as government risk free securities, and it also means a low inducement to some investors. It may increase the incentives for banks and other financial institutions to search for some high growing (more risk) investments, with the aim of getting some higher target of return (Brunnermeier, 2001 and Rajan, 2005).

Generally, the risky assets will be more attractive if the short-term interest rate is low. As a result, investors may search for yield by financial intermediaries in the short run. This will cause both serious agency problems and a strong reliance on short term funding. Hence, the low interest rate may spur bank risk taking. This is known as the search-for-yield effect. The sustained low interest rates stimulate the boom of global capital market and credit market, and it encourages financial institutions to take too much risk under higher leverage.

At the same time, low interest rate induces the third effect, that is it may reduce the degree of risk aversion of banks and other institutions (generally the risk aversion of the shareholders and the managers), which can also induce the financial imbalance. As a result, many banks will ignore a certain extent of risk of themselves. It is not clear that the financial agents are even aware of this effect. It is this part of monetary transmission mechanism that has been termed the risk taking channel of monetary policy by Borio and Zhu (2012), which highlights the influence of monetary policy on the risk perceptions and the risk-tolerance by economic agents. Therefore the third effect is termed as risk-taking-channel effect.

So, it is significantly important that we analyse one of the main causes of the recent financial crisis from a bank risk taking perspective. Meanwhile, studying this topic will also complement the current theory, because there are not enough literature and the theoretical foundations for this topic have not been sufficiently discussed yet. The macroeconomics models have generally looked more at the quantity of credit rather than the credit's quality, such as, the impact of short term interest rates on the aggregate volume of credit in economy (Bernanke and Blinder (1992), Kashyap and Stein (2000), Jiménez, Ongena, Peydro and Saurina, 2012). The papers which thought about risk, have mainly studied how the monetary policy rate changes the level of risk on the borrowers' side, rather than the side of financial institutions' risk attitude (Gertler and Gilchrist, 1991, Bernanke, Gertler and Gilchrist, 1994). According to Dell'Ariccia et al. (2010), a large amount of banking literature has focused on the excessive risk taking by financial intermediaries which operate under limited liability and asymmetric information, while most of these literatures ignored monetary policy. Thus, this is a potential gap, which this chapter will try to fill.

The regulators or the banks themselves can access various instruments or methods in attempting to reduce the probability of a bank failure. One of such instrument and method is that of effective monitoring. This chapter introduces a model about banks spending a level of costly monitoring effort to choose low risk projects which the banks can afford and so reduce the risk of the loan the bank granted. This model will be used to analyse the effect of monetary policy on bank risk taking in two different ways: with the assumption of limited liability of the bank in case of failure; and without the assumption of limited liability of the bank in case of failure.

The remainder of this chapter will be organized as follows. The next section briefly introduces the current research in both related theoretical and empirical papers. Section 2.3 compares two theoretical models with different assumptions and analyse the relationship between monetary policy and bank risk taking. Section 2.4 concludes.

2.2 Literature: Theory and Evidence

This chapter is based on a large number of theoretical works and empirical works, which study either monetary policy, bank risk taking, or the relationship between them in the financial market. In this section, we will introduce the relevant theories and the three effects of how monetary policy (low interest rate) can affect bank risk taking decisions, as well as some empirical evidence, which has been done by other researchers in this topic.

In the financial market, low interest rate (policy rate), determines the market risk free rate and can influence bank risk taking via several different ways. There are three broad approaches that have been used to explain the connection between them. These three approaches are consistent with the three effects introduced in the first section. The first approach to influence bank risk taking decision by low interest rate is through the value effect. It focuses on the impact of low interest rate on valuations, incomes, and cash flows and measured risk (Altunbas et al. 2010). All those factors will have a direct effect on the banks' risk taking decision. If the interest rate keeps low in the long period, the value of asset and collateral will be affected. What is more, it will also affect the banks' estimation of the probability of default, the loss given default, and the market volatility. Meanwhile, if the managers of banks that think the low interest rate will still last for long period and the financial market will keep in positive condition, it will reduce the risk aversion of banks. So, easy monetary conditions may increase the banks' risk tolerance (the search-for-yield effect). This is quite close to the financial accelerator, in which increases in collateral values reduce borrowing constrains (Bernanke et al, 1994). However, others maintain that the risk-taking channel is distinct but complementary to the financial accelerator, because it focuses on the amplification mechanisms, which allow relatively small shocks to propagate through the financial, due to financing frictions in the lending sector (Adrian and Shin, 2009b).

Secondly, the second channel which is the 'the search-for-yield effect', as described by Rajan (2005) is not new. It also appeared in the Global Unbalance literature (see, King, 2010, and Borio and Disyatat, 2011, etc.) and in the Feldstein Horioka puzzle literature (see, Feldstein and Horioka, 1979, and Lucas 1990, etc.). It suggests that low interest rate may tempt the asset managers and single investor to take on more risks. They may blindly pursue return and ignore some potential risks and uncertain factors. When the interest rate is high, banks can invest in riskless assets to obtain the return. However, they have to invest in some risk assets to pay back their debt, when the interest rate is low. And according to Shleifer and Vishny (1997), Brunnermeier and Nagel (2004), there is a quite similar mechanism which might be in place when private investors use short term return as a way to judge the managers' competence and withdraw funds after some poor performance.

The third way, risk taking may also be affected by the risk-taking-channel effect. Such as, the communication policies of a central bank and the characteristics of the policymakers' reaction function, comes from the principal agent problem, in the form of moral hazard (Altunbas et al. 2010). If a central bank will predict their own future policy decisions to a quite high degree, the market uncertainty would be reduced, and banks would like to take many more risks. As a result, the agents and investors will believe that the central bank will ease the bad outcome of monetary policy. Diamond and Rajan (2009) stressed that the monetary policy should be kept tighter than the degree of the current economic conditions. And it will reduce the probability of banks taking on liquidity risk. Another example of the risk-taking-channel effect can be shown by the case of 'Greenspan Put'. In this situation, the central bank will generally take powerful measures to control the state economy and help financial stability, when the economic downturn occurs. The expectation of a bank which the central banks will help to contribute the financial stability, may lead banks to take more risk (Farhi and Tirole, 2009). So, in this case, banks can increase their yield by taking more risks. Even banks default due to the excessive risk taking, they will believe that the central bank is still willing to support them to help the state economy and financial stability. Then, banks risk taking can be affected by the central bank's behaviour to the economic situation. However, this will also lead to the moral hazard, because banks may always believe that the central bank is willing to remedy for their excessive risk taking.

Generally, the first two channels focus on the monetary policy environment, while the last one focuses on the response function of central banks. Except for those three effects mentioned in this chapter, there is another different perspective from other researchers (for example, Dell'Ariccia et al. 2010), to explain the influence of monetary policy on bank risk taking. Focusing on banks themselves, they discuss those effects of monetary policy on bank risk taking from the action of two sides of banks' balance sheet -- the asset side and the liability side (Dell'Ariccia et al. 2010).

On the asset side, how monetary policy affects bank risk taking can be explained by a 'pass through effect' (Dell'Ariccia et al. 2010), which is a quite important determinant of banks' risk taking decision. The 'pass through effect' can influence the bank risk taking level through the asset side of a banks' balance sheet. As a result of monetary easing, the policy rate should be reduced, which can generally determine the interest rate of bank loans in a positive relationship. So, the interest rate of bank loans will also decrease. Banks' profit should be affected by the loan interest rate. In this case, the banks' income will decrease. If a bank wants to achieve the target profit, it will give the bank an incentive to take more risk, and reduce the demand for less risky assets.

On the liability side, the influence of monetary policy on banks risk taking, can be explained by a 'risk shifting effect' (Dell'Ariccia et al. 2010). When a monetary easing policy is working, the risk free rate will reduce, which has a positive influence on banks' liability. As a result, the cost of a bank's liability will be reduced. Banks may just need to invest in some safer assets that can guarantee a higher repayment probability, as well as lower return, to pay the low cost liability. So, banks are willing to choose the safer investments, and the incentive of bank reducing the risk taking will increase. In contrast, in a tight monetary policy, the cost of a bank's liability will increase. Banks need to pay more to the liability. So the incentive of a bank taking more risk will increase. It has an opposite effect on the relationship between monetary policy and bank risk taking, comparing with the pass through effect. So, in reality, how a bank chooses the level of the risk it takes, will depend on the tradeoff of the opposite effects. The description of how these two effects work is very similar to the combination of our first two effects – the value effect and the search-for-yield effect, which both focus on the monetary policy environment.

Alongside the theoretical evidence, there is an increasing volume of empirical literature attempting to test the link between monetary policy and bank risk taking. Jiménez *et al* (2014) used the microdata of the Spanish Credit Register from 1984 to 2006 to test whether the stance of monetary policy has an impact on the level of individual bank loans. They identified the effect of monetary policy on credit risk taking with an exhaustive credit register of loan applications and contracts. They found that the high bank risk taking comes with a period of easy monetary policy, which supports the search-for-yield effect. And due to higher collateral values and the 'search for yield', bank would like to grant a riskier loan and to soften their lending standards ('the risk-taking-channel effect'). In this case, banks will lend more to the borrowers who have a bad credit history and borrowers with more uncertain prospects. Similarly, Maddaloni and Peydró (2011) used the lending standard to study the determinant of banks' lending standards in the Euro Zone's banking. They stressed the impact of low interest rate on lending standard. Altunbas et al. (2010) found that low interest rate will increase the lending risk taking of banks, by using the data of listed banks in the European Union and the United States,

It was examined by researchers whether the risk taking channel works on both the quantity of new loans and their interest rates, and they found that when the interest rate is low, banks increased the number of new risk loans (Ioannidou et al, 2009). What is more, they also reduce the rates, which they charge to the borrowers compared with the rates, which they charge to the less risk borrowers. The same investigators (Ioannidou et al 2015) studied the risk-taking channel of monetary policy in Bolivia. They found that "a lower policy rate spurs the granting of riskier loans, to borrowers with worse credit histories, lower ex-ante internal ratings, and weaker ex-post performance".

Finally, this paper is partly based on Allen et al (2011) and Dell'Ariccia at al (2010). Both of those papers introduced bank monitoring to explain the bank risk taking level, while the first paper ignored the effects of monetary policy. The second paper discussed the relationship between monetary easing, leverage, and bank risk taking, in different situations and market structures.

2.3 Theoretical Models

In this part, we will talk about a theoretical model, with two different assumptions: one is under the assumption of limited liability of the bank in case of failure; and the other one is without the assumption of limited liability of the bank in case of failure. In this theoretical model, we will also discuss if the relationship between monetary policy and bank risk taking changes when banks are facing different monitoring cost functions, and firms have different loan demand functions. At the same time, in each model, we will analyse the performances of banks' risk attitudes in different market structures. Firstly, we introduce some basic assumptions, model framework, and model timing, and then we will analyse this model with two different assumptions in different market structures.

2.3.1 Theoretical Model 1

2.3.1.1 Assumptions and Model Framework

Consider a simple model, with two parties: firms (borrowers), and banks (lenders), in the financial market. These two parties can be described as follows:

Firms (Loan Borrowers): Firms can decide to invest in projects with different risk levels. Because each firm also has an external financial demand in the investment activity, they need to apply for a loan, which is supplied by banks. The firms or the projects a firm processing, can be graded according to their risk level. We assume that, a firm will have more chances to success, if the bank who grants loans to this firm pays more monitoring effort on it. That is because, for example, bank's monitoring can help to reduce the agency problem between the shareholders and the managers of the firm, and as a result, the monitoring behaviour of banks can reduce the risk of the firm and increase the firm's value. Another way of thinking about the reason why bank monitoring can improve firms' performance is that banks can help firms in better behaviour according to the information banks observing. To be more specific, a firm with better performance and better behaviour means that it will have a higher probability to avoid failing and a higher probability to have the ability to repay the loan. What is more, banks' financial expertise can also help firms improve their expected value (see Besanko and Kanatas (1993), Boot and Greenbaum (1993), Boot and Thakor (2000), Carletti (2004), and Dell'Ariccia and Marquez (2006)). For example, banks' financial expertise can improve firm's probability to succeed, and then firm expect value will increase. Meanwhile, a more professional firm will also increase the confidence of the firms' shareholders and investors, who will evaluate the firm higher, and increase the share price of this firm. As a result, the expected value of the firm with banks' financial expertise will rise.

In this chapter, firms' demand function of loan is initially assumed as a linear function, which is negatively correlated with the loan rate charged by banks. This assumption is quite popular in the literature (for example, Den Haan, Summer, and Yamashiro, 2007, etc.). So, the loan demand function can be written as: $F(r_L) = a - br_L$, where r_L is the loan interest rate, charged by banks, both a and b are positive constants. The loan interest rates are different for different firms, and they are set according to the policy rate and banks' evaluation of firms. We will relax this assumption, and discuss two other cases in which two non-linear loan demand functions exist.

Banks who are the loan suppliers can invest in projects or firms with different risk levels. They can choose to monitor their loan portfolio to reduce their risk taking, and increase the probability of loan repayment. We assume that the banks monitoring also works in both good and bad states of the world economy. This is because banks will also have the ability to choose the acceptable firms or projects to invest, and to improve the probability of repayment, even in an extreme world economic condition. For example, in a bad state of the world, it is harder for most firms to be successful. But banks also need to grant loans to firms to get profits. They can use the monitoring effort to increase firms' probability to succeed, even in a lower amount, compared with the case in an average or good economic environment. So, we use the bank monitoring effort as the proxy of bank risk taking. The basic principle is that the more monitoring effort bank pays on their portfolio, the less risk will be borne by banks. This monitoring effort is costly and not contractible. The monitoring effort can also represent the probability of firm success and the loan repayment. As a consequence, banks can choose the level of monitoring to affect their profits of the investment to each firm. So, there should be an optimal monitoring level, under which banks can maximize their profits. The optimal bank's monitoring level is not fixed, and it is different in different firms and projects. Banks finance themselves in two different ways. The first part is financed by debt, and the other part is funded by equity. For simplicity, we assume each bank will only lend to one firm, during the lending and borrowing process.

Regarding the bank monitoring, we assume banks have to choose a level of q $(q \in [0,1])$, which is the monitoring effort, to increase the probability of firm (the borrower) success and the loan repayment. The cost of bank monitoring is $cq^2 + d$ per unit borrowed by firms. Where, c is a positive constant, d is also a positive constant, which means the initial cost of the bank monitoring. The intensity [0, 1] of q, can also be interpreted as the probability of firms' success, which is consistent with the assumption that the probability of firms' success will increase, with a higher and higher monitoring level by banks. The convex cost function captures the idea that it will be increasingly difficult for banks to explore more and more information about the firm in which they invested. It means that banks need to pay more monitoring effort to obtain the same amount of information about the firm, compared with the beginning stage. The convex bank monitoring cost function is supported by a large amount of literature (see, Besanko and Kanatas, 1993, Holmstrom and Tirole, 1997, Carletti, 2004, Dell'Ariccia and Marquez, 2005, etc.).

About the bank's capital structure, we assume that the bank is financed with a portion of k in equity, at a cost of r_E, and a portion of *1- k* in debt, at a cost of r_D. Hence, r_E and r_D also mean the interest rate paid to the shareholders and the depositors. Both of them are positively related to the risk-free rate which is r^*. This allows that monetary policy can change the cost of banks' liabilities by changing the risk-free rate. Then, r_E and r_D can be expressed as: $r_D = r^* + \alpha$, and $r_E = r^* + \beta$, where $\alpha \geq 0$, it can be regarded as the incentive to depositors; and $\beta \geq 0$, it can be regarded as the incentive to equity investors. According to Dell'Ariccia, et al. (2010), in our model we assume that the premium on equity and debt, α and β, are independent of the policy rate, r^*. That is consistent with our goal to isolate the effect of an exogenous change in the stance of monetary policy. However, this might be not consistent with the Modigliani and Miller theorem, because, from an asset pricing perspective, they are likely to be correlated. That might happen through the underlying common factors which may dive both the risk premium and the risk free rate. However, the results continue to hold as long as the within period correlation between them is sufficiently different from (positive) one. Generally, the equity premium as a spread over the risk-free rate can be used to explain the reason why $\beta \geq 0$. On the other hand, banks always would like to pay a higher interest rate than the risk free rate to the depositors, because they need to attract these investments from depositors by a higher return. If not, depositors will withdraw their savings, banks do not have enough funds to invest. They are broadly discussed in the literature (see Dell'Ariccia, et al., 2010, Allen, et al., 2010, Repullo, 2004, Hellmann, et al., 2000 and Berger, et al., 1995, etc.).

The timing of our model can be explained as follows:

Stage 1, the policy rate is set;

Stage 2, banks choose the interest rate to charge on loan --r_L, choose the interest rate paid to shareholders --r_E, and depositors --r_D, and also set the leverage level -- k;

Stage 3, firms apply for the loan and borrow form banks at the rate of r_L;

Stage 4, banks decide whether to grant the loan or not, and choose the monitoring effort q.

2.3.1.2 Equilibrium Bank Monitoring

Given the amount of the factors in the above section, the bank can maximize the expected profits by choosing its optimal level of monitoring. To guarantee bank's maximum expected profits, a negative second order condition must be satisfied. Here, we can write the bank's expected profit as:

$$\Pi = [qr_L - (1-k)r_D - kr_E - C(q)]F(r_L) \qquad (2.3.1)$$

Where, Π *is the bank's expected profit;*

q *is the monitoring effort, or the probability of the loan repayment;*

r_L *is the interest rate charged by banks;*

k *is the portion of bank assets financed with equity;*

$1-k$ *is the fraction of bank's portfolio funded by deposits;*

r_D *is the interest rate paid to depositors by bank;*

r_E *is the interest rate paid to equity investors by bank;*

$C(q)$ *is the cost function of bank monitoring;*

$F(r_L)$ *is the firms' loan demand function.*

By substituting the expression functions of r_D, r_E, $C(q)$, and $F(r_L)$ into the bank's expected profit function, we can obtain a more detailed bank's expected profit function:

$$\mathit{\Pi} = [qr_L - (1-k)(r^* + \alpha) - k(r^* + \beta) - (cq^2 + d)](a - br_L) \quad \textit{(2.3.2)}$$

We can see from the bank expected profit function, the profit per unit lent equals to the possible income of the loan (qr_L), less the costs on both deposit and equity ($(1-k)(r^* + \alpha) + k(r^* + \beta)$), and minus the cost of bank monitoring ($cq^2 + d$).

Equation (2.3.2) is a concave function of the bank monitoring effort. Consequently, there exists a maximum value of the bank's expected profit, because the second order condition of bank's expected profit respect to the monitoring effort is strictly negative. We can maximize the bank's expected profit, by taking the first order condition of the bank expected profit respect to the bank monitoring effort, and letting the new function equals to zero. According to this, the optimal bank monitoring effort can be available. Then, it can be written as:

$$\frac{\partial[qr_L - (1-k)(r^* + \alpha) - k(r^* + \beta) - (cq^2 + d)]}{\partial q}(a - br_L) = 0 \quad \textit{(2.3.3)}$$

We can get the optimal bank monitoring level:

$$q^* = min\left\{\frac{r_L}{2c}, 1\right\} \quad \textit{(2.3.4)}$$

We assume the value of $\frac{r_L}{2c}$ will always be not larger than one. So, the optimal value of bank monitoring effort will equal to $\frac{r_L}{2c}$. It means the relationship between the optimal bank monitoring level and the bank loan interest rate, which is positive: the higher the loan interest rate bank charges, the high the monitoring effort bank pays. Therefore, a lower bank loan interest rate will reduce the monitoring effort, as a result, increase bank risk taking. The intuition for this result is that a higher interest rate loan will increase the incentives for banks to monitor more on it to get a higher probability to receive the loan repayment. That is because banks will value more on a higher interest rate loan.

Recalling the value effect, that we mentioned in previous sections, it is a simple mechanism based on the concept of expected profit in our model. By construction, an increase in the loan rate r_L increases expected profit for given monitoring effort q. Since the bank marginal profit increase linearly with the loan rate r_L, the optimal monitoring effort q^* that the bank chooses in order to maximize profit (when taking the loan rate as given) will be higher with the higher the loan rate r_L. With this intuition from the result, if one further postulate that the loan rate r_L is positively related to the policy rate r^*, it follows that $\frac{\partial q^*}{\partial r^*} > 0$. Therefore, by its nature, the value effect hinges on a generally positive relationship between the bank loan rate r_L and the monetary policy rate r^*, and holds even when the bank does not choose the loan rate r_L. These are also what we will test in the following parts.

Regarding the other two effects, the search-for-yield effect is a different mechanism based on the existence of market power. In fact, it only arises when the bank can choose the loan rate. When the bank is able to choose the loan rate r_L, the profit-maximizing behaviour of the bank is similar to that of a monopolistic producer: the bank will raise the r_L (just like a monopolistic firm would raise the output price above the marginal cost) in order to maximize the pure rents created by a lower level of loans along with the demand schedule (just like the mark-up created by a lower level of output purchased by consumers under monopoly pricing). This means that when banks can set the loan rate, they will have an incentive to raise r_L to increase their yields; it will in turn reinforce the value effect" via the endogenous response of the loan rate r_L set by banks to changes in the monetary policy rate r^*. Based on our model, risk-taking-channel effect will arise when the bank chooses the loan rate and there is limited liability. It is basically a moral hazard story: it tends to counteract the search-for-yield effect because limited liability gives the bank an incentive to reduce monitoring when the interest rate goes up, and vice versa.

In the following parts, we will discuss the relationship between bank monitoring effort level (bank risk taking) and policy rate, when banks are facing a convex monitoring cost function, and firms have different loan demand functions.

2.3.1.3 Linear Loan Demand Function

Firstly, we consider the case where neither the loan interest rate (r_L) nor the portion of bank capital *k* are determined by banks, for example, the regulator chooses the interest rate and the capital *k*. In equation *(2.3.4)*, it means the optimal monitoring effort is fixed according to the level of loan interest rate (r_L) and the coefficient of bank's cost function (*c*). Specifically, the higher loan interest rate set by the regulator will lead to a higher monitoring effort by banks, and the more the monitoring effort cost, the less monitoring effort banks be willing to pay.

Then, we will analyse the situation that banks can choose the loan interest rate by themselves, while the capital k is still determined by the regulator. We can solve this relationship between bank monitoring effort and monetary policy by backwards induction. When we assume that monetary policy can change the cost of banks' capital by changing the risk-free rate, so we just need to know the first order condition of optimal monitoring effort with respect to risk-free rate, which is $\frac{\partial q}{\partial r^*}$. In the equation *(2.3.4)*, because the loan interest rate is a compound function of risk-free rate, we can get:

$$\frac{\partial q}{\partial r^*} = \frac{1}{2c}\left(\frac{\partial r_L}{\partial r^*}\right) \qquad (2.3.5)$$

To obtain $\frac{\partial r_L}{\partial r^*}$, we substitute the optimal bank monitoring level q^* function *(2.3.4)*, into the bank's expected profit function *(2.3.2)*:

$$\Pi = \left[\frac{r_L}{2c} r_L - (1-k)(r^* + \alpha) - k(r^* + \beta) - (c(\frac{r_L}{2c})^2 + d)\right](a - br_L)$$

$$= \left[\frac{{r_L}^2}{4c} - r^* - (1-k)\alpha - k\beta - d\right](a - br_L) \qquad (2.3.6)$$

Assuming $G = \frac{\partial \Pi}{\partial r_L} = 0$, by using the Implicit Function Theorem, we can get the second order condition of bank's expect profit respect to the loan interest rate is:

$$\frac{\partial \Pi^2}{\partial^2 r_L} = \frac{\partial G}{\partial r_L} = \frac{1}{2c}(a - 3br_L) \qquad (2.3.7)$$

The above second order condition equation *(2.3.7)* will be positive, if $r_L < \frac{a}{3b}$, and it will be negative, when $r_L > \frac{a}{3b}$. However, we will only consider the range of $r_L > \frac{a}{3b}$, because only in this case, $\frac{\partial G}{\partial r_L} < 0$, which guarantees bank can achieve the maximum profits consistently. So, in the following parts, we need guarantee all the second order conditions of bank's expected profit to be negative, when we talk about the bank's maximum profit. According to this negative second order condition of bank's expected profit respect to the bank loan interest rate, we can obtain the reasonable rang of loan interest rate. Here, we assume that the parameters *a* and *b*, always satisfy $r_L > \frac{a}{3b}$. And as result, $\frac{\partial \Pi^2}{\partial^2 r_L} = \frac{\partial G}{\partial r_L} < 0$, which means the bank's maximum profit achieves.

Next, to analyse the relationship between the bank loan interest rate and the risk free interest rate, we can now differentiate G with respect to r^*. We will have the result:

$$\frac{\partial G}{\partial r^*} = b > 0 \qquad (2.3.8)$$

$$\text{So, } \frac{\partial r_L}{\partial r^*} = -\frac{\partial G/\partial r^*}{\partial G/\partial r_L} > 0 \qquad (2.3.9)$$

Due to the equation *(3.5)*, $\frac{\partial q}{\partial r^*}$ is positively correlated with $\frac{\partial r_L}{\partial r^*}$.

$$\text{Similarly, } \frac{\partial q}{\partial r^*} > 0 \qquad (2.3.10)$$

In the case that the banks can choose the loan interest rate by themselves, while the capital k is exogenous, the banks monitoring effort will increase (less risk taking by banks), with an increasing policy rate, and the banks monitoring effort will reduce (more risk taking by banks), when the policy rate decreases. Banks' risk attitude will be unambiguous. The loan demand function tells us that the banks can choose a loan interest rate with an intensity $(0, \frac{a}{b})$. Specifically, banks can obtain their maximum profit, only in the case when the loan interest rate is set from $\frac{a}{3b}$ to $\frac{a}{b}$. In this rang, it implies that the relationship between the amount of bank monitoring effort and the risk-free rate is unambiguously positive. It also means that the lower policy rates will spur the bank to take more risks. So, we can obtain the result:

Proposition 1 *When the banks monitoring cost function is a convex function and the firms loan demand function is a linear function, if banks can decide the size of loan interest rate,* r_L*, banks will always set it in the interval of* $\left(\frac{a}{3b}, \frac{a}{b}\right)$ *, and banks* *monitoring increases with monetary policy rate,* $\frac{\partial q}{\partial r^*} > 0$. *Banks take more risk with the monetary policy rate decreases.*

2.3.1.4 Non-Linear Loan Demand Function

This section examines the effect of the alternative loan demand functions. We look at two different cases: first, the loan demand function is a concave function; while second, the loan demand function is a piecewise function.

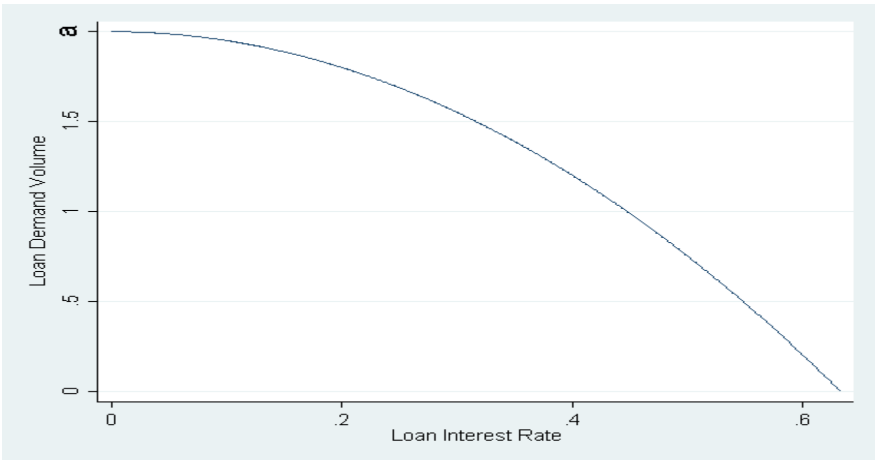
a. Concave Loan Demand Function

In the first case, a concave function, we can assume that the loan demand function is:

$$F(r_L) = a - br_L^2, \textit{ where, } 0 < \mathrm{a} \leq \mathrm{b}, \textit{ and } 0 < r_L < \sqrt{\frac{a}{b}}. \qquad \textit{(2.3.11)}$$

This concave loan demand function can be interpreted as: the intercept *a* is the firms' maximum loan demand, when loan interest rate is zero. When $r_L = \sqrt{\frac{a}{b}}$, firms loan demand function will be zero, which means the loan interest rate $r_L = \sqrt{\frac{a}{b}}$, can be interpreted as either the maximum return on projects, or as the highest rate consistent with borrowers satisfying their reservation utilities. The concave loan demand function suggests that, in the first beginning stage of the loan application, the firms are not so sensitive to the change of loan interest rate, due to the amount of loan demand. In this period, the firms' loan demand does not change a lot, if banks increase the loan interest rate. However, with the growth of the loan interest rate, the firms' loan demand function becomes more and more sensitive. It will change a lot, comparing to the beginning stage, even banks' loan interest rate changes a little. We can see from the *figure 2.1* that the slope of the loan demand function is decreasing, it is consistent with what we describe here.

Figure 2.1 Concave Loan Demand Function



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Similar steps with the previous part, by substituting the expression functions of r_D, r_E, $C(q)$, and new loan demand function $F(r_L)$ into the bank's expected profit function (2.3.1), we can obtain a new expected profit function:

$$\Pi = [qr_L - (1-k)(r^* + \alpha) - k(r^* + \beta) - (cq^2 + d)](a - br_L^2) \quad (2.3.12)$$

We can see from the bank expected profit function, the profit per unit lent equals to the possible income of the loan (qr_L), takes off the costs on both deposit and equity ($(1-k)(r^* + \alpha) + k(r^* + \beta)$), and minus the cost of bank monitoring ($cq^2 + d$).

Equation (2.3.12) is a concave function of the bank monitoring effort as well. There exists a maximum value of the bank's expected profit, because the second order condition of the bank's expected profit respect to the monitoring effort is strictly negative. By maximizing the bank's expected profit, we can get the same optimal bank monitoring level:

$$q^* = \frac{r_L}{2c} \qquad (2.3.13)$$

In the same market structure, banks can choose the loan interest rate by themselves, while the capital k is still determined by others, for example, the regulator. Similarly, if we want to find out the sign of $\frac{\partial q}{\partial r^*}$, we still need to figure out $\frac{\partial r_L}{\partial r^*}$. By substituting the optimal bank monitoring level q^*, into the above bank's expected profit function *(2.3.12)*, we can get:

$$\Pi = \left[\frac{r_L}{2c} r_L - (1-k)(r^* + \alpha) - k(r^* + \beta) - \left(c\left(\frac{r_L}{2c}\right)^2 + d\right)\right](a - br_L^2)$$

$$=\left[\frac{{r_L}^2}{4c} - r^* - (1-k)\alpha - k\beta - d\right](a - br_L^2) \qquad (2.3.14)$$

Assuming $G = \frac{\partial \Pi}{\partial r_L} = 0$, by using the Implicit Function Theorem, we can get the second order condition of bank's expect profit respect to the loan interest rate is:

$$\frac{\partial \Pi^2}{\partial^2 r_L} = \frac{\partial G}{\partial r_L} = -\frac{3b}{c} r^3 + \frac{a}{2c}[r^* + (1-k)\alpha + k\beta + d] \qquad (2.3.15)$$

Therefore, in order to claim that the loan interest rate is chosen by the bank consistently with maximal profits, we need to keep the second order condition of bank profit respect to loan interest rate is strictly negative. It means $\frac{\partial \Pi^2}{\partial^2 r_L} = \frac{\partial G}{\partial r_L} < 0$.

So we can get: $r_L > \sqrt{\frac{a}{6b} + \frac{2c}{3}[r^* + (1-k)\alpha + k\beta + d]}$, if $\frac{\partial \Pi^2}{\partial^2 r_L} = \frac{\partial G}{\partial r_L} < 0$.

(2.3.16)

$$\text{and, } \frac{\partial G}{\partial r_*} = 2br_L > 0 \qquad (2.3.17)$$

$$\frac{\partial r_L}{\partial r^*} = -\frac{\partial G / \partial r^*}{\partial G / \partial r_L} > 0 \qquad (2.3.18)$$

Due to the equation *(2.3.5)*, $\frac{\partial q}{\partial r^*}$ is positively correlated with $\frac{\partial r_L}{\partial r^*}$.

Similarly, $\frac{\partial q}{\partial r^*} > 0$ *(2.3.19)*

This inequality implies that the relationship between the bank monitoring effort and risk-free interest rate is always positive. The higher risk-free rate, the higher a bank monitoring effort will be. Therefore, a lower policy rate will always increase bank risk taking. So, we can obtain our result as follows:

Proposition 2 *When the banks monitoring cost function is a convex function and the firms loan demand function is the assumed concave function, if banks can decide the size of loan interest rate,* r_L *, banks will always set it in the interval of* $\left(\sqrt{\frac{a}{6b} + \frac{2c}{3}[r^* + (1-k)\alpha + k\beta + d]}, \sqrt{\frac{a}{b}}\right)$ *, banks monitoring increases with monetary policy rate,* $\frac{\partial q}{\partial r^*} > 0$. *Banks will take more risk if the monetary policy rate decreases.*

The intuition behind those two propositions is that a low monetary policy rate will result in a low loan interest rate, a low interest rate paid to debt and equity. Consequently, banks would reduce the valuations of their investments, pay low effort, and take more risk. This is explained from the value effect perspective, and for the search-for-yield effect, if the policy rate is low, banks will search for the projects with higher return, which generally come with higher risk. So, banks would like to grant loans to those projects with higher risk to get higher return, and the higher return will be used to pay the cost of debt and equity. Therefore, from banks perspective, the search-for-yield effect will occur at the stage of searching for loans, and the value effect will work at the stage of loan monitoring effort allocation.

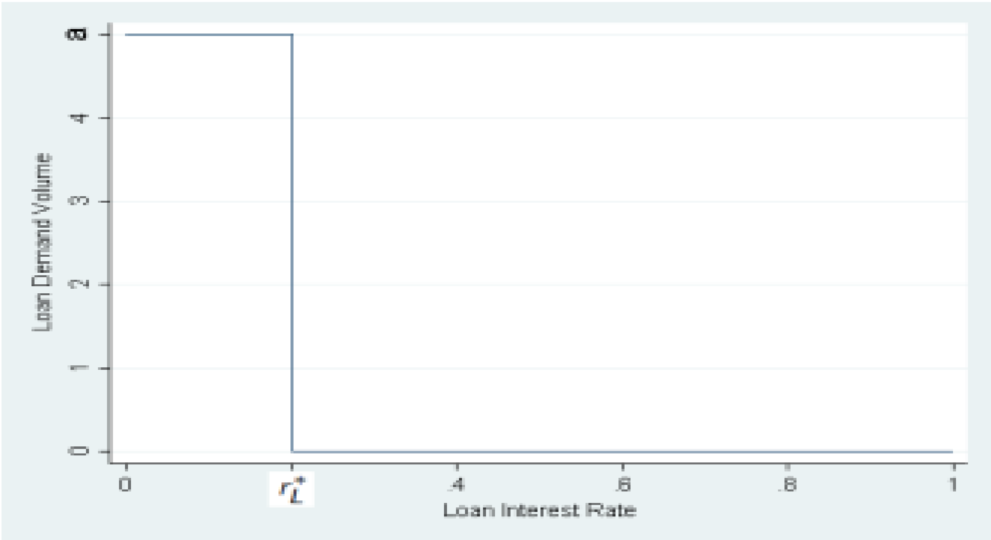
b. Piecewise Loan Demand Function

In the second case, a piecewise function, we can assume that the loan demand function is:

$$F(r_L) = \begin{cases} a, if\ r_L \leq r_L^* \\ 0, if\ r_L > r_L^* \end{cases}, \text{ where } 0 < r_L^* < 1 \qquad \textit{(2.3.20)}$$

r_L^* can be interpreted as either the maximum return on projects, or as the highest rate consistent with borrowers satisfying their reservation utilities. In this case, firms will have a fixed loan demand, which is *a,* as long as $r_L \leq r_L^*$. This is because firms still need the loan from banks, as long as the loan interest rate is lower than their project's return. There will be some profit for firms. So, their demand function will not change, if the banks do not charge more than their yield. This case can be shown by *Figure 2.2*.

Figure 2.2 Piecewise Loan Demand Function



Similarly, by substituting the expression functions of r_D, r_E, $C(q)$, and new loan demand function $F(r_L)$ into the bank's expected profit function (1), we can obtain a new expected profit function:

$$\Pi = \begin{cases} [qr_L - (1-k)(r^* + \alpha) - k(r^* + \beta) - (cq^2 + d)]a, if\ r_L \leq r_L^* \\ 0, if\ r_L > r_L^* \end{cases} \quad (2.3.21)$$

In this case, it will be always optimal that banks choose the maximum loan interest rate -- r_L^*. So, banks will always set the loan interest rate at the level of r_L^*, to achieve the maximum profit. Then the expected profit function will be:

$$\Pi = [qr_L^* - (1-k)(r^* + \alpha) - k(r^* + \beta) - (cq^2 + d)]a \qquad (2.3.22)$$

Following the similar procedure, we can calculate the optimal bank monitoring effort according to this concave bank's expected profit function:

$$q^* = \frac{r_L^*}{2c} \qquad (2.3.23)$$

So, q^* is consistent, and irrelevant with monetary policy rate. Banks will always choose the optimal loan interest rate level r_L^*, and the monitoring level $\frac{r_L^*}{2c}$. Then, we can obtain the result:

Proposition 3 *When the banks monitoring cost function is a convex function and the firms loan demand function is the assumed piecewise function, banks will always choose a fixed optimal level of loan interest rate and a fixed optimal monitoring level, which is depended on the optimal loan interest rate. Banks risk taking level is not affected by monetary policy rate.*

2.3.2 Theoretical Model 2

In this part, we will introduce a similar theoretical model, while with the assumption of limited liability of banks in case of failure, to analyse if the relationship between monetary policy and bank risk taking changes or not.

Now, we still assume there are two parties, which are firms (borrowers) and banks (lenders), in the financial market. Except for the assumption of limited liability of banks in case of failure, rather than the unlimited liability of banks, all other assumptions in our model 2 are the same with those in model 1. Under the assumption of limited liability of banks, the lenders are not liable for the debts if the borrowers fail to repay the loan. Therefore, our new banks' expected profit function can be expressed as:

$$\Pi = [q(r_L - (1-k)r_D) - kr_E - C(q)]F(r_L) \qquad (2.3.24)$$

Where, Π *is the bank's expected profit;*

q *is the monitoring effort, or the probability of the loan repayment;*

r_L *is the interest rate charged by banks;*

k *is the portion of bank assets financed with equity;*

$1-k$ *is the fraction of bank's portfolio funded by deposits;*

r_D *is the interest rate paid to depositors by bank;*

r_E *is the interest rate paid to equity investors by bank;*

$C(q)$ *is the cost function of bank monitoring;*

$F(r_L)$ *is the firms' loan demand function.*

By substituting the expression functions of r_D, r_E, $C(q)$, and $F(r_L)$ into the bank's expected profit function, we can obtain a more detailed bank's expected profit function:

$$\Pi = [qr_L - q(1-k)(r^* + \alpha) - k(r^* + \beta) - (cq^2 + d)](a - br_L) \quad \textit{(2.3.25)}$$

We can see from the bank expected profit function, the profit per unit lent equals to the possible income of the loan (qr_L), less the costs on deposit if the borrowers success to repay the loan $\left(q(1-k)(r^* + \alpha)\right)$, takes off the cost of equity $\left(k(r^* + \beta)\right)$, and minus the cost of bank monitoring $(cq^2 + d)$. If a bank's projects succeed, it will receive the payment from the loan and pay costs of debt, equity and bank monitoring. When a bank's project fails, which means the borrower cannot return any repayment, the bank will receive no revenue, but, because of the limited liability, it does not need to pay the cost of debt either. Bank has to repay shareholders always, because the cost of equity is borne irrespective of the bank's revenue. Because the above equation is a concave function of the bank's monitoring effort, there exists a maximum value of the bank's expected profits, and an optimal level of bank's monitoring effort. We can get the optimal monitoring effort level, by calculating the function:

$$\frac{\partial\left[qr_L - q(1-k)(r^* + \alpha) - k(r^* + \beta) - (cq^2 + d)\right]}{\partial q}(a - br_L) = 0 \quad (2.3.26)$$

Therefore, the optimal bank monitoring effort level will be:

$$q^* = min\left\{\frac{r_L-(1-k)(r^*+\alpha)}{2c}, 1\right\} \quad (2.3.27)$$

We assume the value of $\frac{r_L-(1-k)(r^*+\alpha)}{2c}$ will always be not larger than one. So the optimal value of bank monitoring effort will equal to $\frac{r_L-(1-k)(r^*+\alpha)}{2c}$. The above function shows a more complicated relationship between bank's optimal monitoring effort level, loan interest rate and risk free interest rate. In the following part, we will discuss more detail about the relationship between bank monitoring effort level (bank risk taking) and policy rate, when the lender is facing a convex monitoring cost function, and the borrower has different loan demand functions.

2.3.2.1 Linear Loan Demand Function

Taking the loan interest rate (r_L) as given, the relationship between bank monitoring effort and risk free interest rate is non-positive, because $\frac{\partial q^*}{\partial r^*} \leq 0$. But in most cases, bank can decide the loan interest rate by itself. So, we will now mainly consider the case, in which, bank can choose the level of loan interest rate. Similarly, to obtain the effect of monetary policy on bank risk taking, we need to know the first order condition of bank optimal monitoring effort with respect to risk free rate, because the assumption that monetary policy can affect the cost of bank's capital by changing the risk free rate.

$$\frac{\partial q^*}{\partial r^*} = \frac{\frac{\partial r_L}{\partial r^*} - (1-k)}{2c} \qquad (2.3.28)$$

To obtain $\frac{\partial r_L}{\partial r^*}$, we can substitute the optimal bank optimal monitoring effort q^* into the bank's expected profit function:

$$\Pi = \left[\frac{r_L - (1-k)(r^* + \alpha)}{2c}(r_L - (1-k)r_D) - kr_E - \left[c\left(\frac{r_L - (1-k)(r^* + \alpha)}{2c}\right)^2 + d\right]\right](a - br_L)$$

$$= \left[\frac{\left(r_L - (1-k)(r^* + \alpha)\right)^2}{4c} - k(r^* + \beta) - d\right](a - br_L) \qquad (2.3.29)$$

We assume $G = \frac{\partial \Pi}{\partial r_L}$, by using the Implicit Function Theorem, we can get:

$$\frac{\partial r_L}{\partial r^*} = -\frac{\partial G / \partial r^*}{\partial G / \partial r_L} \qquad (2.3.30)$$

To achieve the maximum expected profit, bank has to set the level of loan interest rate to satisfy $\frac{\partial G}{\partial r_L} < 0$. So, we just need to consider the sign of $\frac{\partial G}{\partial r^*}$:

$$\frac{\partial G}{\partial r^*} = -\frac{1-k}{2c}(a - br_L) - b\left[\frac{\left[r_{L-(1-k)(r^*+\alpha)}\right](k-1)}{2c} - k\right] \quad (2.3.31)$$

For $k \to 0$, $\frac{\partial G}{\partial r^*} < 0$, as a result, $\frac{\partial r_L}{\partial r^*} < 0$ as well. As $k \to 0$, $\frac{\partial q^*}{\partial r^*} = \frac{\frac{\partial r_L}{\partial r^*} - (1-k)}{2c} \to \frac{1}{2c}\left(\frac{\partial r_L}{\partial r^*} - 1\right) < -1 < 0$. For $k \to 1$, $\frac{\partial G}{\partial r^*} > 0$, as a result, $\frac{\partial r_L}{\partial r^*} > 0$ as well. As $k \to 1$, $\frac{\partial q^*}{\partial r^*} = \frac{\frac{\partial r_L}{\partial r^*} - (1-k)}{2c} \to \frac{1}{2c}\left(\frac{\partial r_L}{\partial r^*}\right) > 0$. Therefore, at one extreme of k, $k \to 0$, the effect of monetary policy on bank monitoring effort is negative, while at the other extreme of k, $k \to 1$, the effect is positive. This means there must exist a value $k^* \in (0,1)$, for any $k < k^*$, $\frac{\partial q^*}{\partial r^*} < 0$, and for any $k > k^*$, $\frac{\partial q^*}{\partial r^*} > 0$. It is showing that, following a change in monetary policy, risk taking can react in either direction depending on whether the bank finances with equity a high or a low fraction of its assets. According to this, we can obtain our next proposition:

Proposition 4 *When banks monitoring cost function is a convex function and firms loan demand function is a linear function, if banks can decide the size of loan interest rate, r_L, banks that financed with low portion of equity, will pay less monitoring effort with the increase of monetary policy, $\frac{\partial q^*}{\partial r^*} < 0$. Banks will take more risk with the monetary policy increases. Banks who financed with high portion of equity, will pay more monitoring effort with the increase of monetary policy, $\frac{\partial q^*}{\partial r^*} > 0$. Banks will take more risk with the monetary policy decreases.*

2.3.2.2 Non-Linear Loan Demand Function

In this section, we will also test the effect of the alternative loan demand functions. We look at two different cases: first, the loan demand function is a concave function; while second, the loan demand function is a piecewise function.

a. Concave Loan Demand Function

In the first case, we assume that the concave loan demand function is:

$$F(r_L) = a - br_L^2, \textit{ where, } 0 < \mathrm{a} \leq \mathrm{b}, \textit{ and } 0 < r_L < \sqrt{\frac{a}{b}}. \qquad \textit{(2.3.32)}$$

Therefore, the new bank expected profit function is:

$$\Pi = [q[r_L - (1-k)(r^* + \alpha)] - k(r^* + \beta) - (cq^2 + d)](a - br_L^2) \qquad (2.3.33)$$

The above equation (2.3.33) is a concave function about the bank monitoring effort. So, there is a maximum value of bank's expected profit. By maximizing the bank's expected profit, we can obtain the optimal bank monitoring level:

$$q^* = min\left\{\frac{r_L-(1-k)(r^*+\alpha)}{2c}, 1\right\} \qquad (2.3.34)$$

In the same market structure, in order to find out the sign of $\frac{\partial q}{\partial r^*}$, we can figure out the sign of $\frac{\partial r_L}{\partial r^*}$ first. By substituting the optimal bank monitoring level q^* into the above bank's expected profit function (2.3.33):

$$\Pi = \left[\frac{r_L-(1-k)(r^*+\alpha)}{2c}(r_L-(1-k)r_D) - kr_E - \left[c\left(\frac{r_L-(1-k)(r^*+\alpha)}{2c}\right)^2 + d\right]\right](a - br_L^2)$$

$$= \left[\frac{\left(r_L-(1-k)(r^*+\alpha)\right)^2}{4c} - k(r^*+\beta) - d\right](a - br_L^2) \qquad (2.3.35)$$

Assuming $G = \frac{\partial \Pi}{\partial r_L}$, according to the Implicit Function Theorem:

$$\frac{\partial r_L}{\partial r^*} = -\frac{\partial G/\partial r^*}{\partial G/\partial r_L} \qquad (2.3.36)$$

To achieve the maximum expected profit, bank has to set the level of loan interest rate to satisfy $\frac{\partial G}{\partial r_L} < 0$. So, we just need to consider the sign of $\frac{\partial G}{\partial r^*}$:

$$\frac{\partial G}{\partial r^*} = -\frac{1-k}{2c}(a - br_L) - 2br_L\left[\frac{\left[r_{L-(1-k)(r^*+\alpha)}\right](k-1)}{2c} - k\right] \quad (2.3.37)$$

If $k \to 0$, $\frac{\partial G}{\partial r^*} < 0$, it means, $\frac{\partial r_L}{\partial r^*} < 0$ as well. When $k \to 0$, $\frac{\partial q^*}{\partial r^*} = \frac{\frac{\partial r_L}{\partial r^*} - (1-k)}{2c} \to \frac{1}{2c}\left(\frac{\partial r_L}{\partial r^*} - 1\right) < -1 < 0$. While for $k \to 1$, $\frac{\partial G}{\partial r^*} > 0$, as a result, $\frac{\partial r_L}{\partial r^*} > 0$. As $k \to 1$, $\frac{\partial q^*}{\partial r^*} = \frac{\frac{\partial r_L}{\partial r^*} - (1-k)}{2c} \to \frac{1}{2c}\left(\frac{\partial r_L}{\partial r^*}\right) > 0$. Therefore, at one extreme of k, $k \to 0$, the effect of monetary policy on bank monitoring effort is negative, while at the other extreme of k, $k \to 1$, the effect is positive. This means there must exist a value $k^* \in (0,1)$, for any $k < k^*$, $\frac{\partial q^*}{\partial r^*} < 0$, and for any $k > k^*$, $\frac{\partial q^*}{\partial r^*} > 0$. According to this, we can obtain our proposition 5:

Proposition 5 *When banks monitoring cost function is a convex function and firms loan demand function is the assumed concave function, if banks can decide the size of loan interest rate, r_L, banks that financed with low portion of equity, will pay less monitoring effort with the increase of monetary policy, $\frac{\partial q^*}{\partial r^*} < 0$. Banks will take more risk with the monetary policy increases. Banks who financed with high portion of equity, will pay more monitoring effort with the increase of monetary policy, $\frac{\partial q^*}{\partial r^*} > 0$. Banks will take more risk with the monetary policy decreases.*

The intuition behind the proposition 4 and proposition 5 is that: in the case of limited liability for banks, when the policy rate is low, banks with high equity ratio need to search for higher yield projects to pay the cost of equity. That is because high equity ratio banks only finance themselves in a small percentage of debt, if there is not enough successful loan repayment, they are only not liable for those small part of the debt. Banks still need to pay for the equity cost, which takes a large percentage. This is explained from the search-for-yield effect perspective, while from the value effect perspective, a low monetary policy rate will result in a low loan interest rate, a low interest rate paid to debt and equity. Consequently, banks with higher equity ratios generally need a higher return. Therefore, they would reduce the valuations of their investments, which are in low interest rate, and banks will pay low effort, meanwhile, take more risk. Similarly, from the bank's perspective, the search-for-yield effect will occur at the stage of searching for loans, and the value effect will work at the stage of loan monitoring effort allocation.

b. Piecewise Loan Demand Function

In the second case, similar with the first theoretical model, we assume the new loan demand function is:

$$F(r_L) = \begin{cases} a, if\ r_L \leq r_L^* \\ 0, if\ r_L > r_L^* \end{cases}, \text{ where } 0 < r_L^* < 1 \qquad (2.3.38)$$

r_L^* can be interpreted as either the maximum return on projects, or as the highest rate consistent with borrowers satisfying their reservation utilities. By substituting this new loan demand function into bank's expected profit function:

$$\Pi = \begin{cases} [q[r_L - (1-k)(r^* + \alpha)] - k(r^* + \beta) - (cq^2 + d)]a, if\ r_L \leq r_L^* \\ 0, if\ r_L > r_L^* \end{cases} \quad (2.3.39)$$

If firms have this kind of loan demand function, banks will always optimally set their loan interest rate at the level, r_L^*, to achieve the maximum profit. And the expected profit function will be:

$$\Pi = [q[r_L^* - (1-k)(r^* + \alpha)] - k(r^* + \beta) - (cq^2 + d)]a \quad (2.3.40)$$

Similar with previous parts, the optimal bank monitoring effort is:

$$q^* = \frac{r_L^* - (1-k)(r^* + \alpha)}{2c} \quad (2.3.41)$$

Because the level of r_L^*, is fixed, bank optimal monitoring effort is unambiguously negative correlated with the monetary policy rate. So, a higher monetary policy rate will reduce the level of bank optimal monitoring effort, which means a higher monetary policy rate will increase the level of bank risk taking. According to this, we can obtain our final proposition:

Proposition 6 *When banks monitoring cost function is a convex function and firms loan demand function is the assumed piecewise function, if banks can decide the size of loan interest rate, r_L, banks will take more risk with the monetary policy rate increases.*

2.4 Conclusion

In this chapter, we identify the impact of the monetary policy on the behaviour of banks risk taking in theoretical foundation with different assumptions in different market structures. In our model, monetary policy may affect banks' perceptions of risk taking, and their attitude to risk taking in three forces: the value effect, the search-for-yield effect and the risk-taking-channel effect.

We analyse several cases in which different market structures, a reasonable bank monitoring cost functions and different loan demand functions exist. By letting banks maximize their profits and achieve the equilibrium, we have the theoretical results of our model, with the assumption of unlimited liability for the bank. Firstly, for a convex monitoring cost function, and a linear loan demand function, when the capital structure is exogenous, and banks can choose loan interest rate, a lower risk-free rate unambiguously reduces monitoring and, hence, unambiguously increases bank risk taking. Secondly, for a convex monitoring cost function, and the assumed concave loan demand function, when the capital structure is exogenous, banks can also choose loan interest rate, the result is similar that banks monitoring increases with monetary policy rate. Banks will take more risk with the monetary policy rate decreases. Finally, for a convex monitoring cost function, and the assumed piecewise loan demand function, when the capital structure is exogenous, bank's risk taking level is fixed according to the optimal loan interest rate and it is not affected by monetary policy rate.

Some different results exist when we include the assumption of limited liability for the bank in the case of failure. Firstly, for a convex monitoring cost function, if a bank finances itself with a high equity ratio, both models with linear loan demand function and the assumed concave loan demand function, can predict a positive correlation between the risk free interest rate and bank monitoring effort. Therefore, they can also predict a negative correlation between the policy rate and bank risk taking. A low policy rate level will increase bank risk taking, and a high policy rate level will reduce bank risk taking. Secondly, for a convex monitoring cost function, the model with the assumed piecewise loan demand function, can predict a negative correlation between risk free interest rate and bank monitoring effort. Banks will take more risk with the monetary policy rate increases.

Chapter 3

Bank Risk-Taking and Monetary Policy: Evidence from the United States

3.1 Introduction

Credit risk constitutes a key source of risk for all banks in the world. Since the severe financial crisis of 2007 to 2009 and the ensuing economic contraction, the topic of credit risk taking by banks has become even more important and significant to lots of scholars and bankers. That is because the accumulation of excessive risk taking by many financial institutions, especially in the banking sector, led to severe systemic problems and the eventual collapse of many financial institutions, when the crisis finally occurred. Scholars and other observers are intrigued by what triggered the excessive risk taking for years, which eventually contributed to the building up of the recent financial crisis. A consensus has been placed on the monetary policy and the role it played in influencing financial intermediaries' behaviour (Ioannidou et al., 2015; Jiménez et al., 2014). From a historical perspective, easy monetary policy is generally considered to be a classic ingredient of the financial crisis, since low interest rates may contribute to an excessive expansion of credit, and hence to boom-bust type business fluctuations (Fisher, 1933; Hayek, 1939; Kindleberger and Aliber, 2011). Although it is widely known that the excessive risk taking by banks can weaken the stability of the financial system, and low interest rate may spur banks to soften their lending standards and take on excessive risk, investors, firms, and other market participants still requested central banks to reduce the monetary policy rate to improve their financial situation, which made the whole financial market even worse, during the period of the recent financial crisis. By the middle of the 2000s, these policies of some central banks led to the short-term interest rate dropping to a historical low level. In the US, the federal funds rate decreased from 6.62% in 2000 to 2.27% in 2005, and in 2003 it even reached the lowest level of 0.93%. similarly, in the UK and countries in the Euro area, the short-term interest rate also has an obvious drop during this period. In the UK, it went down from 6.1% in 2000 to 3.5% in 2005, with a record low of 1.2% in 2003, while in the Euro area, the short-term rate fell from 4.4% in 2000 to 2.2% in 2005, with a record low of 2.1% in 2004.

Hence, it is important to find the link between low interest rates and bank risk taking, and analyse how the monetary transmission mechanism works, because low interest rate could indeed induce financial imbalances by means of a reduction in risk aversion of banks and other investors. This part of the monetary transmission mechanism has been recently referred to as the risk-taking channel and relates to how changes in monetary policy rates affect either risk perceptions or risk-tolerance (Borio and Zhu (2008), Adrian and Shin (2009)).

The bank risk taking channel can operate in several main ways to indicate how the low interest rates may affect the bank risk taking level. First, low interest rates can influence valuations, incomes, and cash flows. All those factors will have a direct effect on how banks measure risk, and then influence the level of bank risk taking (Borio and Zhu (2008), Adrian and Shin (2009)).

Second, low interest rate means a low return on general investments, such as government risk free securities. It may increase the incentives for banks to search for some high growth investments, with the aim of getting a higher target of return, and take on more risk for contractual or institutional reasons (Brunnermeier, 2001 and Rajan, 2005). Generally, the risky assets will be more attractive if the short-term interest rate is low. As a result, investors may search for yield by financial intermediaries in the short run. This will cause both serious agency problems and a strong reliance on short term funding. Hence, the low interest rate may spur bank risk taking. The sustained low interest rates stimulate the boom of the global capital market and credit market, and it encourages financial institutions to take too much risk under higher leverage.

Third, low interest rate may reduce the degree of risk aversion of big size banks and other institutions, which will also induce financial imbalance in turn. In this case, banks will soften their lending standards, and believe the central bank will ease the bad outcome of monetary policy, whenever the economic state is good or bad. It can be explained by the part of monetary transmission mechanism which has been termed the risk-taking channel of monetary policy by Borio and Zhu (2012). And they highlight the influence of monetary policy on the risk perceptions and the risk-tolerance by economic agents.

In this chapter, we will investigate the relationship between short-term low interest rates and bank risk-taking in U.S. banking system, by using a unique quarterly data that includes balance sheet information for listed top 30 banks over the period from 2000 to 2017. This chapter finds evidence that low interest rates will contribute to the increase of bank risk-taking. Moreover, this effect of monetary policy on bank risk-taking is stronger after the financial crisis, and weaker before the financial crisis. We also discuss the different effects of short term interest rates on risk-taking by banks with different characteristics, such as, the capacity of bank's capitalization, and bank's equity ratio. The result indicates that the effect monetary policy on bank risk-taking is positively correlated with the size of bank's capitalization and bank's equity ratio. These results are consistent with the evidence collected by a growing empirical literature on the effects of monetary policy on risk-taking (see, for example, Maddaloni and Peydró, 2011, Dell' Ariccia et al, 2010, and Ioannidou et al., 2009).

As a background of our model in this chapter, we adopt a theoretical bank profit model, under the assumption of limited liability, where banks can engage in costly monitoring effort to reduce the credit risk in their loan portfolios. This is a simple model about the relationship between bank risk-taking and monetary policy, it predicts that there is a negative correlation between bank risk taking and risk-free interest rate. Dell'Ariccia et al (2010) indicate that the monetary policy rate can determine the bank's deposit rate and affect the bank's incentive to take risks through two channels. The first one is a pass-through effect, which acts through the asset side of a bank's balance sheet. An easy monetary policy will reduce the policy rate, which will reduce the bank's loan interest rate. This means a bank will receive a relatively lower gross return on its loan portfolio. And as a result, bank would generally reduce the level of the monitor, because a higher monitoring level will increase the probability of the bank's loan repayment. This effect can also be explained by the portfolio reallocation effect in portfolio choice models, in which, banks will typically increase their demand for risky assets, if monetary easing reduces the real yield on safe assets (Fishburn and Porter, 1976). The second effect presented by Dell'Ariccia et al (2010) is a standard risk-shifting effect working through the liability side of a bank's balance sheet, which is an opposite effect with the first effect. It is because that monetary easing will reduce the cost of a bank's liabilities. In that case, banks will obtain more profits if they succeed to receive the repayment. With this effect, bank's incentive to taking risks will be reduced, while the first effect will spur banks risk taking decisions. Based on those, the two effects tend to offset each other. In this theoretical model, the first effect has been provided to be more powerful. And its strength depends on the equity ratio of banks. So, we will compare the strength of our empirical model with high and low equity ratio banks.

The remainder of this chapter will be organized as follows. The next section briefly introduces the current research in both related theoretical and empirical papers. Section 3.3 presents the methodology used to analyze the relationship between the policy rate and banks risk taking. Section 3.4 will present the empirical methodology and data in this chapter. Section 3.5 presents and explains the empirical results. Section 3.6 concludes.

3.2 Literature: Theory and Evidence

This chapter is based on a large number of theoretical works and empirical works, which study either monetary policy, bank risk taking, or the relationship between them in the financial market. In this section, we will introduce the relevant theory about how monetary policy (low interest rate) can affect bank risk taking decisions, as well as some empirical evidence, which has been done by other researchers in this topic.

To achieve a target level for a short term interest rate, the central banks in the major developed countries implement policy to intervene in monetary market (Walsh, 2017). According to Walsh (2017), the instruments which are the variables directly controlled by the central bank, generally include the interest rate charged on reserve borrowed from the central bank, the reserve requirement ratio which will determine the level of reserves, and the composition of the central bank’s own balance sheet. With the help of those instruments, monetary policy can affect nominal rates, in both the short run and the long run. In the financial market, if the interest rate (policy rate) keeps in low level, it will determine the market risk free rate and can influence bank risk taking via several different ways. There are three broad approaches that have been used to explain the connection between them. The first approach to influence bank risk taking decisions by low interest rate is through the impact of low interest rate on valuations, incomes and cash flows and measured risk (Altunbas et al. 2010). All those factors will have a direct effect on the banks’ risk taking decisions. If the interest rate keeps low in the long period, the value of assets and collateral will be affected. What is more, it will also affect the banks’ estimation of the probability of default, the loss given default, and the market volatility. Meanwhile, if the managers of banks that think the low interest rate will still last for a long period and the financial market will keep in positive condition, it will reduce the risk aversion of banks. So, easy monetary conditions may increase the banks’ risk tolerance. This is quite close to the financial accelerator, in which increases in collateral values reduce borrowing constrains (Bernanke et al, 1994). However, others maintain that the risk-taking channel is distinct but complementary to the financial accelerator, because it focuses on the amplification mechanisms, which allow relatively small shocks to propagate through the financial, due to financing frictions in the lending sector (Adrian and Shin, 2009b).

Secondly, the channel is described by Rajan (2005) as 'search for yield' is not new. It also appeared in the Global Unbalance literature (see, King, 2010, and Borio and Disyatat, 2011) and in the Feldstein Horioka puzzle literature (see, Feldstein and Horioka, 1980, and Lucas 1990). It suggests that low interest rate may tempt the asset managers and single investor to take on more risks. They may blindly pursue return and ignore some potential risks and uncertain factors. When the interest rate is high, banks can invest in riskless assets to obtain the return. However, they have to invest in some risk assets to pay back their debt, when the interest rate is low. And according to Shleifer and Vishny (1997), Brunnermeier and Nagel (2004), there is a quite similar mechanism which might be in place when private investors use short term return as a way to judge the managers' competence and withdraw funds after some poor performance.

Risk taking may also be affected by a third way, such as the communication policies of a central bank and the characteristics of the policymakers' reaction function, comes from the principal agent problem, in the form of moral hazard (Altunbas et al. 2010). If a central bank will predict its own future policy decisions to a quite high degree, the market uncertainty would be reduced, and banks would like to take many more risks. As a result, the agents and investors will believe that the central bank will ease the bad outcome of monetary policy. Diamond and Rajan (2009) stressed that the monetary policy should be kept tighter than the degree of the current economic conditions. And it will reduce the probability of banks taking on liquidity risk. Another example of this effect can be shown in the case of 'Greenspan Put'. In this situation, the central bank will generally take powerful measures to control the state economy and help financial stability, when the economic downturn occurs. The expectation of a bank which the central banks will help to contribute the financial stability, may lead banks to take more risk (Farhi and Tirole, 2009). So, in this case, banks can increase their yield by taking more risks. Even banks default due to the excessive risk taking, they will believe that the central bank is still willing to support them to help the state economy and financial stability. Then, banks risk taking can be affected by the central bank's behaviour to the economic situation. However, this will also lead to the moral hazard, because banks may always believe that central bank is willing to remedy for their excessive risk taking.

Generally, the first two channels focus on the monetary policy environment, while the last one focuses on the response function of central banks. Except for those three channels, the influence of monetary policy on bank risk taking can also be explained through a different perspective, which is from the action of two sides of banks' balance sheet -- the asset side and the liability side (Dell'Ariccia et al. 2010).

On the asset side, how monetary policy affects bank risk taking can be explained by a 'pass through effect' (Dell'Ariccia et al. 2010), which is a quite important determinant of banks' risk taking decisions. The 'pass through effect' can influence the bank risk taking level through the asset side of a banks' balance sheet. As a result of monetary easing, the policy rate should be reduced, which can generally determine the interest rate of bank loans in a positive relationship. So, the interest rate of bank loans will also decrease. Banks' profit should be affected by the loan interest rate. In this case, the banks' income will decrease. If a bank wants to achieve the target profit, it will give the bank an incentive to take more risk, and reduce the demand for less risky assets.

On the liability side, the influence of monetary policy on banks risk taking, can be explained by a 'risk shifting effect' (Dell'Ariccia et al. 2010). When a monetary easing policy is working, the risk free rate will reduce, which has a positive influence on banks' liability. As a result, the cost of a bank's liability will be reduced. Banks may just need to invest in some safer assets that can guarantee a higher repayment probability, as well as lower return, to pay the low cost liability. So, banks are willing to choose the safer investments, and the incentive of banks reducing the risk taking will increase. In contrast, in a tight monetary policy, the cost of a bank's liability will increase. Banks need to pay more to the liability. So, the incentive of a bank taking more risk will increase. It has an opposite effect on the relationship between monetary policy and bank risk taking, comparing with the pass through effect. So, in reality, how a bank chooses the level of the risk it takes, will depend on the tradeoff of the opposite effects.

Alongside the theoretical evidence, there is an increasing volume of empirical literature attempting to test the link between monetary policy and bank risk taking. Jiménez et al (2014) used the microdata of the Spanish Credit Register from 1984 to 2006 to test whether the stance of monetary policy has an impact on the level of individual bank loans. They identified the effect of monetary policy on credit risk taking with an exhaustive credit register of loan applications and contracts. They found that high bank risk taking comes with a period of easy monetary policy. And due to higher collateral values and the 'search for yield', bank would like to grant the riskier loans and to soften their lending standards. In this case, banks will lend more to borrowers who have a bad credit history and the borrowers with more uncertain prospects. Similarly, Maddaloni and Peydró (2011) used the lending standard to study the determinant of banks' lending standards in the Euro Zone's banking. They stressed the impact of low interest rate on the lending standards. Altunbas et al. (2010) found that low interest rate will increase the lending risk taking of banks, by using the data of listed banks in the European Union and the United States.

It was examined by researchers whether the risk taking channel works on both the quantity of new loans and their interest rates, and they found that when the interest rate is low, banks increased the number of new risk loans (Ioannidou et al, 2009). What is more, they also reduce the rates, which they charge to the borrowers compared with the rates, which they charge to the fewwe risk borrowers. The same investigators (Ioannidou et al 2015) studied the risk-taking channel of monetary policy in Bolivia. They found that "a lower policy rate spurs the granting of riskier loans, to borrowers with worse credit histories, lower ex-ante internal ratings, and weaker ex-post performance".

3.3 Theoretical Methodology

In this part, we adopt a simplified version of the theoretical model described in Chapter 1: consider a simple model, with two parties: firms (borrowers), and banks (lenders), in the financial market. Firms can decide to invest in projects with different risk levels. Because each firm also has an external financial demand in the investment activity, they need to apply for a loan, which is supplied by banks. The firms or the projects a firm processing, can be graded according to their risk level. We assume that a firm will have more chances to success, if the bank who grants loans to this firm pays more monitoring effort on it. That is because, for example, bank's monitoring can help to reduce the agency problem between the shareholders and the managers of the firm, and as a result, the monitoring behaviour of banks can reduce the risk of the firm and increase the firm's value. Another way of thinking about the reason why bank monitoring can improve firms' performance is that banks can help firms in better behavior, such as controlling risk taking levels, doing more effective investments, or adjusting firms' strategy properly, according to the information banks observing. To be more specific, a firm with better performance and better behaviour means that it will have a higher probability to avoid failing and a higher probability to have the ability to repay the loan. What is more, banks financial expertise can also help firms improve firms' probability to succeed, and their expected value (see Besanko and Kanatas (1993), Boot and Greenbaum (1993), Boot and Thakor (2000), Carletti (2004), and Dell'Ariccia and Marquez (2006)). Meanwhile, a firm with better performance will also increase the confidence of the firm's shareholders and investors, who will evaluate the firm higher, and increase the share price of this firm. As a result, the expected value of the firm with bank's financial expertise will rise.

In this theoretical model, the borrower's demand function of loan is initially assumed as a linear function, which is negatively correlated with the loan rate charged by banks. This assumption is quite popular in the literature (for example, Den Haan, Summer, and Yamashiro, 2007, etc.). So, the loan demand function can be written as: $F(r_L)=a-b*r_L$, where r_L is the loan interest rate, charged by banks, both a and b are positive constants, and a is the maximum amount of loan a firm can borrow from the lender, b is the loan interest rate elasticity of loan demand. The loan interest rates are different for different borrowers, and they are set according to the policy rate and banks' evaluation of firms.

Banks who are the loan suppliers will grant loans to projects or firms with different risk levels. They can choose to monitor their loan portfolio to reduce their risk taking, and increase the probability of loan repayment. We can assume that the banks monitoring also works in both good and bad states of the economy. This is because banks will also have the ability to choose the acceptable firms or projects to invest, and to improve the probability of repayment, even in an extreme economic condition. For example, in a bad state of the world, it is harder for most firms to be successful. But banks also need to grant loans to firms to get profits. They can use the monitoring effort to increase firms' probability to succeed, even in a lower amount, compared with the case in an average or good economic environment. So, we use the bank monitoring effort as an inverse proxy of bank risk taking. The basic principle is that the more monitoring effort bank pays on their portfolio, the less risk will be borne by banks. This monitoring effort is costly and not contractible. The monitoring effort can also represent the probability of firm success and the loan repayment. As a consequence, banks can choose the level of monitoring to affect their expected profits of the investment to each firm. So, there should be an optimal monitoring level, under which banks can maximize their profits. The optimal bank's monitoring level is not fixed, which is different in different firms and projects. For simplicity, we assume each bank will only lend to one firm, during the lending and borrowing process in this model.

Concerning the bank model, we assume banks have to choose a level of q $(q \in [0,1])$, which is the monitoring effort, to increase the probability of firm (the borrower) success and the loan repayment. The cost of bank monitoring is cq^2+d per unit borrowed by firms. Where, c is a positive constant, d is also a positive constant, which means the fixed cost of the bank monitoring. The intensity [0, 1] of q, can also be interpreted as the probability of firms' success, which is consistent with the assumption that the probability of firms' success will increase, with a higher and higher monitoring level by banks. The convex cost function captures the idea that it will be increasingly difficult for banks to explore more and more information about the firm in which they invested. It means that banks need to pay more monitoring effort to obtain the same amount of information about the firm, compared with the beginning stage. The convex bank monitoring cost function is supported by a large amount literature (see Besanko and Kanatas, 1993, Holmstrom and Tirole, 1997, Carletti, 2004, Dell'Ariccia and Marquez, 2005, etc.).

Regarding the bank's capital structure, banks finance themselves in two different ways. The first part is financed by debt, and the other part is funded by equity. We assume that the bank is financed with a portion of k in equity, at a cost of r_E, and a proportion of $1- k$ in debt, at a cost of r_D. Hence, r_E and r_D also mean the interest rate paid to the shareholders and the depositors. Both of them are positively related to the risk-free rate which is r*. This allows that monetary policy can change the cost of banks' liabilities by changing the risk-free rate. Then, r_E and r_D can be expressed as: $r_D = r^* + \alpha$, and $r_E = r^* + \beta$, where, $\alpha \geq 0$, it can be regarded as the incentive to depositors; and $\beta \geq 0$, it can be regarded as the incentive to equity investors. According to Dell'Ariccia, et al. (2010), in our model we assume that the premium on equity and debt, α and β , are independent of the policy rate, r^*. That is consistent with our goal to isolate the effect of an exogenous change in the stance of monetary policy. However, this might be not consistent with the Modigliani and Miller theorem, because, from an asset pricing perspective, they are likely to be correlated. That might happen through the underlying common factors which may dive both the risk premium and the risk free rate. However, the results continue to hold as long as the within period correlation between them is sufficiently different from (positive) one. Generally, the equity premium as a spread over the risk-free rate can be used to explain the reason why $\beta \geq 0$. On the other hand, banks always would like to pay a higher interest rate than the risk free rate to the depositors, because they need to attract these investments from depositors by a higher return. If not, depositors will withdraw their savings, banks do not have enough funds to invest. They are broadly discussed in the literature (see Dell'Ariccia, et al., 2010, Allen, et al., 2005, Repullo, 2004, Hellmann, et al., 2000 and Berger, et al., 1995, etc.).

There will be four stages in this model: stage 1, the policy rate is set by the central bank; stage 2, banks choose the interest rate to charge on loan – r_L, the interest rate paid to shareholders – r_E, and depositors – r_D, and they also set the leverage level -- k; stage 3, firms apply for the loan and borrow from banks at the rate of r_L; stage 4, banks investigate the firm or its project at the initial fixed cost *d*, and decide whether to grant the loan or not. If banks do accept the loan, they choose the monitoring effort q.

Given the amount of the factors in the above section, the bank can maximize the expected profits by choosing its optimal level of monitoring. Here, under the limited liability of a bank, we can write the bank's expected profit function as:

$$\Pi = [q * \left(r_L - (1-k)(r^* + \alpha)\right) - k(r^* + \beta) - (cq^2 + d)](a - br_L)$$

(3.3.1)

Where, Π is the bank's expected profit;

q is the monitoring effort, or the probability of the loan repayment;

r_L is the interest rate charged by banks;

k is the portion of bank assets financed with equity;

1- k is the fraction of bank's portfolio funded by deposits;

r^**is risk-free interest rate;*

$cq^2 + d$ *is the cost function of bank monitoring;*

$a - br_L$ *is the firms' loan demand function.*

This function shows the bank's profit from the loan, and it depends on the probability q. In other words, if a bank's project succeeds, it will receive the payment from the loan and pay costs of debt, equity, and bank monitoring. When a bank's project fails, which means the borrower cannot make any payment to the bank, a bank will receive no revenue, but it will still need to pay the cost of capital. In other words, the bank attempts to repay shareholder, in this model, even it fails. That is because, the cost of equity is borne irrespective of the bank's revenue. However, for the cost of debt, a bank does not need to pay it, if it fails, because of the limited liability

To maximize bank profit with respect to q, in the above function, we can obtain the optimal bank monitoring effort level:

$$q^* = min\left\{\frac{r_{L-(1-k)(r^*+\alpha)}}{2c}, 1\right\} \qquad (3.3.2)$$

As a result, this model predicts that banks financed with low portion of equity, will pay less monitoring effort with the increase of monetary policy, $\frac{\partial q^*}{\partial r^*} < 0$. Banks will take less risk with the monetary policy decreases. Banks who financed with high portion of equity, will pay more monitoring effort with the increase of monetary policy, $\frac{\partial q^*}{\partial r^*} > 0$. Banks will take more risk with the monetary policy decreases. Thus, this model can predict a negative relationship between bank risk taking and monetary policy for the high equity ratio banks. This effect can be affected by the fraction of equity and debt.

3.4 Empirical Methodology and Data

In this section, we will use empirical regression to test and analyse the effect of monetary policy on bank risk taking based on the above theoretical model. Our basic regression model is:

$$q_{i,t} = \alpha + \gamma \Pi_{i,t} + \delta r_{i,t} + \theta r_t^* + \rho k_{i,t} + u_i + \varepsilon_{i,t} \qquad (3.3.3)$$

Where, $q_{i,t}$ *is risk taking variable of bank i, in period t;*

Π_{it} *is the profit of bank i, in period t;*

r_{it} *is the loan interest rate charged by bank i, in period t;*

r_t^* *is the risk-free rate in period t;*

k_{it} *is the portion of assets financed with equity in bank i;*

u_i *is the random effect specific to individual bank i;*

ε_{it} *is the error term.*

All the variables in the above theoretical model are included in this empirical model. Because we want to test the effect of monetary policy rate on bank risk taking, we set the bank risk taking variable at the left side of the function and set the policy rate variable as the main independent variable. Other independent variables include loan interest rate, equity ratio, bank profit, etc. These variables are nominal.

In this chapter, we use a unique database, which includes the balance sheet information (market values, ratios, etc.) for the listed top 30 banks by capitalization size over the period 2000 to 2017 in United Stated. The list of banks sample is in the table 1 in the Appendix. All the data involved in this chapter are quarterly data, from quarter 1 in 2000 to quarter 1 in 2017. There are a totally 1950 observations for all these 30 banks. Most bank relative data come from the Orbis BankFocus, and the policy rate data comes from Thomson Reuters DataStream.

Next, we will describe the variables in our model. We use Z-Score (Altman, 1968) as an inverse proxy of bank risk taking level – dependent variable $q_{i,t}$, in other words, it can be used as a proxy of bank monitoring effort level. It is a very common practice in existing literature (see, Demirguc-Kunt and Huizinga, 2010; Houston et al., 2010; Laeven and Levine, 2009). There are also various other risk measures, but these often require market as well as accounting data and so may not be feasible in this case. Z-score can be used to measures the distance from insolvency (Roy, 1952), which is defined as a state where losses are larger than equity. A high Z-score means more stability is the bank. So, the higher Z-score is, the more monitoring effort will be paid by a bank, and the less risk will bank take. It can be calculated by the return on assets plus the equity to asset ratio divided by the standard deviation of return on assets. That is $Z = \frac{ROA+CAR}{\sigma(ROA)}$, where, ROA is the rate of return on assets (which is profit after tax over total equity), CAR is the capital assets ratio, and $\sigma(ROA)$ is an estimate of the standard deviation of return on assets.

Intuitively, this measure of Z-score represents the number of standard deviations below the mean by which profits would have to fall so as to just deplete equity capital (Boyd, De Nicolò, and Al Jalal, 2006). It has been widely used to measure the bank risk taking level recently (e.g. Houston et al 2010, Laeven and Levine, 2009). Regarding the independent variables, we use banks' net income to measure the banks' profit (in a hundred thousand US Dollars). It is the banks' profit after tax. In our database, this variable is calculated by profit before tax takes off the income tax expense, then plus the net profit for the year from discontinued operations. The loan interest rate (which is interest on loans over performing loans), equity ratio and policy rate are all measured in percentage. Because we are testing the effect of short term interest rate on banks risk taking, in this chapter, the 3-month U.S. Treasury bill rate will be adopted to measure to risk free rate. For the data stationary, we will use the first difference of risk free rate in our model.

Although all the variables have been included in the equation (3), the empirical estimation of this model still presents a number of challenges. The two main identification limitations of testing the effect of monetary policy rate on bank risk taking are the potential endogeneity of monetary policy rate to the risk taking variable in the banking sector (Jiménezet al., 2014), and the persistence of bank risk taking level (Delis and Kouretas, 2011). Besides, the bank characteristics, such as profitability, bank equity ratio, loan interest rate, etc., may also be endogenous to the risk taking level by banks. That is because causality may run in both directions – from left hand side variable to right hand variables and vice versa. Concerning the endogeneity of monetary policy to the bank risk taking on the right hand side of the equation, it is maybe particularly true during the period of the financial crisis, because there is a rapid expansion on the set of conventional and unconventional policy measure by central banks to improve the situation of banks and other financial institutions (Altunbas et al., 2014). That means that central banks may have to change the monetary policy, especially the short term interest rates, to affect banks' risk taking level, with the aim of simulating the economy and stabilizing the financial market, in that period. For other bank specific controls, it is well-known that they can interact with the bank risk taking variable, for example, the equity ratio can be regarded as a measure of bank capitalization, and a bank can change its capital structure by taking different levels of risk, which can change the investors' investment strategy, according to their risk preference. On the other hand, a bank can also set different risk taking targets by changing its capital structure, because "search for yield". Hence, the bank can tradeoff higher levels of equity capital for risk assets, which indicates an endogenous relationship. From an econometric perspective, endogeneity implies that the interest rate and other bank specific variables are correlated with the error term, $\varepsilon_{i,t}$, which may bias the estimation results. To tackle endogeneity, an instrumental variable method can be adopted, which will be introduced below.

The second main identification challenge in equation (3.3.3) is the persistence of bank risk taking. To deal with it, we will estimate a dynamic panel data model, which accounts for risk persistence. This means a lagged dependent variable ($\beta * q_{i,t-1}$) can be added in the right hand side of equation (3.3.3) to build up this dynamic model. The coefficient β on the lagged risk variable may be viewed as the speed of adjustment from past risk taking by banks. A value of β close to 0 means that the bank will accompany with a high speed to escape from the influence of its past risk taking level, while a value of β close to 1 implies that the bank's adjustment of past risk taking is very slow. All the values between 0 and 1 suggest the presence of risk persists, and the past risk taking level must have a positive influence on banks' current risk taking level. Therefore, the new equation that will be estimated in this stage has the following functional form:

$$q_{i,t} = \alpha + \beta q_{i,t-1} + \gamma \Pi_{i,t} + \delta r_{i,t} + \theta r_t^* + \rho k_{i,t} + u_i + \varepsilon_{i,t} \qquad (3.3.4)$$

According to Delis and Kouretas (2011), there are several theoretical reasons, which can be provided to explain the dynamic nature of bank risk term. First, persistence may reflect the existence of intense competition, which tends to increase the risk taking of banks (e.g. Keeley, 1990; Cordella and Yeyati, 2002). Second, relationship-banking with risky borrowers will have a lasting effect on the levels of bank risk taking, although banks will reduce the operating cost and improve efficiency, if they work with the same client. Thirdly, if the risk is associated with the business cycle, banks may spend more time to ease the effects of macroeconomic shock. Fourth, risks may persist due to regulation, in particular, banks may have to invest in risk assets over a long period time, under some specific policy condition, e.g. in the periods, when risk free interest rate is low, or money supply is low, etc.

To obtain consistent and unbiased estimates of the relationship between monetary policy and bank risk taking, the above equation (3.3.4) can be estimated using the Generalised Method of Moments (GMM) for dynamic panel data. This model is introduced by Holtz-Eakin et al. (1988) and Arellano and Bond (1991) and further developed by Arellano and Bover (1995) and Blundell and Bond (1998). Here, we choose the Arellano – Bond GMM estimator, that is because: first, it can be used to solve the endogeneity between risk taking level and some of the right hand side variables by means of appropriate instruments. Compared with the instrumental variable estimation -- two-stage least squares or 2SLS, in the Arellano – Bond GMM estimator model, not only use the exogenous listed instruments, it also adds lagged levels of other endogenous regressors. This makes the endogenous variables pre-determined, and as a result, they will not be correlated with the error term in equation (3.3.3) (Roodman, 2006). Second, the presence of the lagged dependent variable $q_{i,t-1}$ on the right hand side may give rise to autocorrelation. It will render the Ordinary Least Squares estimator biased and inconsistent even if the idiosyncratic errors are not serially correlated (Baltagi, 2013). Hence, to solve it, the first-differenced lagged dependent variable will be used in the Arellano – Bond GMM estimator model.

There are two available Arellano–Bond estimators in STATA, one called xtabond which has been incorporated into STATA, and one called xtabond2, which is a proprietary program written by Roodman (2006). Although the first estimator is easier to use in STATA, we found the second one is better with more additional features and it is more plausible to analysis the effect of monetary policy on bank risk taking. Concerning the second command, as shown by Blundell and Bond (1998, 2000) and Bond et al. (2000), the Arellano – Bond difference GMM estimator is less efficient than the system GMM, when the autoregressive parameter is high, and the time-series dimension of the underlying data is moderately small. This means that the lagged values of the variables are only weakly correlated with the endogenous variables and are weak instruments (Hou and Chen, 2013). The first-differences GMM estimation also suffers from a loss of valuable observations. Under these conditions, the first-differences GMM estimation is likely to perform poorly. Hence, we will adopt the system GMM estimator suggested by Arellano and Bover (1995), Blundell and Bond (1998), because it is more plausible.

The system GMM estimator uses a system of two sets of equations: one differenced and one in levels. To be more specific, it combines the standard set of equations in first differences and an additional set of level equations. The system of equation takes the following form:

$$\begin{cases} q_{i,t} = \alpha + \beta q_{i,t-1} + \gamma \Pi_{i,t} + \delta r_{i,t} + \theta r_t^* + \rho k_{i,t} + u_i + \varepsilon_{i,t} & (3.3.4) \\ \Delta q_{i,t} = \alpha + \beta \Delta q_{i,t-1} + \gamma \Delta \Pi_{i,t} + \delta \Delta r_{i,t} + \theta \Delta r_t^* + \rho \Delta k_{i,t} + \varepsilon'_{i,t} & (3.3.5) \end{cases}$$

Before talking about the empirical estimation results, we will have a look at the summary statistics and correlation coefficients between these variables. Table 3.1 shows the descriptive statistics of all the unbalanced panel data in this model. The mean of Z-score is 0.1839, with the standard deviation of 0.0966. Because Z-score is used to describe the probability of bank succeeds, the highest success probability is around 0.5, while the lowest is 0.003. The average loan interest rate in last 17 years is 0.03% higher than the average 3-month U.S. treasury bill rate. The equity ratio in U.S. top 30 banks varies from 4.54 to 54.03 in the last 17 years, which is a big range. So, we will have a look at the different performance of banks risk taking decisions for banks with high equity ratio and low equity ratio.

Table 3.1 Descriptive Statistics.

Variable	Observation	Mean	Standard Deviation	Min	Max
Z-score	1,950	0.1839292	0.0965261	0.0025459	0.4920304
Risk-free interest rate	1,950	1.419405	1.76845	-0.01	6.21
Loan interest rate	1,950	1.443896	0.5958023	-3.671252	5.405406
Equity ratio	1,950	10.89607	4.425616	4.54	54.03
Profit	1,950	8.106195	15.6693	-180	77.8

Z-Score is an inverse proxy of bank risk taking level,

Loan interest rate, equity ratio and risk-free interest rate are all measured in percentage,

Risk-free interest rate is measured by 3-month U.S. treasury bill rate.

Source of data: Orbis BankFocus and Thomson Reuters DataStream

Table 3.2 reports the correlation coefficients between all explanatory variables. It suggests that only the correlation between the interest rate variables (loan interest rate and risk free interest rate) is moderate, but still at an acceptable level. The result shows that multicollinearity will be unlikely to affect the following estimates. In what follows, some further empirical estimations will be discussed.

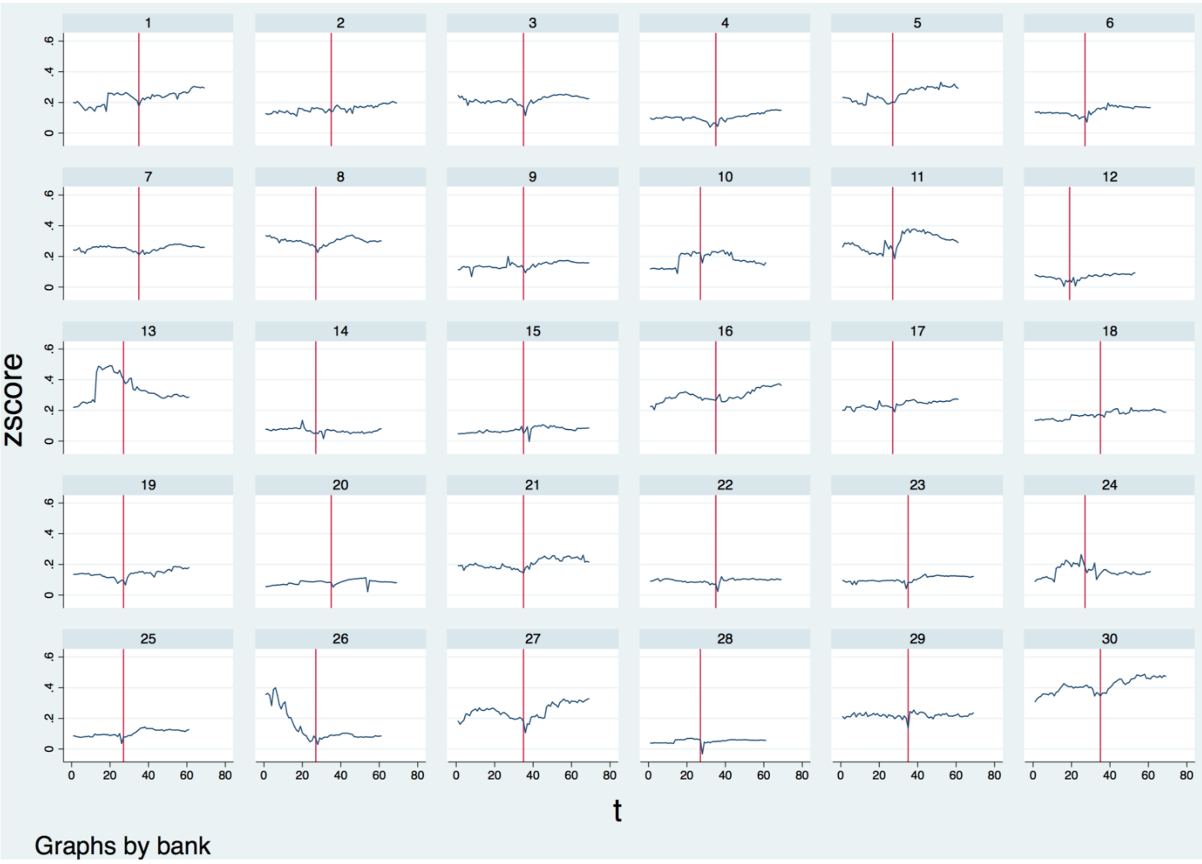
Table 3.2 Correlation Matrix.

	Risk-free interest rate	Loan interest rate	Equity ratio	Profit
Risk-free interest rate	1			
Loan interest rate	0.4517	1		
Equity ratio	-0.1537	0.1306	1	
Profit	-0.0079	0.0578	-0.0794	1

Source of data: Orbis BankFocus and Thomson Reuters DataStream

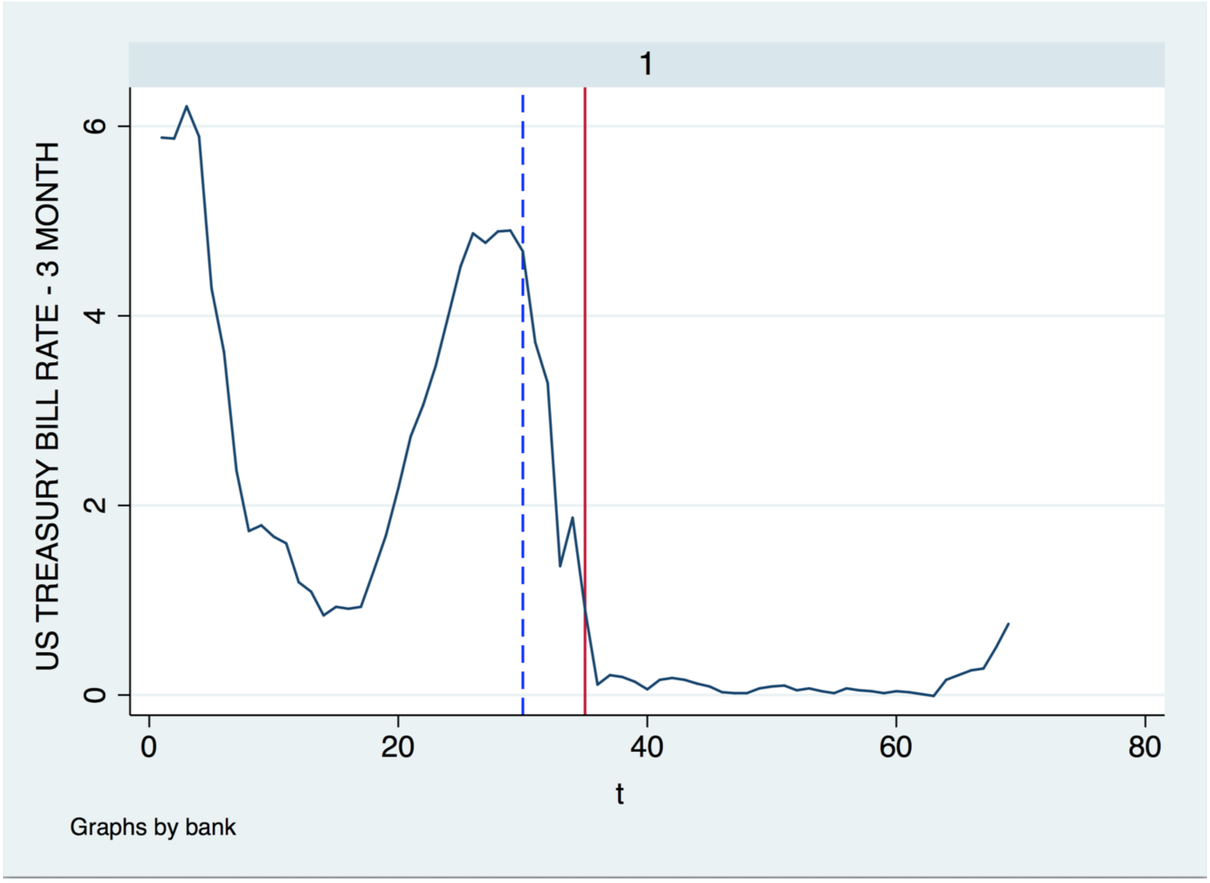
To find out if the financial crisis changed the banks' risk attitude, in Figure 3.1, we compare the trend of their monitoring effort in the past 17 years first, especially during the period of the financial crisis. We set t=35, which is the third quarter in 2008, at the period of financial crisis, and from the following figures, we find most banks have a significant drop of the Z-score value in 2008. That means, from this period, lots of banks relaxed the monitoring, and took more risk. This is consistent with the fact that around the period of 2008, lots of banks take on excessive risk, and eventually lead to the financial crisis. Moreover, most banks loan portfolio monitoring levels had an increasing trend after the recent financial crisis. This can be explained that after the crisis, bankers and policymaker paid more attention to the risk taking and be more enthusiastic to monitor banks' loan portfolios, to avoid excessive risk taking. In Figure 3.2, we set the same time for the change of the monetary policy rate, which is the solid vertical line. We also add a dashed vertical line in Figure 3.2, which is 2007 quarter 2. It is the time when the short term interest rate started to drop. Between 2007 quarter 2 and the recent financial crisis, there is a one year gap, in which, the bad outcome occurred. During that period, banks released their lending standard, took more and more risks, and finally, the financial crisis occurred. It is obvious that in the year 2008, U.S. short-term treasurer bill rate drops a lot. Thinking about the change of banks' risk taking level at the same period, there must be some interaction between the monetary policy rate and bank risk taking during the financial crisis, Therefore, in the following section, we will discuss the influence of the financial crisis on bank risk taking behavior for further detail.

Figure 3.1 Individual bank time series values of Z-score



Vertical line at 2008 Q3. Source of data: Orbis BankFocus and Thomson Reuters DataStream

Figure 3.2 U.S. Short-Term Treasury Bill Rate



Solid vertical line at 2008 Q3, dashed vertical line at 2007 Q2

Source of data: Orbis BankFocus and Thomson Reuters DataStream

3.5 Empirical Results

Here, we present the main results of our empirical models. And depending on these results, we will conclude the relationship between bank risk taking and monetary policy rate. we will also do some other tests to analyze bank risk taking behavior. Let us start with results of our main estimations -- Arellano-Bond dynamic panel data estimation, which is sectionalized into different periods.

3.5.1 Main Estimations

Following Roodman (2006), for the purpose of avoiding instruments proliferation, we use a collapsed instrument matrix. It can help to create one instrument for every variable and lag distance. Otherwise, considerably more instrument variables will be created for each period of time, variable, and lag distance. On the other side of the number of instruments, the Hansen test may be weakened by too many instruments, which will affect the instruments' validity. Therefore, in our results, the number of instruments is restricted by the collapsed instrument matrix to be 30, which is not larger than the number of groups. Moreover, we also use the dynamic panel-data estimation, with two-step system GMM, in which, the standard covariance matrix is robust to panel-specific autocorrelation and heteroskedasticity. The Arellano-Bond tests the first order autocorrelation, AR1, in the first difference errors. The result accepts the presence of the first order serial correlation, which means that the first lag of the dependent variable is exogenous. But the result rejects the presence of the second order serial correlation, AR2. Meanwhile, the Hansen test of overidentifying restrictions indicates that our instruments variables set is valid.

Table3.3 Short-Term Interest Rate and Bank Risk Taking: Arellano-Bond Dynamic Panel GMM Estimators

	2000-2017	2000-2008	2008-2017
Lagged inverse bank risk	0.412***	0.411***	0.524***
	(0.010)	(0.009)	(0.029)
Risk-free interest rate	0.002***	0.003***	0.011***
	(0.000)	(0.001)	(0.003)
Profit	0.0005***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Loan interest rate	0.014***	-0.003***	0.003*
	(0.001)	(0.001)	(0.001)
Equity ratio	0.007***	0.008***	0.008***
	(0.000)	(0.000)	(0.001)
T	0.0005***	0.0002***	0.0002***
	(0.000)	(0.000)	(0.000)
No. of observations	1920	1020	870
No. of Instruments	30	30	30
No. of Banks	30	30	30
Wald-test	53616.330	66173.920	45272.140
Wald-test p-value	0.000	0.000	0.000
AR(1)	0.000	0.000	0.001
AR(2)	0.112	0.351	0.111
Hansen	0.218	0.554	0.277
Difference-in-Hansen tests (Hansen p-value)	0.175	0.332	0.230
Difference-in-Hansen tests (difference)	0.484	0.930	0489

** indicate statistical significance at the 10%, ** indicate statistical significance at the 5%, and *** indicate statistical significance at the 1%. Standard errors are in parentheses.*

The table 3.3 presents the results of our main empirical estimations. It reports the coefficients, standard errors which are in parentheses, and its p-values which are indicated by *. In the first column, the full period observations are included, from the first quarter in 2000 to the first quarter in 2017, which involves the periods pre-crisis and post-crisis. In the second column, only the data before the financial crisis are analyzed. It contains the period from quarter 1 in 2000 to quarter 3 in 2008. Similarly, we test the observations after quarter 3 in 2008 as a post-crisis analysis, in the last column. The dependent variable is the inverse risk proxy-- Z-score. In the following section, we will also test the effect of monetary policy on bank risk taking by adopting other bank risk taking measures for the purpose of robustness checks. Similarly, another measure of interest rates will also be compared to test the robustness, because there is a fixed variable for short term interest rates used in this stage estimations. The Wald-test and its associated p-value denote the goodness of fit of the regressions, AR1 and AR2 are the tests for first and second-order autocorrelation.

Following the results in the first column, it is obvious that the coefficients of all the variables are positive and strongly significant. It indicates all the explanatory variables have a positive influence on the inverse bank risk proxy – Z-score. in other words, these explanatory variables can affect the bank risk taking behavior in a negative way. For the key variable – risk free interest rate, the positive and significant coefficient suggests that there is very strong evidence lower short-term risk-free interest rate will reduce the bank monitoring effort level, and encourages bank risk taking significantly. With every percentage point decrease of monetary policy rate, banks will take 0.002 percentage more risk. The profit and equity ratio also have a positive effect on bank monitoring effort level with the strength of 0.0005 and 0.007 respectively. This means that banks with less profit and low equity ratio would take more risk. This is because banks with less profit or low equity ratio will be more incentive to search higher return by taking more risk. A significantly positive regression also displays between the loan interest rate and inverse bank risk, with a coefficient 0.014. It implies that banks with lower loan interest rates may seek higher risk. That is because, for a bank with a low loan interest rate, it will have a low loan interest revenue. This will in turn spur banks to invest in high risk assets to get high yield, and as a result, it will take more risk.

From Table 3.3, we can also conclude that bank risk taking is persistent. There is strong evidence that the last period's dependent variable has a significant positive effect on its current risk choice, with the coefficient 0.412. This means that banks' last year risk taking preference will have a positive effect on the current year's risk taking decision, compared with that in the year before last year, and this effect of last year will eventually dissipate.

We also compare the second and the third regressions, which are the periods before and after the 2008 financial crisis. Similar to the result in regression I, both last period inverse bank risk and risk-free interest rate have a positive effect on current bank risk taking. However, the strength of these effects is stronger after the financial crisis, because the coefficient after the crisis of lagged inverse bank risk (0.524) is greater than that before the crisis (0.411), and the coefficient after the crisis of risk-free interest rate (0.011) is also larger than that before the crisis (0.003). This means with every percentage point decrease of risk free rate, banks will take more risk after crisis compared with that before crisis, and bank last period risk taking preference will affect more current risk behavior of banks. The sign of the loan interest rate's coefficient has changed in the table. Banks take different strategies to take risk, when they consider loan interest rate only. This might be caused by some new regulations proposed after the crisis. In the following parts, we will consider a dummy variables estimation, to check the different risk taking attitudes by different banks.

3.5.2 Dummy Variables Estimation

Here, we compare the effects of monetary policy rate on bank risk taking with different bank characteristics, such as, big banks and small size banks, high equity ratio banks and low equity ratio banks, and we also test the effect of monetary policy rate on bank risk taking by adding the quarter variable into our model to check if the bank risk taking behavior is different in different quarters. All these analyses are operated via dummy variables. The following Table 3.4 shows the results of dummy variables in the Arellano-Bond dynamic panel model.

Table 3.4 Arellano-Bond Dynamic Panel Model with Dummy Variables.

	2000-2017	2000-2008	2008-2017
Lagged inverse bank risk	0.175***	0.142***	0.257***
	(0.049)	(0.020)	(0.063)
Risk-free interest rate	0.004**	0.004***	-0.004***
	(0.002)	(0.001)	(0.003)
Profit	0.0003***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Loan interest rate	0.007**	0.010***	0.017***
	(0.003)	(0.002)	(0.004)
Equity ratio	0.005***	0.007***	0.004*
	(0.001)	(0.000)	(0.002)
Post-crisis	-0.041***		
	(0.009)		
Big cap bank	0.132***	0.106***	-0.060***
	(0.015)	(0.018)	(0.007)
High equity ratio	0.086***	0.057***	0.038***
	(0.016)	(0.012)	(0.006)
Quarter 2	-0.001	-0.006***	0.001
	(0.002)	(0.001)	(0.001)
Quarter 3	0.002	-0.009***	0.002***
	(0.002)	(0.001)	(0.001)
Quarter 4	0.002	-0.004***	-0.003***
	(0.003)	(0.001)	(0.001)
No. of observations	1920	1020	870
No. of Instruments	30	30	30
No. of Banks	30	30	30
Wald-test	2681.510	37351.290	74121230
Wald-test p-value	0.000	0.000	0.000
AR(1)	0.000	0.000	0.000
AR(2)	0.250	0.711	0.024
Hansen	0.692	0.569	0.384
Difference-in-Hansen tests (Hansen p-value)	0.919	0.648	0.252
Difference-in-Hansen tests (difference)	0.151	0.324	0.683

*The three regressions perform the estimation with period from Q1 2000 to Q1 2017, Q1 2000 to Q3 2008, and Q4 2008 to Q1 2017, respectively. * indicate statistical significance at the 10%, ** indicate statistical significance at the 5%, and *** indicate statistical significance at the 1%. Standard errors are in parentheses.*

Alongside the basic Arellano-Bond dynamic panel data estimation, we run a dummy estimation again which contains the post-crisis dummy, big capitalization banks dummy, high equity ratio dummy, and seasonal dummy. For the post-crisis dummy, we set the period after the financial crisis equal to 1 and the period before the financial crisis equal to 0. We rank these 30 banks by the size of capitalization and set the first 15 biggest banks to take the value 1, and others to be 0. For the equity ratio dummy, we divide these 30 banks into two groups. The group containing banks with equity ratio below the median equity ratio have the value 0, and the other group containing the banks with equity ratio above the median equity ratio take the value 1.

From the Table 3.4, we draw the following conclusions: the sign of right hand side variable coefficients are all the same with the previous the Arellano-Bond dynamic panel data estimation (in the third regression, the short term interest rate has a negative sign coefficient which is not the same as the results in Table 3. However, it has a large P-value, which means the result of its coefficient is not significant). The results in the first and second regressions suggest there is a significant positive effect of risk free rate on bank monitoring effort level. However, this effect is stronger than the previous estimation (the coefficients in Table 4 are 0.004 in both regressions while the coefficients in Table 3 of the risk-free interest rate is 0.002 and 0.003 respectively). After adding the dummy variables into the models, the lagged inverse bank risk receives low coefficients. The dummy variables do not change the effect of monetary policy on bank risk taking. There is still significant evidence that short term interest rate has a positive effect on bank monitoring effort, and therefore, a negative effect on bank risk taking.

Regarding the dummy variables themselves, the crisis reduces the bank's risk taking level by 0.041 units. And for the capitalization dummy variable, before the crisis, the banks with big sizes in capitalization have are more sensitive to the change of risk free interest. For every unit decrease of the policy rate, big size banks will take more risk, compared with the small size banks. However, after the crisis, the effect of monetary policy on bank risk taking changes. the banks with small size in capitalization have are more sensitive to the change of risk free interest. But in the whole period of our sample, the case is still the same with that before the crisis. Therefore, the general effect of short-term interest rates on bank risk-taking is less pronounced for poorly capitalized banks. This can be explained by the "too big to fail" theory. About the equity dummy, the effect of short-term interest rates on bank risk-taking is stronger for the banks financed with a higher portion of equity. And this kind of effect has been reduced since financial crisis. We also involve the seasonal dummy variables to test if the bank's risk taking differ over seasons. The results suggest that the seasonal dummy variables will change bank risk taking levels, before the crisis. Season is still an important factor, but less important than that in the period before the crisis. For the whole period data, the seasonal dummies appear insignificant, because of the high level of P-value. However, before the crisis, banks would take less risk in the first quarter, compared with other quarters. This may be because, at the beginning of every year, banks will start their new project, but they have less stress to get all the target finished. Compared with other quarters, the quarter near the end of the year might will spur banks more to take risk to get the return. This is the reason why in quarter 3, before the crisis, the bank risk taking level is higher than that in other quarters.

3.5.3 Other Measures of Bank Risk Taking and Interest Rate

To evaluate the robustness of our findings, we perform a different proxy of bank risk taking variable and policy rate. First, we adopt the Non-Performing Loan (NPL) ratio to replace the Z-score. NPL ratio is a direct proxy to measure bank risk. It can be also regarded as a proxy for credit risk, while the Z-score is a measure of bank insolvency risk. NPL ratio can be calculated by the ratio of Non-Performing Loans to total loans. It reflects the quality of bank assets. Therefore, a high Non-Performing Loan ratio is associated with high credit risk. The effect of monetary policy on Non-Performing Loan ratio should be intuitively opposite, compared with the effect of monetary policy on Z-score. For the short term interest rate, we use the federal funds rate to proxy the monetary policy rate. The following results show the estimations of robustness tests. The coefficients on our main variables are qualitatively consistent and changing the proxies does not change the effect of monetary policy on bank risk taking.

Table 3.5 Arellano-Bond Dynamic Panel Model with Other Proxies of Main Variables

	I	II	III	IV
Lagged inverse bank risk	0.412***	0.453***		
	(0.010)	(0.012)		
Lagged Non-Performing Loan ratio			1.055***	1.054***
			(0.003)	(0.004)
3-month U.S. treasury bill rate	0.002***		-0.012***	
	(0.000)		(0.002)	
Federal funds rate		0.001***		-0.019***
		(0.0002)		(0.004)
Profit	0.0005***	0.0005***	-0.008***	-0.008***
	(0.000)	(0.000)	(0.000)	(0.000)
Loan interest rate	0.014***	0.008**	0.155***	0.057***
	(0.001)	(0.000)	(0.004)	(0.005)
Equity ratio	0.007***	0.009***	-0.020***	-0.023***
	(0.000)	(0.000)	(0.001)	(0.001)
No. of observations	1920	1920	1920	1920
No. of Instruments	30	30	30	30
No. of Banks	30	30	30	30
Wald-test	53616.330	62398.010	1990000	96920.41
Wald-test p-value	0.000	0.000	0.000	0.000
AR(1)	0.000	0.000	0.000	0.000
AR(2)	0.112	0.258	0.763	0.762
Hansen	0.218	0.300	0.259	0.263
Difference-in-Hansen tests (Hansen p-value)	0.175	0.239	0.148	0.124
Difference-in-Hansen tests (difference)	0.484	0.534	0.768	0.898

*The four regressions perform the estimation with: Z-score and 3-month U.S. treasury bill rate as the main variables in regression I, Z-score and federal funds rate as the main variables in regression II, NPL and 3-month U.S. treasury bill rate as the main variables in regression III, NPL and federal funds rate as the main variables in regression IV. * indicate statistical significance at the 10%, ** indicate statistical significance at the 5%, and *** indicate statistical significance at the 1%. Standard errors are in parentheses.*

3.6 Conclusion

Due to the recent financial crisis, researchers and policymakers have paid more attention to the relationship between monetary policy and bank risk taking. The bank risk taking channel can work through three ways: first, low interest rates can influence valuations, incomes, and cash flows. All those factors will have a direct effect on how banks measure risk, and then influence the level of bank risk taking. Second, low interest rate means low return on general investments, such as government risk free securities. It may increase the incentives for banks to search for some high growth investments, with the aim of getting a higher target of return, and take on more risk. Third, low interest rate may reduce the degree of risk aversion of big size banks and other institutions, which will also induce financial imbalance in turn. In this case, banks will soften their lending standards, and believe the central bank will ease the bad outcome of monetary policy.

This chapter provides strong and wide evidence, via the empirical analysis, to show that a low short-term interest rate can contribute to the increase of bank risk-taking. Banks will take more risk if the monetary policy rate decreases. Bank risk taking behavior can be affected by lots of factors, such as bank's capitalization, equity ratio, season, etc. The bank risk taking level had been reduced by the recent financial crisis, and banks take less risk after the crisis, than that in the period of pre-crisis. Meanwhile, for bank's characteristics, the effect of short-term interest rates on bank risk-taking is less pronounced for poorly capitalized banks; the effect of short-term interest rates on bank risk-taking is also stronger for the banks financed with a higher portion of equity.

Finally, seasons will change bank risk taking behavior as well, and power is especially strong at the period of pre-crisis.

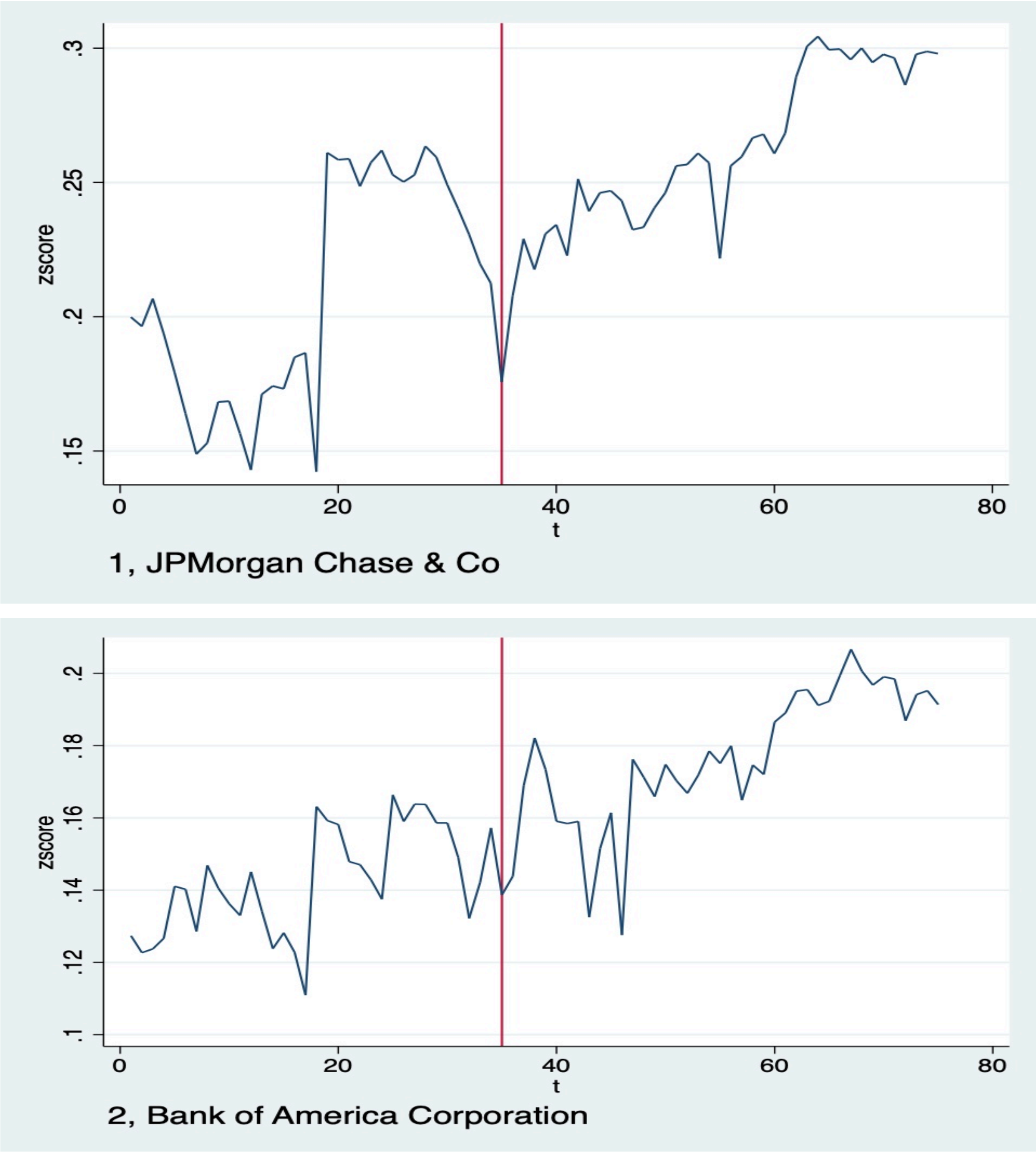
Even banks pay more effort to control risk taking after the recent financial crisis, the risk free interest rate is still at a low level. So, for the bankers and policymakers, it is important to monitor the banks' risk taking level regularly and frequently.

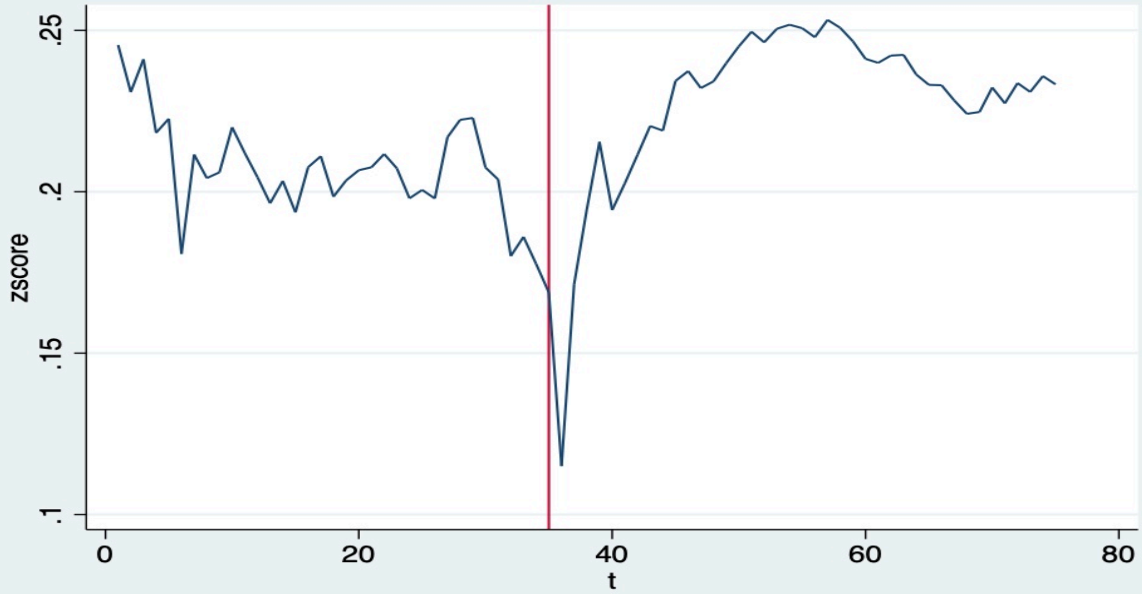
3.7 Appendix

Table 3.6 Listed Top 30 U.S. Banks

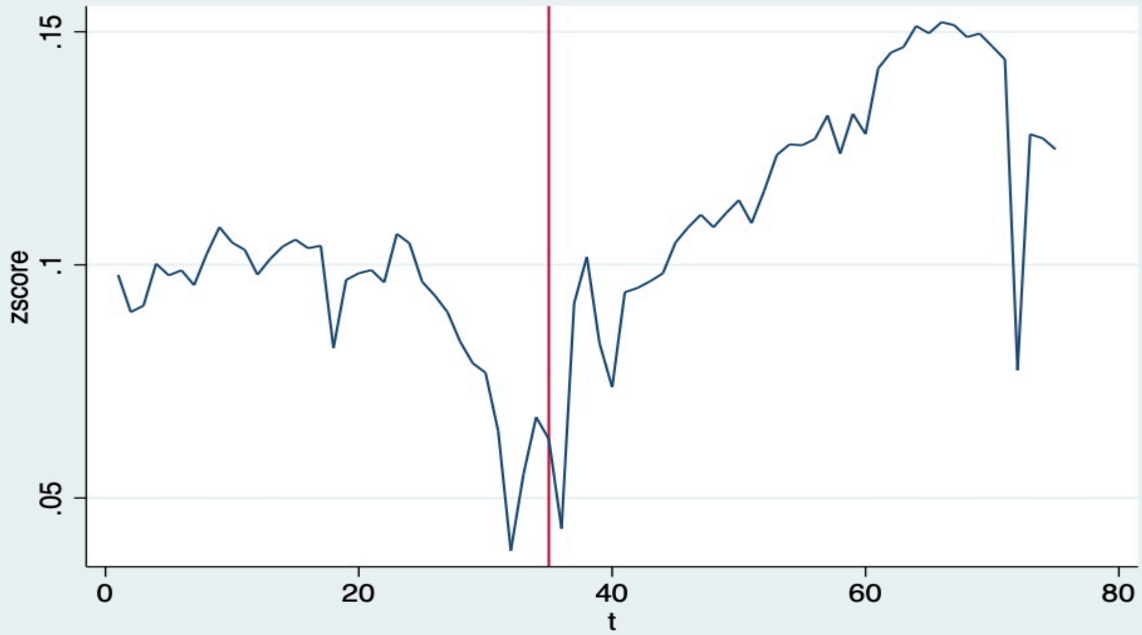
1, JPMorgan Chase & Co	2, Bank of America Corporation	3, Wells Fargo & Company
4, Citigroup Inc	5,Bank of America, National Associstion	6, Citibank NA
7, US Bancorp	8, US Bank National Association	9, PNC Financial Services Group
10, Capital one national association	11, PNC Bank national Association	12, HSBC North America Holding INC
13, TD Bank National Association	14, Bank of new york mellon	15, State Street Corporation
16, BB&T Corporation	17, Branch Banking and Trust	18, SunTrust Banks
19, HSBC BANK USA	20, Citizens Financial Group	21, Citizens Financial Group
22, Fifth Third Bancorp	23, keyCorp	24, Chase Bank USA
25. KeyBank National Association	26, Morgan Stanley Bank	27. BMO Financial Corp
28, Regions Bank	29, Northern Trust Corporation	30, M&T Bank Corporate

Figure 3.3 Individual Bank Risk Taking Level Again Time

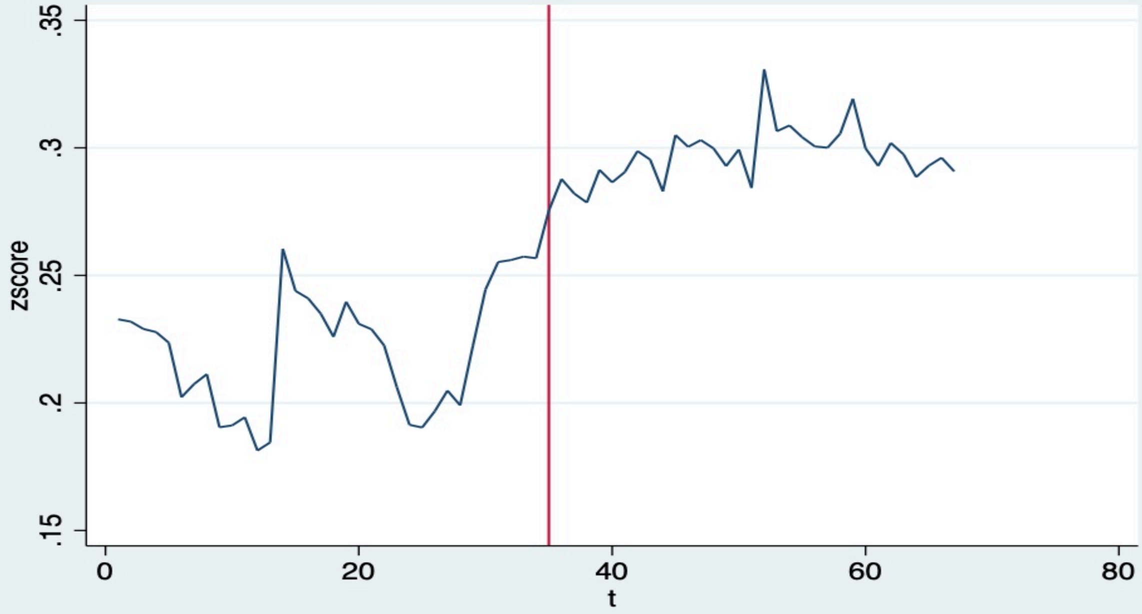




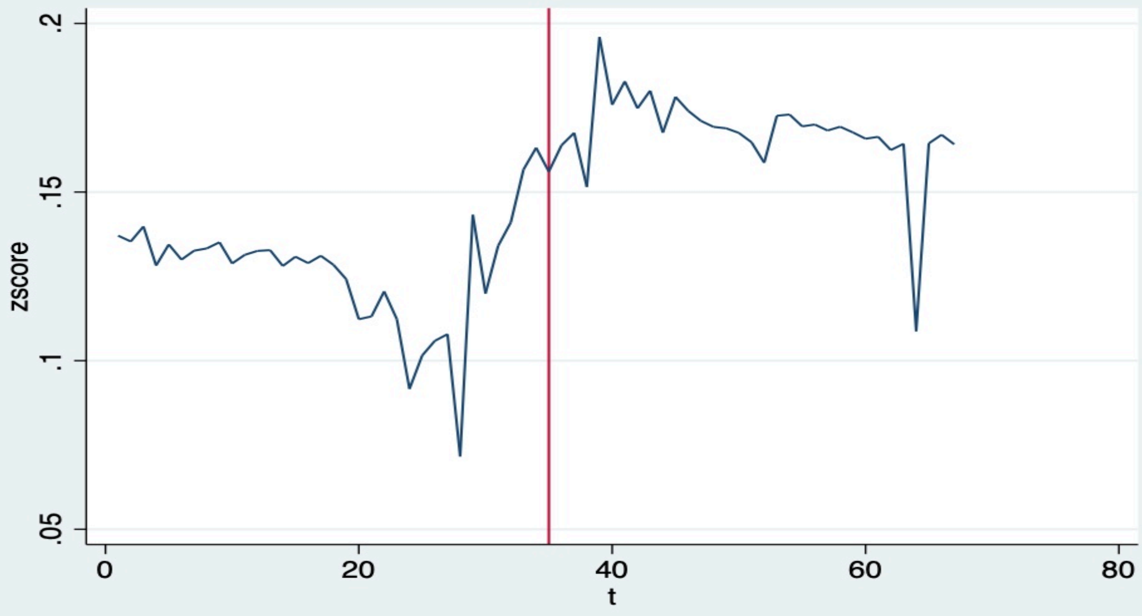
3, Wells Fargo & Company



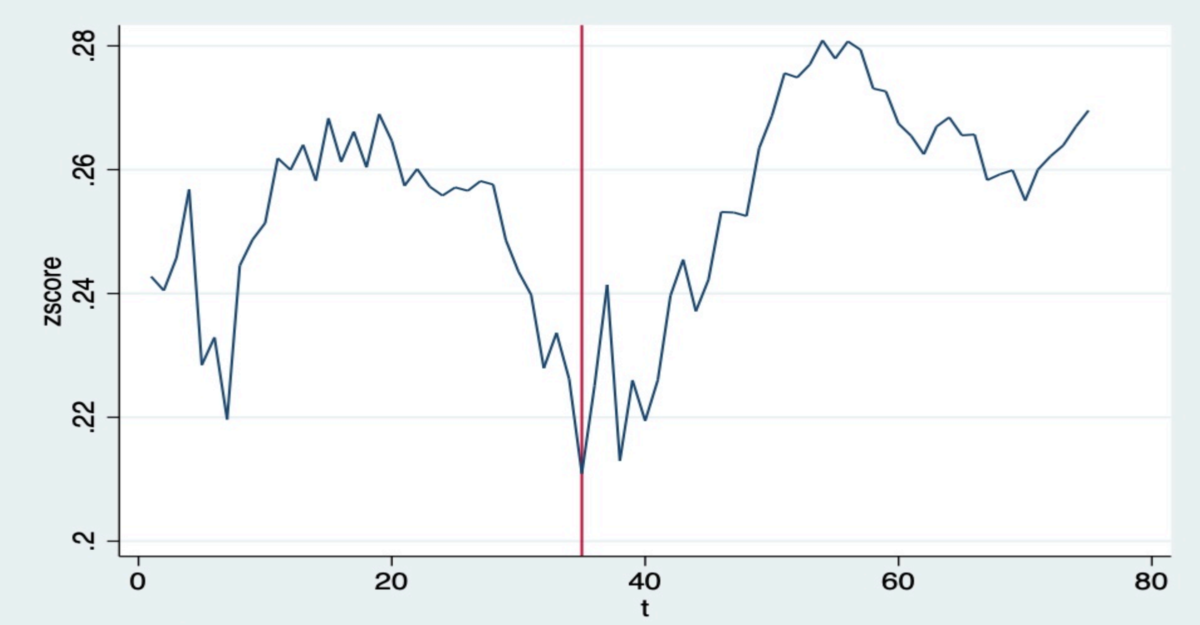
4, Citigroup Inc



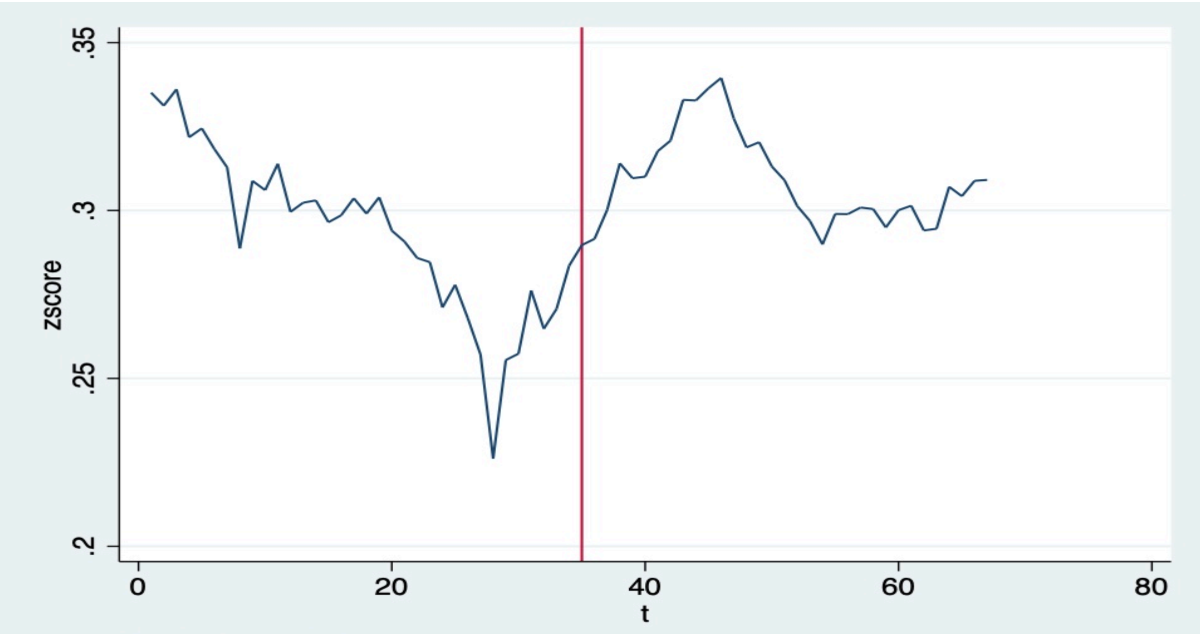
5,Bank of America, National Associstion



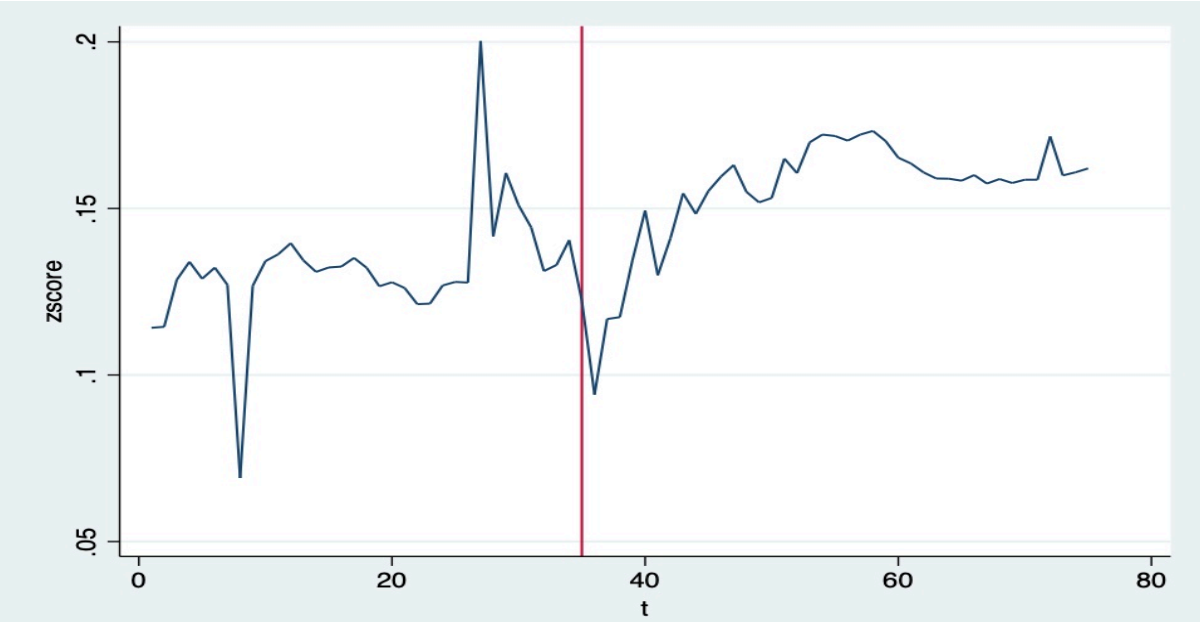
6, Citibank NA



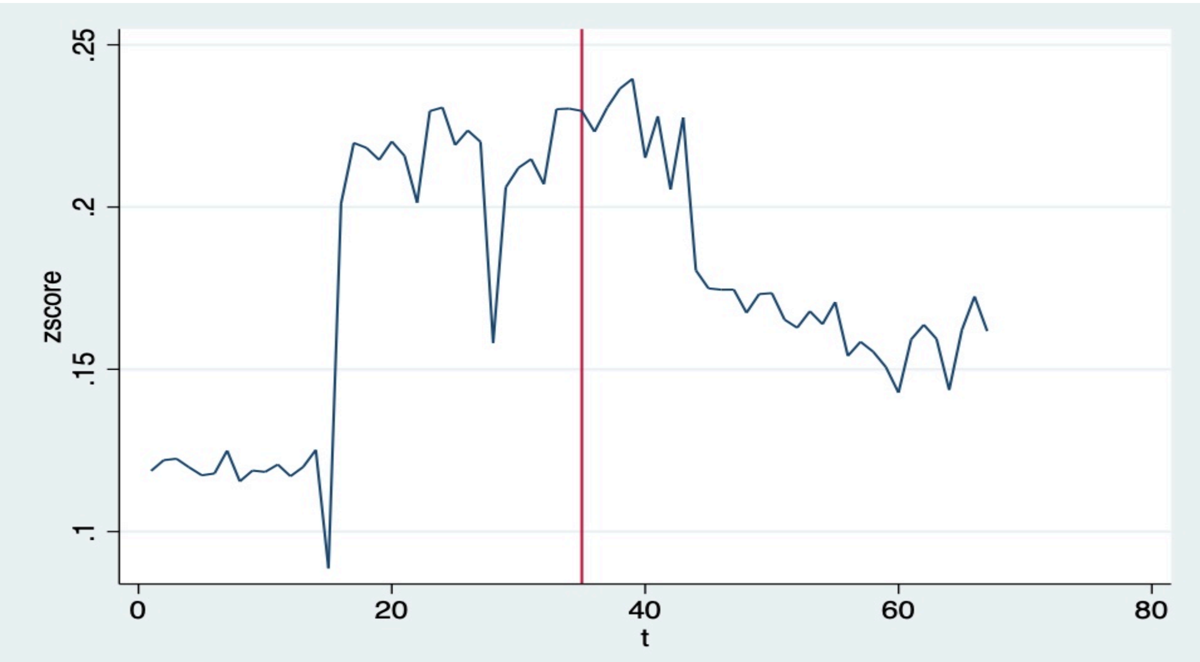
7, US Bancorp



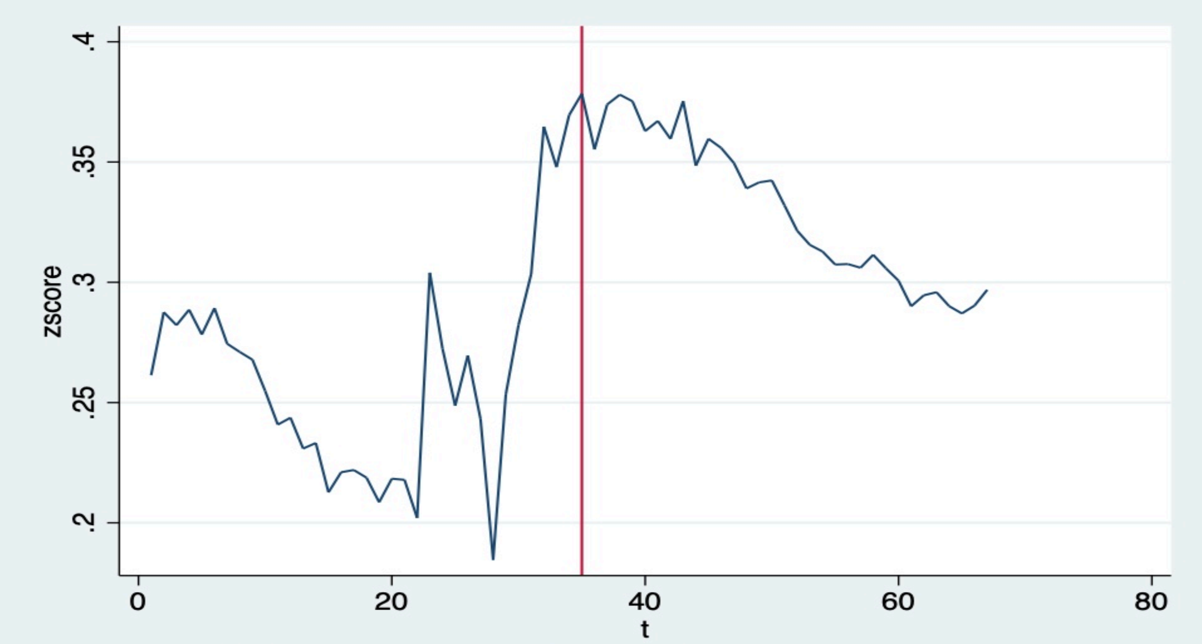
8, US Bank National Association



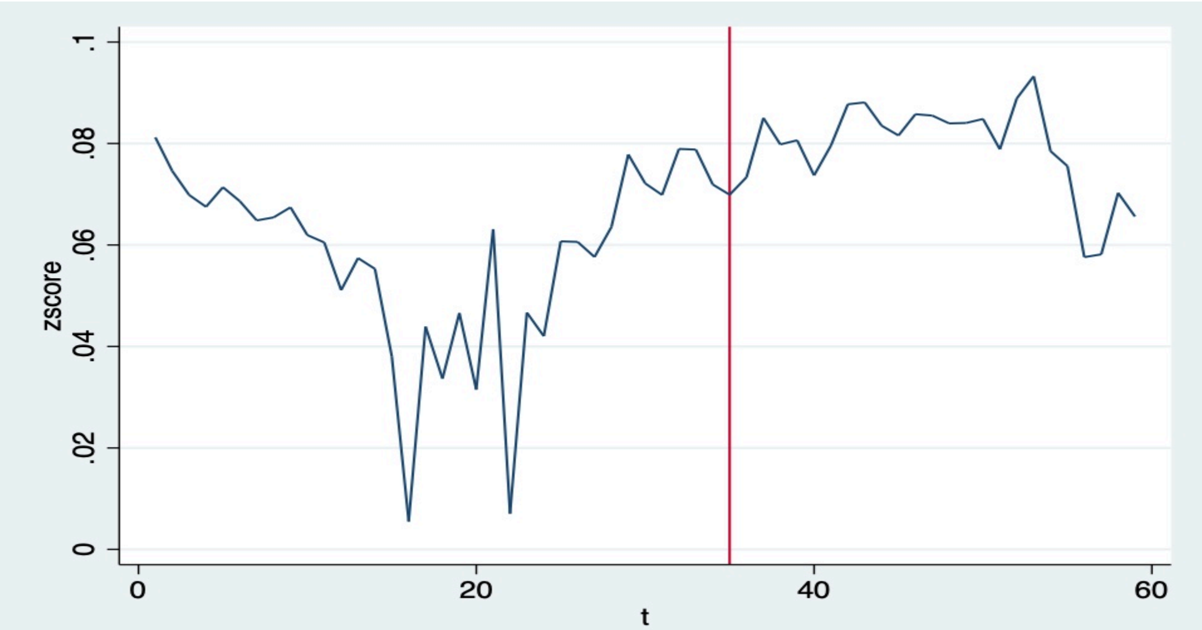
9, PNC Financial Services Group



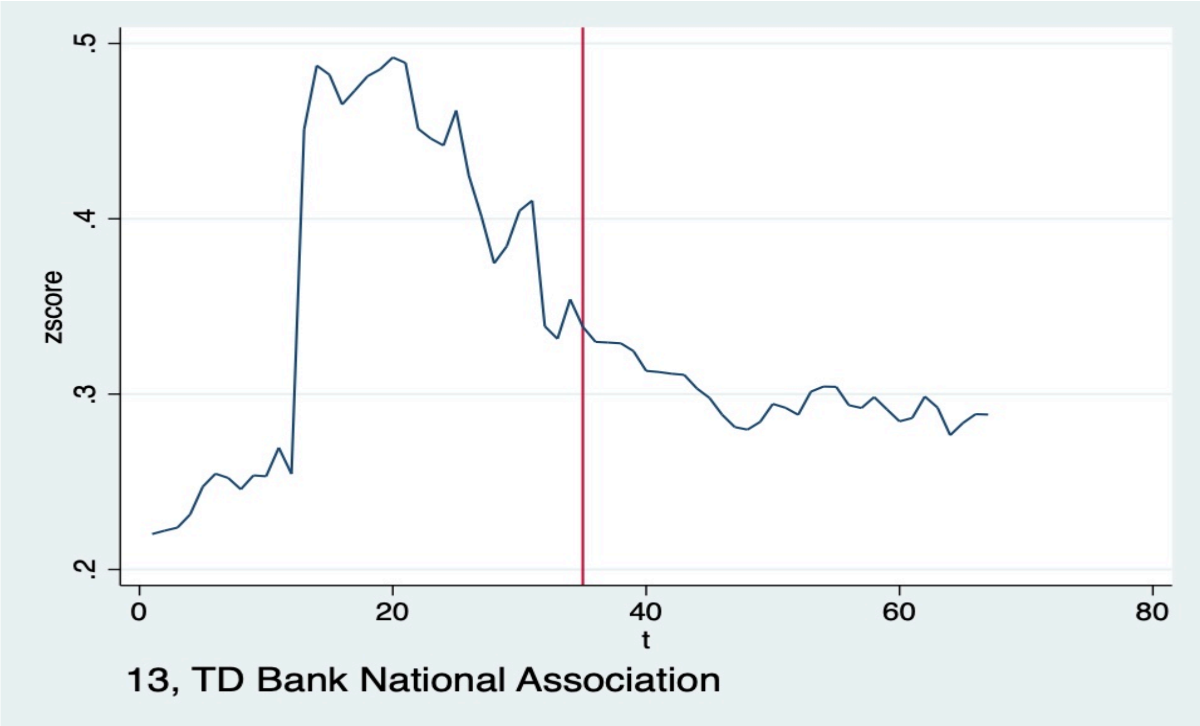
10, Capital one national association



11, PNC Bank national Association



12, HSBC North America Holding INC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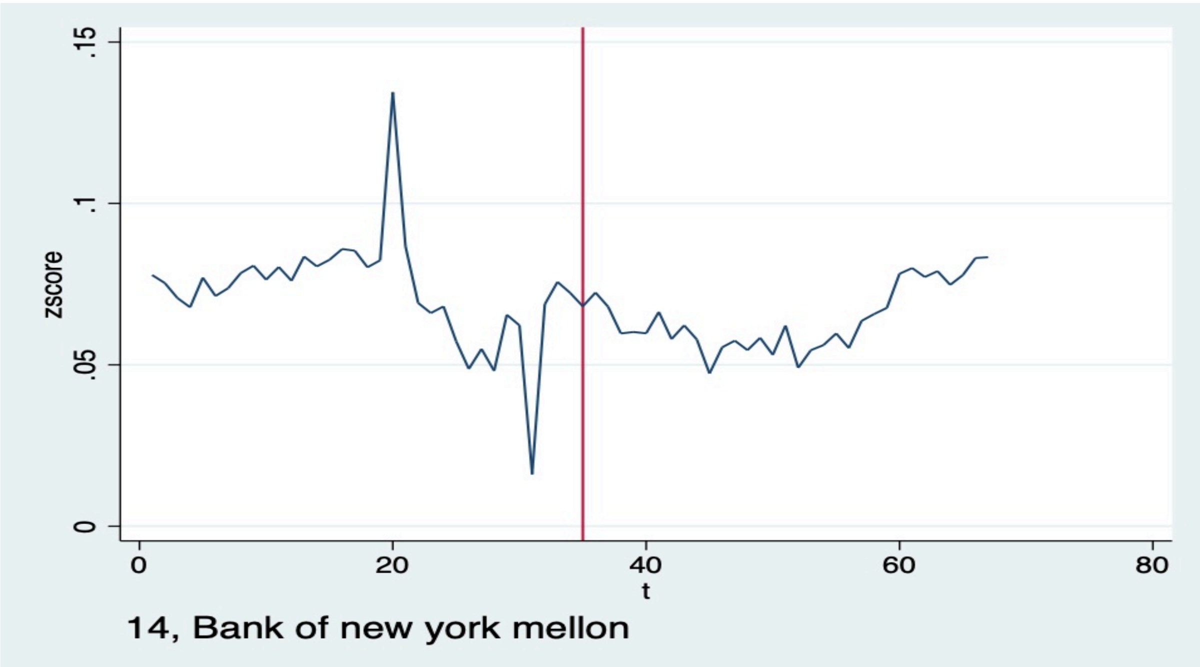
13, TD Bank National Association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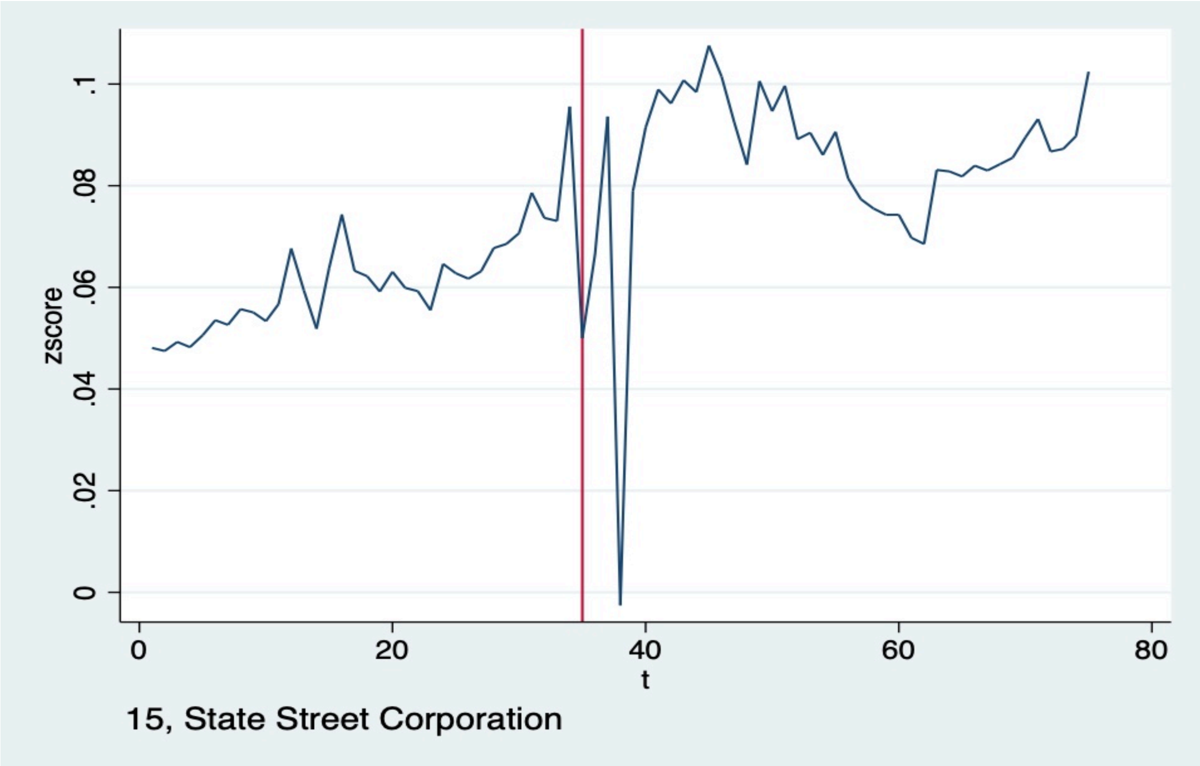
14, Bank of new york mellon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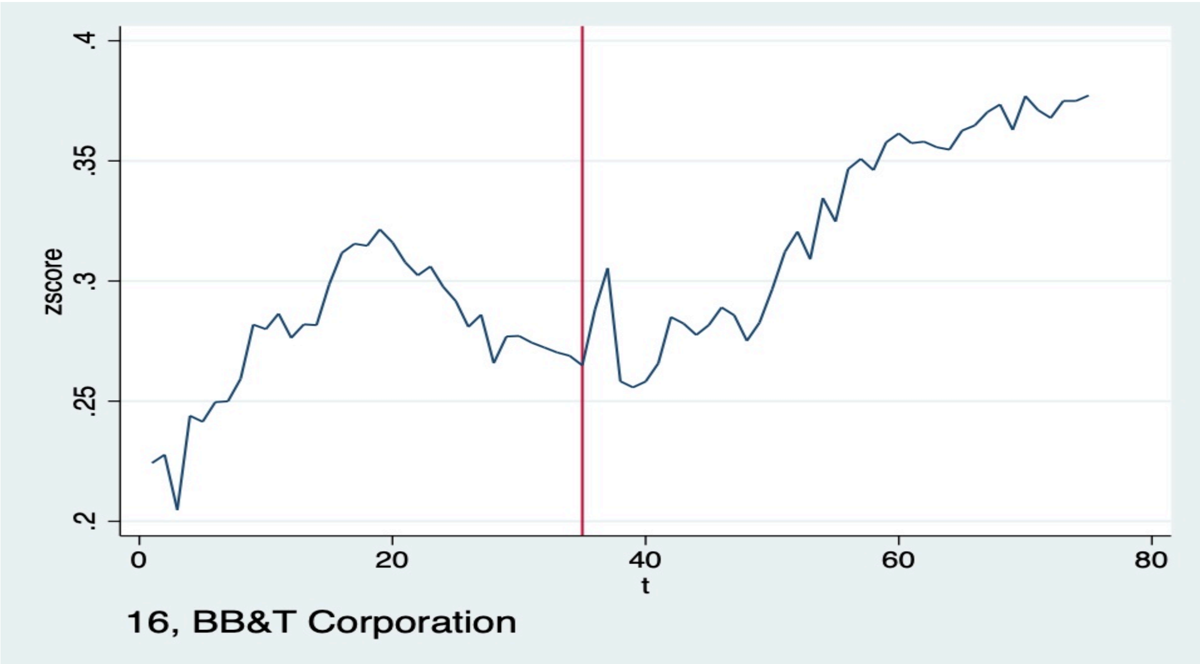
15, State Street Corporation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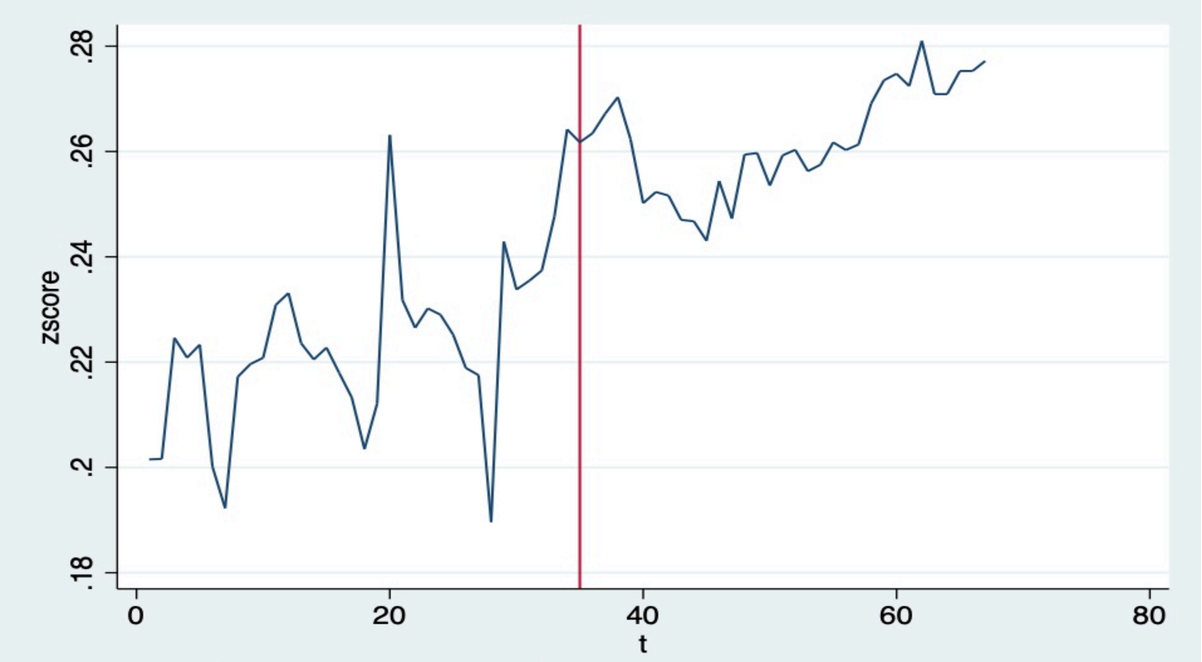
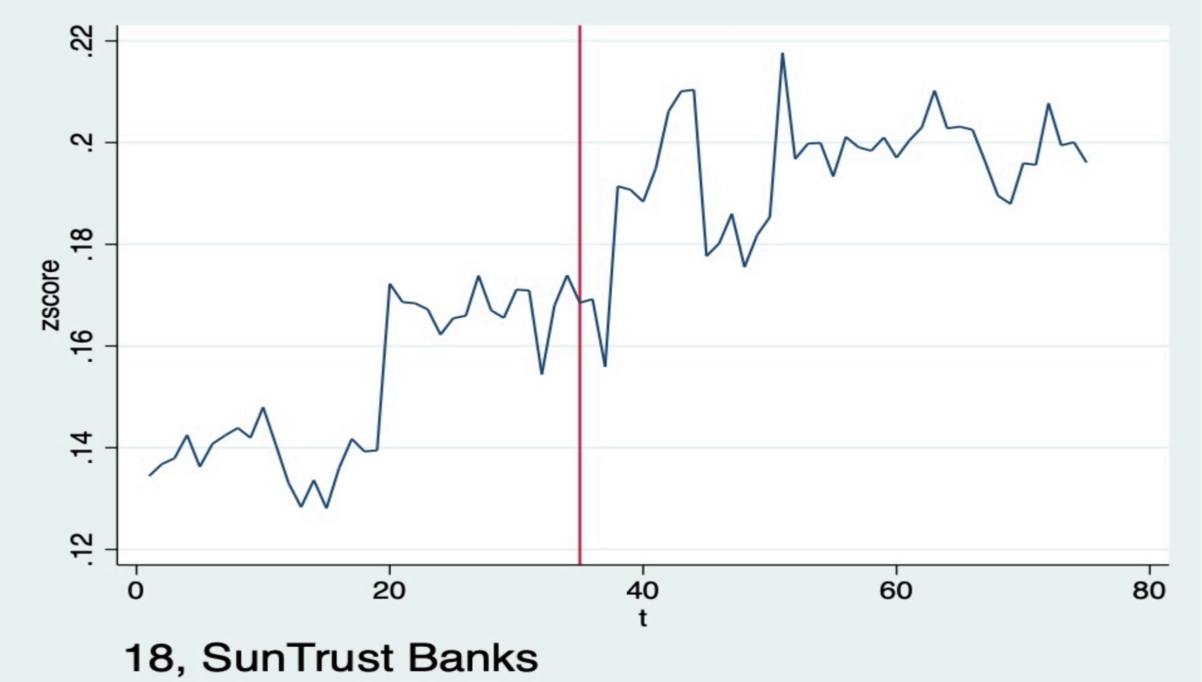
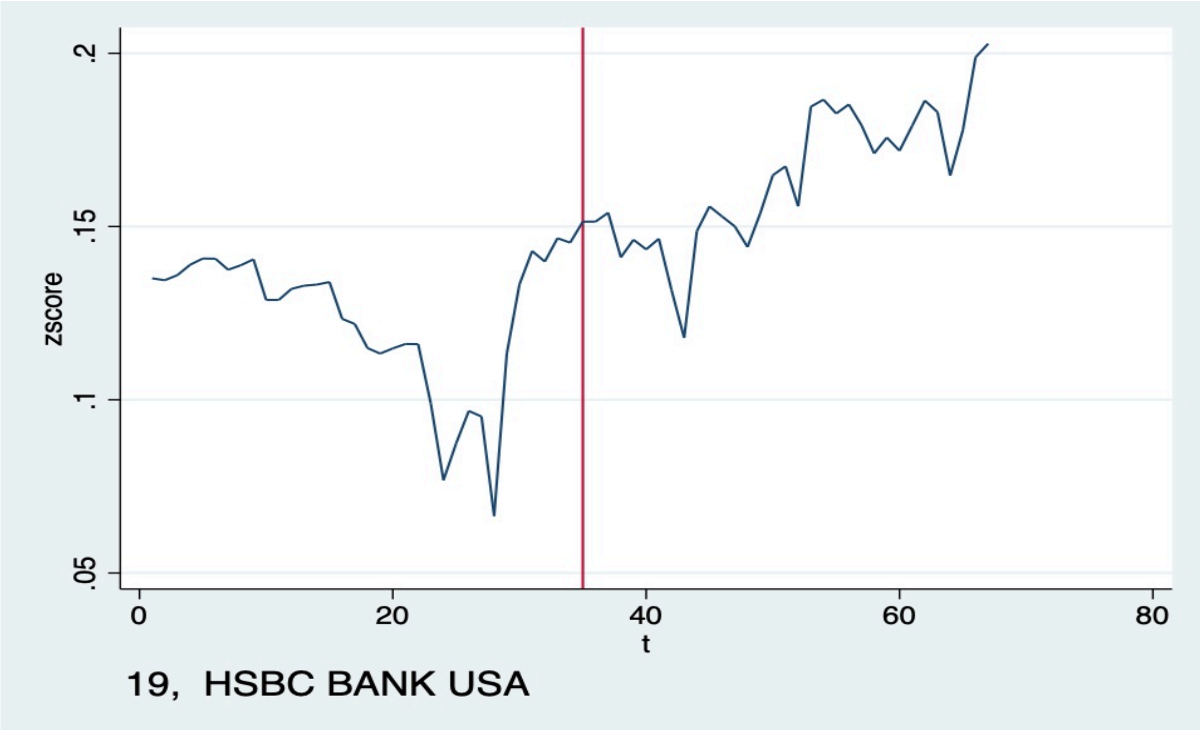
16, BB&T Corporation



17, Branch Banking and Trust



18, SunTrust Banks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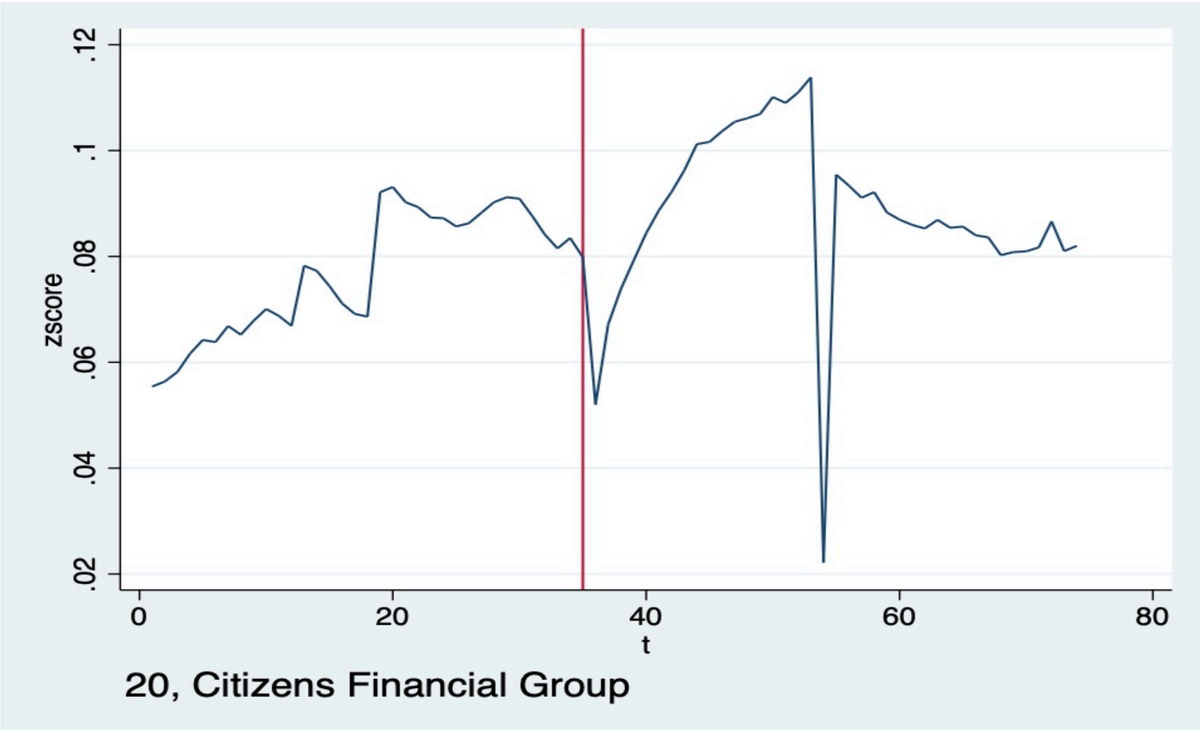
19, HSBC BANK USA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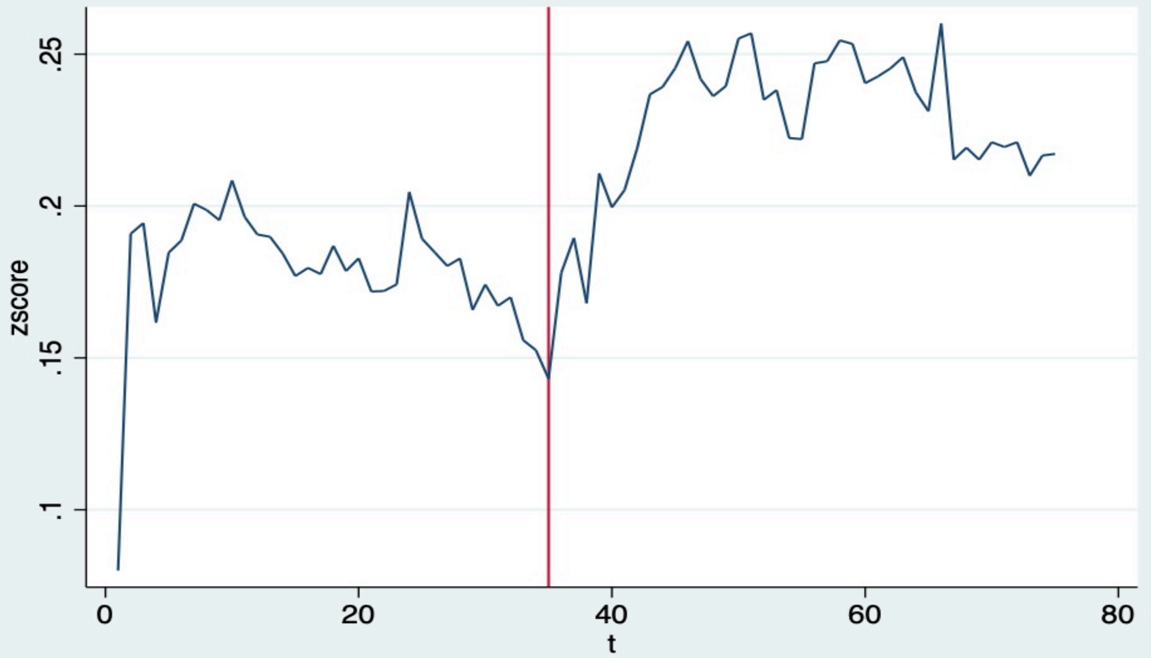
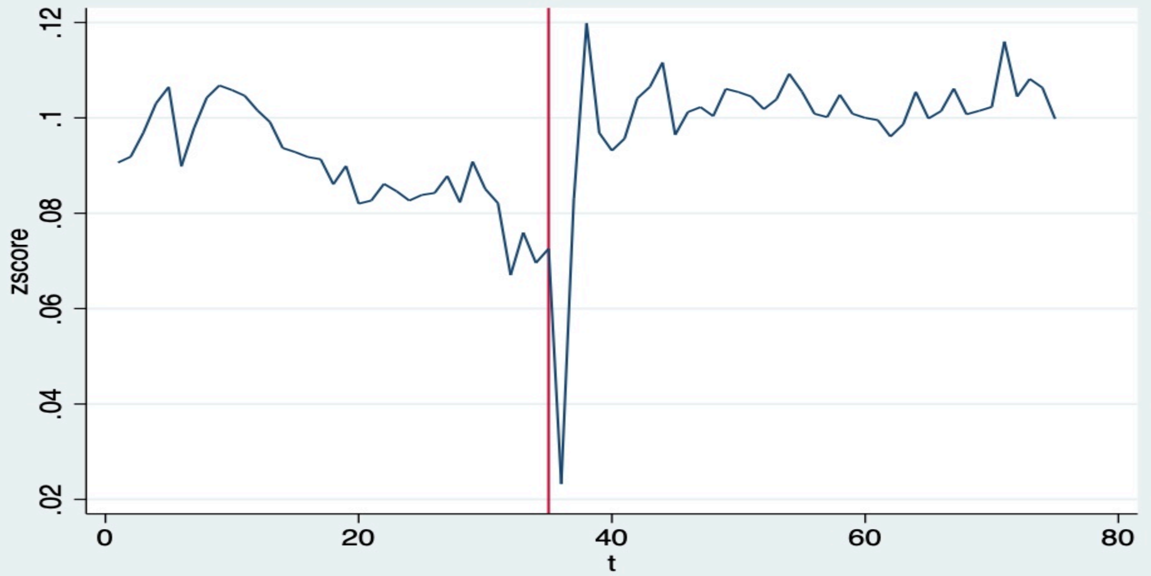
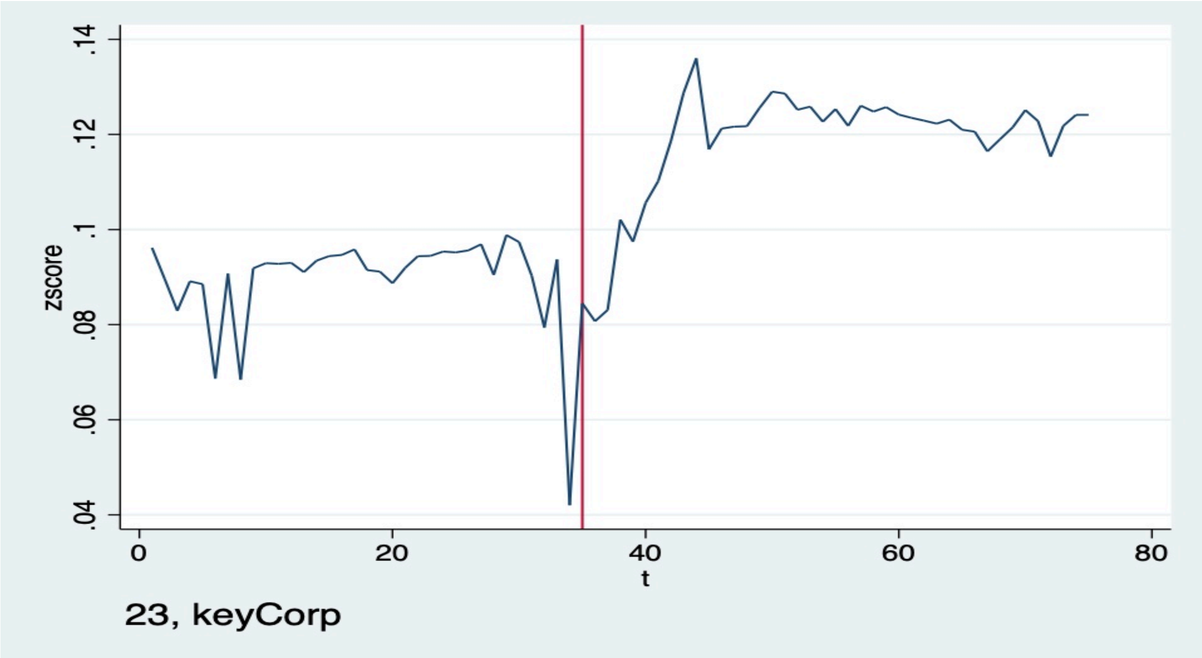
20, Citizens Financial Group



21, Citizens Financial Group



22, Fifth Third Bancorp



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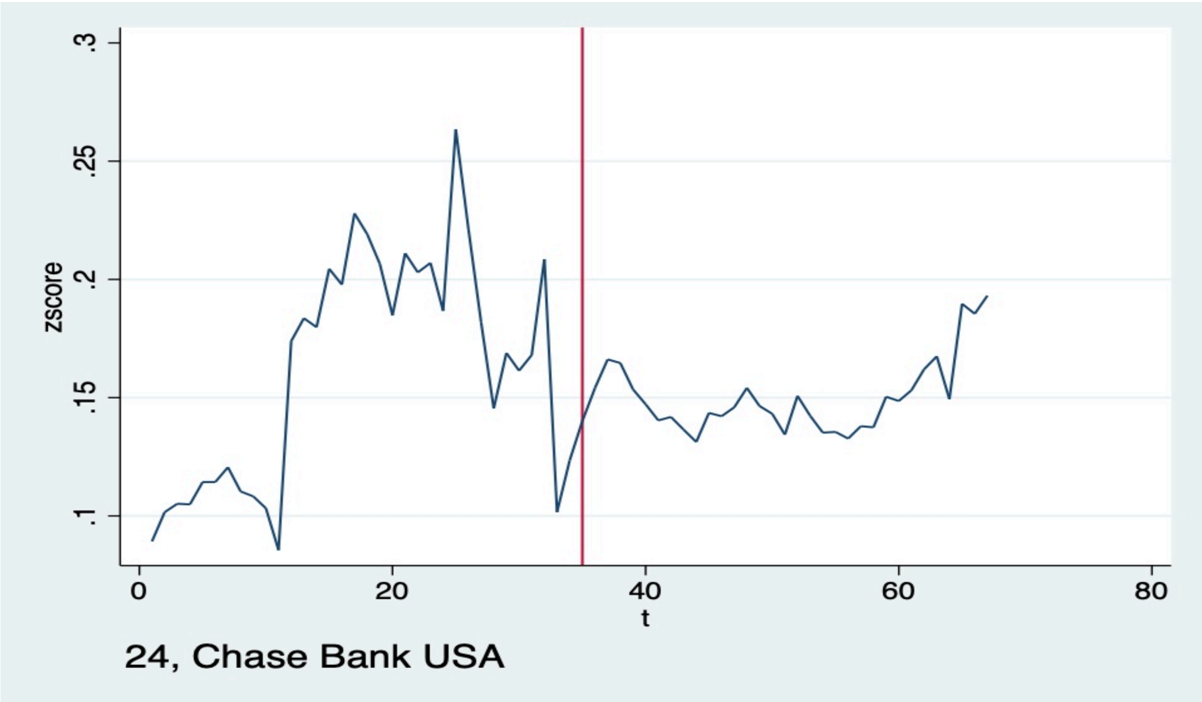
23, keyCorp



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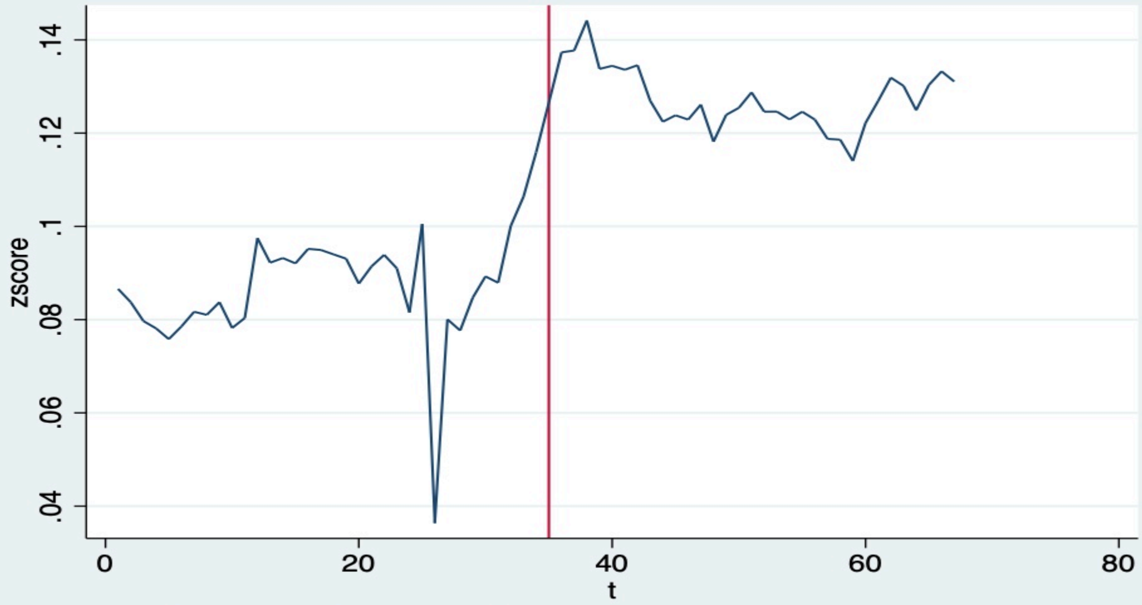
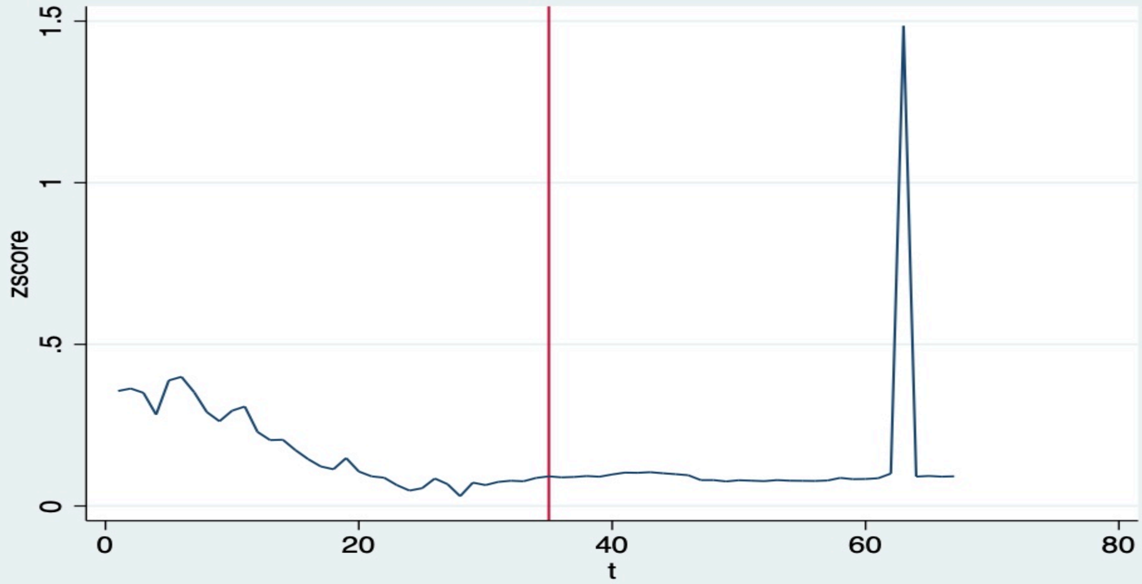
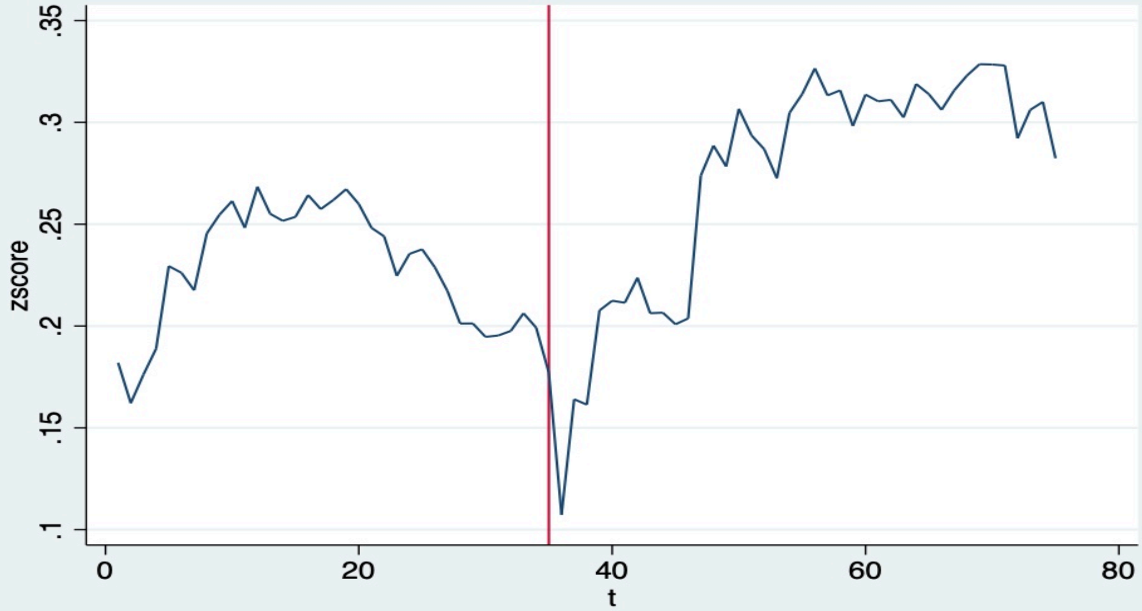
24, Chase Bank USA



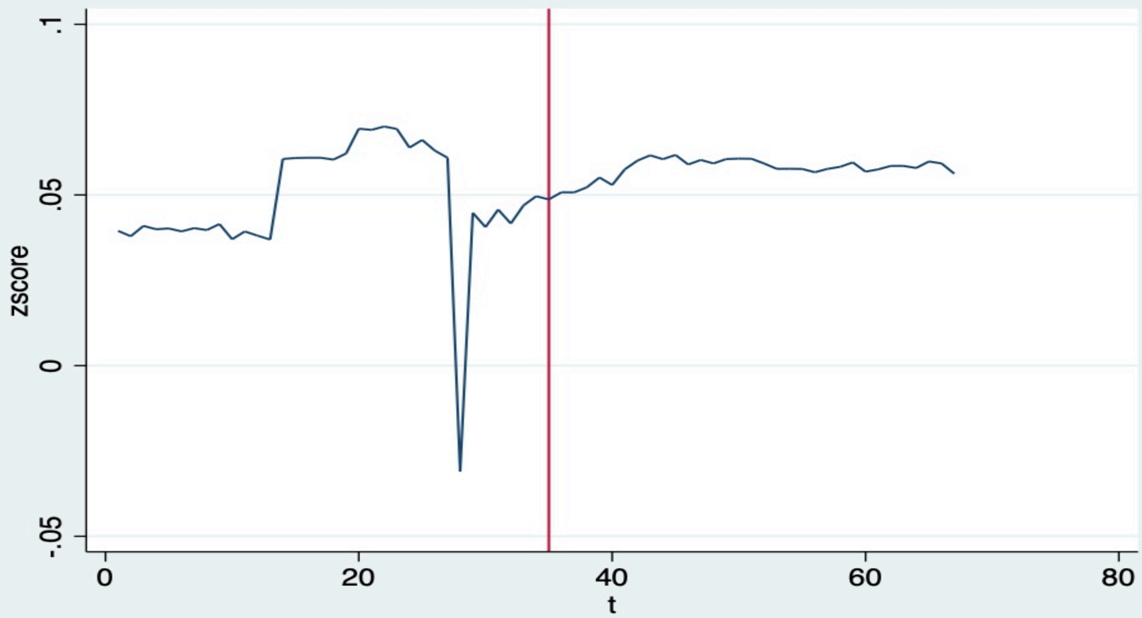
25. KeyBank National Association



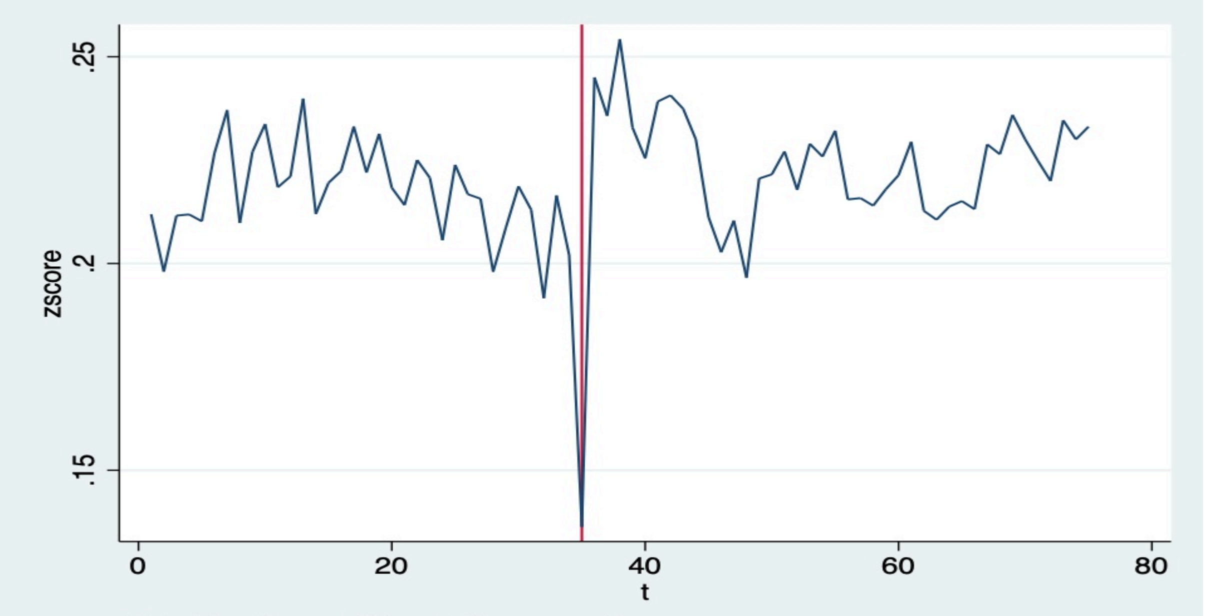
26, Morgan Stanley Bank



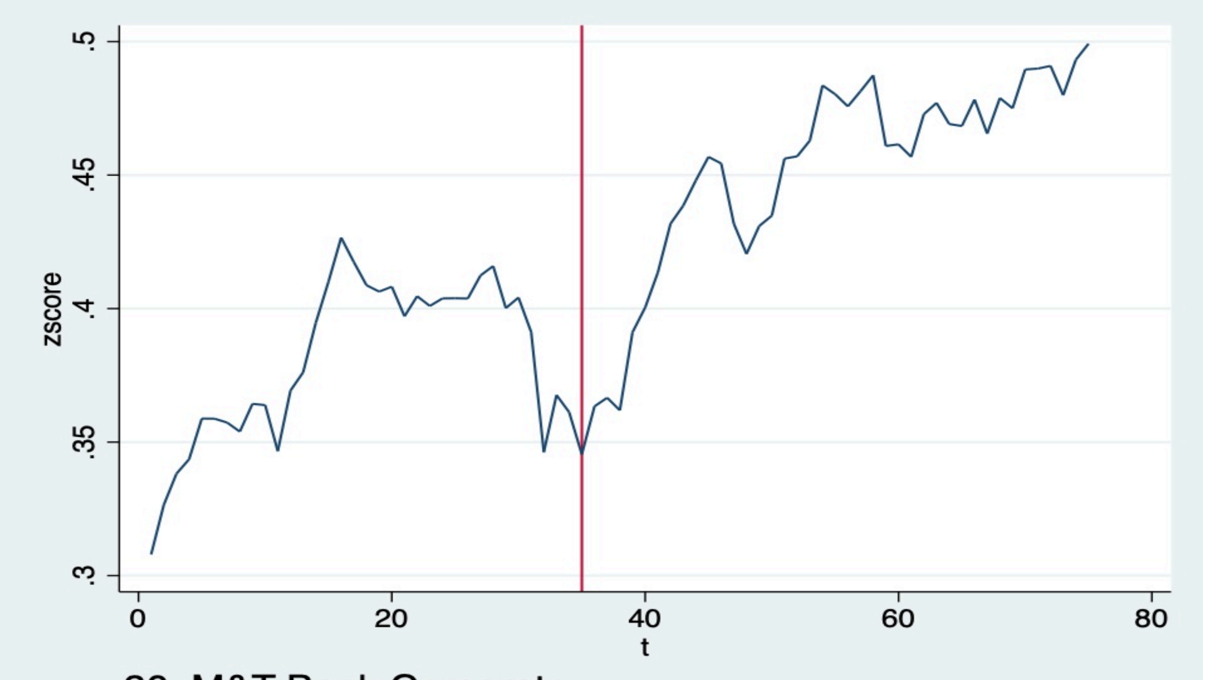
27. BMO Financial Corp



28, Regions Bank



29, Northern Trust Corporation



30, M&T Bank Corporate

Chapter 4

The Effect of Quantitative Easing on Bank Risk-Taking: Evidence from The Federal Reserve's LSAPs

4.1 Introduction

Following the 2007-2008 financial crisis, central banks in developed economies around the world have undertaken various unconventional monetary policies, including large-scale assets purchases (LSAPs), colloquially referred to as "Quantitative Easing" or QE. Even nearly a decade after the financial crisis, those central banks in developed countries continue to resort a lot to QE to stimulate the economy, particularly to provide the monetary stimulus, for example, reducing the long-term interest rate, which has been widely accepted (Gagnon et al, 2011; Christensen and Rudebusch, 2012; Eser and Schwaab, 2016, etc.). The reason why these unconventional monetary policy measures are widespread used by the monetary authorities is: after the recent financial crisis, central banks in these countries lower their monetary policy rates effectively to the zero lower bound, because of the recession in both financial markets and of the real economy. As a conventional monetary policy, the interest rates are an effective tool used by central banks to shape monetary policy, for example, keeping the inflation rate around the target level, stimulate economic growth, or maintaining the unemployment rate at an acceptable level. However, the zero lower bound of interest rates reduces the ability of central banks in these aspects. To solve this situation, lots of central banks begin to use unconventional monetary policy measures. For example, in late 2008, United States, to push down bond yields and provide additional monetary policy stimulus to the economy, the Federal Reserve Bank began to purchase longer term securities, because the zero lower bound target policy rate gave a deteriorating outlook for the economic growth and a perceived threat of price deflation (Christensen and Rudebusch, 2012). Nearly at the same time, in the early spring 2009, United Kingdom, to increase nominal economic activity, the Bank of England announced plans to purchase government bonds, due to the weak UK economic growth and a low medium-term inflation rate, which were both caused by the policy interest rate had been lowered to its effective zero lower bound.

After the use of the large-scale assets purchases, it seems to become the more important instrument for some central banks compared with conventional monetary policy. As a result, the effectiveness of these measures has been a vivid topic over the last couple of years. Among academic economists and policymakers, they debate a lot about the effects of the extensive use of these unconventional monetary policy measures on economic outcomes in general, and financial stability in particular. Especially when the Fed announced the third round of QE, the overall economic impact of this policy has been widely discussed and summarized (Walker, 2014). Most of those assessments, try to pay attention to some uniform macroeconomic effects, such as, long-term interest rates (which is referring to nominal interest rates on long-maturity bonds, because real interest rates are not affected by monetary interventions in the long run), changes in confidence and inflation expectations. According to Kurtzman et al. (2018), there are mainly two aspects of views, with which the academic economists and policymakers are concerned. On one hand, from the perspective of the proponents of LSAPs, they tend to emphasize that such interventions increased the investors' and consumers' confidence and risk-taking and therewith overall economic activity, because the asset prices have been increased and yields on U.S. Treasuries or mortgage-backed securities (MBS) have been reduced. As a result of the increase of overall confidence, it would contribute to more consuming and borrowing decisions. According to this view, with the implementation of unconventional monetary policy, the recovery after the crisis was much faster than it would have been without unconventional monetary policy (see, e.g., Kurtzman, etc. 2018; Williams, 2012). On the other hand, from the standpoint of critics of LSAPs, some of they argue that LSAPs were not effective, and moreover, some of them presented that LSAPs have potentially been setting the stage for the next financial crisis by encouraging excessive risk-shifting, fueling asset bubbles, and inducing incentives to "reach for yield" (see, e.g., Bernanke, 2013; Rosengren, 2015).

Therefore, the effect of this unconventional monetary policy on the economy, especially on bank risk-taking and lending behavior is an important topic for academic economists and policymakers. Meanwhile, in U.S., the LSAPs is a representative application of these unconventional monetary policies. In this study, therefore, we will examine whether and how the Federal Reserve's LSAPs, referred to as QE, affected lending standards, and especially the bank risk-taking behavior, by using U.S. individual bank's data.

Until now, there have been lots of studies focusing on examining the effects of QE, and how these unconventional monetary policies are transmitted throughout the economy. Some of these researches test the transmission mechanisms with the respect of policy signaling (see, e.g., Bauer and Rudebusch (2014) and Krishnamurthy and Vissing-Jorgensen (2011)), and some of these studies focus on the prices and yields of financial assets, (see, e.g., Gagnon et al. (2011), D'Amico and King (2013), and Gilchrist and Zakrajšek (2013)). Accoreding to Kandrac and Schlusche (2017), one important contribution of these studies is the demonstration that different types of assets purchased by central banks have potentially differential effects (see, e.g., Swanson and Reichlin (2011), Krishnamurthy and Vissing-Jorgensen (2013), and Di Maggio et al. (2016)). In this chapter, we will try to explore the relevant channels by which LSAPs might have an effect on the bank's risk taking and lending standards.

The first possible channel is the signaling channel. This signaling channel would affect bank risk taking levels via changing the interest rates. The unconventional monetary policy can benefit to low long term bond yields if such policy serves as a credible commitment by the central bank to keep interest rates low even after the economy recovers (Eggertson and Woodford, 2003). Meanwhile, the market might regard the implementation of unconventional monetary policy, such as QE, by the central bank, as that the central bank is willing to keep its policy rate low for an extended period. And under the long period of low interest rate conditions, commercial banks and other financial intermediaries will have a higher incentive to take more risk, due to "search for yield". What is more, if the managers of banks that think the low interest rate will still last for long period and the financial market will keep in positive condition, it will reduce the risk aversion of banks.

The second channel we will introduce is the net worth channel. When the central bank purchases large scale assets, the security prices will be affected obviously. If the security prices go up, the mark-to-market value of bank security holdings will increase due to this unconventional monetary policy. Therefore, if we assume that commercial banks target constant leverage ratios (Adrian and Shin 2010b), these changes induce banks to expand their lending and take on additional debt. As a result, bank's net worth raises, which will have an impact on the banks' estimation of the probability of default, the loss given default, and the market volatility, and in turn affect the bank risk taking level.

The third channel is the liquidity channel. As the QE strategy involves purchasing MBS, and it becomes more liquid assets. So, during the central bank's LSAPs process, commercial banks and other financial intermediaries would swap MBS for reserves, and thereby the liquidity premium of them will be reduced. As a result, commercial banks and other financial intermediaries will expand their lending, which would bring more risk to them, because additional risk coming from more lending.

The fourth channel is the prepayment risk channel. LSAPs involve a large amount of MBS. There is some theoretical and empirical evidence showing that mortgage prepayment risk carries a positive risk premium, and that this premium depends on the quantity of prepayment risk borne by mortgage investors (Gabaix, et al. 2007). During the waves of QE, the long-term interest rate would be reduced, therefore, the mortgage investors will have strong incentives to refinance their existing mortgages. Hence, the total amount of mortgages prepayments received by commercial banks and other financial intermediaries will increase. The higher of MBS held by banks, the greater number of prepayments will be received by these banks. Regarding these banks who receive more cash holdings, they could have been able to extend relatively riskier loans.

The last channel is the default risk channel. Banks rated with lower grades will carry high default risk. QE will have an influence on quantity if such default risk. According to Krishnamurthy, and Vissing-Jorgensen (2011), QE succeeds to stimulate the economy, and does contribute to the recovery after the financial crisis, we can expect that the default risk of corporations will fall. A decrease of the bank's default risk will spur them to take risks.

Because this chapter is focusing on the LSAPs in the United State bank market, before introducing the relative literature, we will briefly introduce what Quantitative Easing is, and how it works in the United States. Quantitative easing can be described as the process of the central bank purchasing large-scale assets, from banks or other financial intermediaries. In the United States, to implement QE, the Federal Reserve, which is the central bank, purchase securities from authorized Primary Dealers. According to Kandrac and Schlusche (2017), the Federal Reserve credits reserve balances to the accounts of banks associated with each dealer counterparty. There are two kinds of ultimate sellers – bank and non-bank. If the ultimate seller of the securities to the Federal Reserve is a bank, these reserve balances are effectively swapped for securities on the bank's balance sheet. If non-banks are the ultimate sellers of the securities to the Federal Reserve, reserves will still increase by the precise value of the securities purchased, but bank deposits will, at least temporarily, also rise. Regardless of the ultimate seller, the reserves created through QE must be held by banks and, will ultimately reside with the banks that face the lowest cost of holding those reserves. How does QE work? The Federal Reserve purchases long term securities from the open market, including longer-term government bonds, as well as other types of assets, such as mortgage-backed securities (MBS). As a result of buying these securities, the supply of money increases, which means the cost of money decreases. That will encourage lending and investment.

The remainder of this chapter will be organized as follows. The next section briefly introduces the current research in both related theoretical and empirical papers. Section 4.3 briefly introduces the LSAPs, especially the Federal Reserve's QE programs. Section 4.4 discusses the model, data, empirical analysis and the results. Section 4.5 concludes.

4.2 Literature

This chapter is widely related to the literature on quantitative easing, bank lending channel of monetary policy transmission, and banks risk taking channel. There are a lot of studies conducted on this different influence of unconventional monetary policy.

Regarding these unconventional monetary policies, the early work on the impact of LSAP, which is regarded as an effective tool of monetary policy, should start from "Operation Twist" in the United States, in 1961. To lower the long term interest rates, this operation includes the change of Treasury issuance, and Federal Reserve purchases of long term bonds.

More recently, one of those related researches by Doh (2010), finds that LSAPs change the supplies of long-term bonds in the U.S., and, thus, decrease the term premia in long-term bond yields, by applying a simplified version of a preferred-habitat model. He also argues that the LSAPs can produce a bigger decline in term premium, because the risk aversion of investors is high, due to the case of the recent financial crisis. Joyce et al. (2010) examine the effect of the Bank of large-scale asset purchases program in

2010, on the gilt prices. They find that there is a negative influence of this unconventional monetary policy on gilt prices, with about 100 basic points reduction.

To test the effect of the first two waves of the Federal Reserve's QE policy on interest rates, Krishnamurthy and Vissing-Jorgensen (2011) use an event study method, and find there is a drop in nominal interest rates on some long-term assets, with low risk levels, such as treasuries, agency bonds and highly-rated corporate bonds. Except that, they also check how the MBS rates change during the first two rounds of QE, and indicate that the QE1 does have an impact on MBS rates, while QE2 does not. In another study, Gagnon et al. (2011) examine the effect of LASPs on longer-term interest rates of securities. They also find that during the waves of QE in the U.S., a reduction in the ten-year term premium occurs. Similar to the finding by Joyce et al. (2010) about the effect on MBS, they find a more powerful effect, on the agency MBS as well as agency debt. As a result of lowering longer term borrowing rates, they conclude that the Federal Reserve's LSAP programs would be successful in stimulating the economic activity.

Expect these, regarding the effect on longer-term U.S. treasury yield, the study by D'Amico et al. (2012) shows that both the first round and the second round of LSAPs program reduce the longer-term U.S. treasury yield, and compared with the level of these two effects, the second wave of QE has a greater influence on the longer-term U.S. treasury yield. Similarly, Vough (2011) also studies the effect of the quantitative easing on long-term interest rates, in the United States financial markets. The research uses an ordinary least squares (OLS) regression analysis and U.S. economic data, to report that due to the implementation of quantitative easing policy, the mortgage rates in the U.S. market have been reduced. However, the results can not indicate a statistically insignificant impact on Treasury rates.

To measure the impact of the initial British quantitative easing program used by the Bank of England, Breedon et al. (2012) and Kapetanios et al. (2012) state their research in a similar way. The former finds a significant influence on the U.K. bond market, but the effect on the economy, in general, is still controversial and needs to be checked in the future. The latter researchers demonstrate a variety of vector autoregression (VAR) models to examine the macroeconomic impact, include: a large Bayesian VAR; a change-point structural VAR; and a time-varying parameter VAR. The results indicate the British QE program had a maximum effect on the level of the real GDP and a peak effect on annual CPI inflation.

Starting from a novel perspective, Szczerbowicz (2012) focuses on how the bank and government borrowing costs are affected by all European Central Bank's (ECB) unconventional monetary policies carried out between 2007 and 2012. The results show that the ECB unconventional monetary policies do have an impact on reducing significantly borrowing costs of banks and governments, namely the sovereign bond purchases, covered bond purchases and three-year refinancing operations, but only part of these policies have this influence.

Moreover, there are some but not many empirical and theoretical studies involve bank characters with the quantitative easing research, such as bank risk-taking attitude, lending standard, reserve, etc.. Bernanke and Reinhart (2004) define the accumulation of reserves as the characteristic of QE to explain the transmission channels of QE in their study. They present that “large increases in the money supply will lead investors to seek to rebalance their portfolios, raising prices and reducing yields on alternative, non-money assets.” In the work of Christensen and Krogstrup (2016), they examine three unique episodes in Swiss, and where the Swiss National Bank expanded reserves by purchasing only short- term debt securities. They find that the QE announcements reduce the long-term yields on benchmark Swiss Confederation bonds. And that can be explained by a lower expected path of short- term interest rates, they also conclude that the reason for the decreasing longer-term yields would be the anticipated creation of reserves.

In addition, the effect of QE on bank risk-taking and lending behavior can be linked to the literature on the impact of monetary policy on banks’ investment decisions (Bernanke and Gertler (1995) and Kashyap and Stein (2000)), because this topic is related to risk-taking effects caused by monetary policy. Regarding the effects of monetary policy on bank risk taking, most of the current literature focuses on the risk taking by financial institutions in low interest rate environments (see, for example, Maddaloni and Peydro (2011), Jimenez et al. (2014), Ioannidou et al. (2015), Di Maggio and Kacperczyk (2016), and Dell’Ariccia et al. (2016)) and in an environment with negative rates (see, for example, Heider et al. (2019)). However, the connection between bank risk taking and this unconventional monetary policy is very limited.

Moreover, this topic is also related to the impact of unconventional monetary policy (LSAPs) on bank investment decisions. For example, Chakraborty et al. (2019) use micro-level data, and find that banks who benefit from MBS purchases by the central bank, have an increase of the mortgage origination, compared with other banks. At the same time, these banks reduce commercial lending and firms that borrow from these banks decrease investment. Acharya et al. (2019) examine the effect of the ECB Outright Monetary Transactions (OMT) program which indirectly recapitalized European banks through its positive impact on periphery sovereign bonds. However, they find even the banking sector has been reestablished the stability, but economic growth is not fully benefited, as the stability is not fully translated into economic growth. Meanwhile, Di Maggio et al. (2016) test the impact of the zero lower bound interest rate policy on the industrial organization of the U.S. money fund industry. They find that under the low interest rates condition, the response of banks to such policy is that they will change their investment strategy and invest in riskier assets.

Some of the mechanism channel mentioned in this chapter is related to the redistributive monetary policy, which is first presented by Brunnermeier and Sannikov (2016). They explain that monetary policy can affect the value of assets held by agents on their books, in turn, to impact the real economy. For example, according to Rodnyansky and Darmouni (2017) "raising the price of a long-term security effectively improves the balance sheets of agents who hold this asset and relaxes financial constraints. In other words, such policy is equivalent to a stealth recapitalization of these agents."

Apart from the above literature we discussed, these other recent studies about the effect of LASPs is also highly related to this chapter. Morais et al. (2019) provide evidence of international risk-taking channel and spillovers of core countries' monetary policies (such as U.S. and European countries) to emerging markets. The research of Rodnyansky and Darmouni (2017), indicates that banks' exposure to large-scale asset purchases affects lending following unconventional monetary policy shocks. Based on a difference-in-differences (DID) identification strategy, they find the first and third waves of QE have strong effects on credit, while QE2 has no significant impact. Kurtzman et al. (2018) examine how the Federal reserve's LSAPs affect lending standards. By using lending standard and internal risk rating on loan data, they find the first and third rounds of QE significantly lower lending standards and increase loan risk characteristics. Similar results are concluded by Nakashima et al. (2017), which is that an increase in the share of unconventional assets held by the Bank of Japan, will contribute the bank with lower liquidity ratio and higher risk appetites to lend to firms with higher credit risks. Another relevant study by Kandrac and Schlusche (2017) assesses the effect of reserve accumulation as a result of QE on bank-level lending and risk taking activity. They argue that banks' total loan growth is higher, and their share of riskier loans also increases, due to the reserves created in QE programs.

4.3 A Review of the Federal Reserve's QE Programs

In the following part, this chapter will outline the large-scale asset purchase programs that the Federal Reserve carried out since 2008, including three rounds of QE, denoted using QE1, QE2, and QE3.

To respond the recent financial crisis and deepening recession, the initial wave of QE was on 25th November 2008. The Federal Open Market Committee (FOMC) announced a program to purchase agency mortgage - backed securities (MBS) with the stated intentions of providing support to mortgage lending and housing markets, as well as fostering improved conditions in financial markets more generally (Rodnyansky and Darmouni, 2017). The purchases began in the following month, and were authorized for "up to" $100 billion in direct obligations of government-sponsored enterprises (GSEs) and $500 billion in MBS guaranteed by Fannie Mae, Freddie Mac, and Ginnie Mae. One and half years later, the purchases were completed on 31st March 2010. Until that time, Fed had accumulated $1.25 trillion in MBS, $175 billion in federal agency debt (issued by Fannie Mae, Freddie Mac, and Ginnie Mae) and $300 billion in long-term Treasury securities. According to Rodnyansky and Darmouni, (2017), at that point, the Fed's market share of agency MBS had reached approximately 25%, and in QE1, the purchase of $300 billion in long-term Treasuries was meant to reduce interest rates in general, and the total purchase of $1.425 trillion of MBS and agency debt was aimed at increasing credit availability in private markets, resuscitating mortgage lending, and supporting the housing market. To conclude QE1, there are $172 billions of agency debt, $1.25 trillion of MBS, and $300 billion of Treasury securities.

In mid-2010, a lot of economists and policymakers are worried about that the U.S. might suffer the similar problem to Japan's experience during the 1990s, which is deflationary spiral might lead to a lost decade of economic growth. Under this circumstance, a second round of QE was introduced by FOMC, with the intensions of deal with the problem of deflation, and the continued weakness of the U.S. economy after QE1. The second round of QE entailed the total purchase of $778 billion in long-term Treasury securities, which included $600 billion in announced program purchases of longer-term Treasury securities by the end of the second quarter of 2011 and $178 billion as reinvestment of principal payments from the Fed's agency debt and MBS holdings. This second round of quantitative easing lasted from 3rd November 2010 until 30th June 2011, and with the purchase of Treasury securities at a pace of $75 billion per month.

In September 2011, the Federal Reserve initiated further adjustments its portfolio, due to the numerous concerns about threatening to further destabilize the U.S. economy by the onset of Europe's sovereign debt crisis. This maturity extension program introduced by FOMC was known as Operation Twist. These adjustments involved the sale of short-term Treasury securities and an equal purchase of long-term Treasury securities to exert downward pressure on long-term interest rates, at the same time to maintain the same amount of securities on the Fed balance sheet (Rodnyansky and Darmouni (2017). After that point, Operation Twist extended in June 2012, and continued through the end of 2012. Overall, the total amount FOMC purchased, sold and redeemed in Treasury securities through this program was $667 billion, and with a result of dispensing all holdings of short-term securities with a maturity of one year or less.

Finally, on 13th September 2012, a most recent and largely unanticipated QE program was undertaken by FOMC, which is QE3. The purchases initially involved $40 billion in agency MBS per month. Especially, for the first time, the FOMC opted open-ended purchases for the ultimate size of the QE program. However, after Operation Twist ended in December 2012, the FOMC added $45 billion in long-term Treasury securities to the monthly purchase. And the FOMC reduced the monthly asset purchases for the first time at its December 2013 meeting. The total amount of the monthly asset purchases dropped to $75 billion from $85 billion, and the QE3 program continued as state-contingent and open-ended initiative until 29th October 2014, when it was formally discontinued. According to Rodnyansky and Darmouni (2017), by the end of all three QE rounds, the Fed had accumulated $1.75 trillion in MBS, representing around 30% of the entire agency MBS market.

The following table 4.1 shows the compilation of dates, announcements, and each round of QE, during the Federal Reserve's LSAPs programs, which was developed by Woodford (2012) and Hancock and Passmore (2015). Table 4.1 shows the detailed information about the three rounds of QE, the first column is the list of the order of all the announcement, listed according to the announcement time. The second column is the announcement time, while the next column is the contents of each announcement. The fourth column is the classification of each round of QE. The three rounds of QE are denoted using QE1, QE2, and QE3 respectively. The Operation Twist is denoted by OT. The last column indicates the change in LSAPs, denoted by "increase" and "decrease", where increase means that the announcement is about an increase in LSAPs, and vice versa. The contents of "Com" in the last column is described as a communication about asset purchases.

Table 4.1 QE Announcement Descriptions.

Order	Date	Announcement	Program	Type
1	11/25/2008	The Federal Reserve will purchase "up to $100 billion in GSE direct obligations, and up to $500 billion in MBS."	QE1	Increase (increased purchases)
2	12/1/2008	In a speech, Chairman Bernanke states that the Federal Reserve "could purchase longer-term Treasury or agency securities ... in substantial quantities."	QE1	Com (communication)
3	12/16/2008	The FOMC "anticipates ... exceptionally low levels of the federal funds rate for some time." It also "stands ready to expand its purchases of agency debt and mortgage-backed securities ... [and] is also evaluating the potential benefits of purchasing longer-term Treasury securities."	QE1	Com
4	1/28/2009	The FOMC "is prepared to purchase longer-term Treasury securities."	QE1	Com
5	3/18/2009	The FOMC "anticipates ... exceptionally low levels of the federal funds rate for an extended period." It will also purchase "up to an additional $750 billion of agency mortgage-backed securities, up to $100 billion" in agency debt, and "up to $300 billion of longer-term Treasury securities over the next six months."	QE1	Increase
6	8/12/2009	The FOMC "decided to gradually slow the pace" of Treasury purchases ("up to" language with reference to Treasury purchases is also removed).	QE1	Decrease (decreased purchases)
7	9/23/2009	The FOMC "will gradually slow the pace" of agency MBS purchases ("up to" language with reference to agency MBS purchases is also removed).	QE1	Decrease
8	11/4/2009	The FOMC "will purchase ... about $175 billion of agency debt" ("up to" language with reference to agency debt is also removed).	QE1	Increase
9	8/10/2010	The FOMC will reinvest "principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities."	QE2	Increase
10	8/27/2010	In a speech, Chairman Bernanke announces that "additional purchases of longer-term securities ... would be effective in further easing financial conditions."	QE2	Com
11	9/21/2010	The FOMC "is prepared to provide additional accommodation if needed."	QE2	Com

Table 4.1 Continued.

Order	Date	Announcement	Program	Type
12	11/3/2010	The FOMC "intends to purchase a further $600 billion of longer term Treasury securities by the end of the second quarter of 2011, at a pace of about $75 billion per month."	QE2	Increase
13	9/21/2011	The FOMC "intends to purchase, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of six years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of three years or less. To help support conditions in mortgage markets, the Committee will now reinvest principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities."	OT	Increase
14	6/20/2012	The FOMC "decided to, continue through the end of the year its program to extend the average maturity of, its holdings of securities." An accompanying statement by the Federal Reserve Bank of New York clarifies that this continuation will "result in the purchase, as well as the sale and redemption, of about $267 billion in Treasury securities by the end of 2012."	OT	Increase
15	9/13/2012	The FOMC "will increase the Committee's holdings of longer-term securities by about $85 billion each month through the end of the year, including purchasing additional agency mortgage-backed securities at a pace of $40 billion per month."	QE3	Increase
16	12/12/2012	The FOMC will continue purchasing "at least as long as the unemployment rate remains above 6–1/2%, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2% longer-run goal, and longer-term inflation expectations continue to be well anchored."	QE3	Com
17	5/22/2013	In a speech to Congress, Ben Bernanke states that "If we see continued improvement, and we have confidence that it is going to be sustained, in the next few meetings we could take a step down in our pace of purchases."	QE3	Decrease

Note: this table provide a summary of major statements made by the Federal Reserve from November 2oo8 to May 2013. The statements using Hancock and Passmore' s (2015) " How Does the Federal Reserve's Large-Scale Asset Purchases (LSAPs) Influence Mortgage-Backed Securities (MBS) Yields and US Mortgage Rates?"

4.4 Data and Empirical Strategy

4.4.1 Data

There are mainly two data sources in this chapter. The bank balance data set mainly comes from the Consolidated Reports of Condition and Income (Call Reports). This call report is collected by Federal Financial Institutions Examination Council (FFIEC). Every National Bank, State Member Bank and insured Nonmember Bank (in other words, all commercial banks with insured deposits) is required to file a call report every quarter, and submits to the FFIEC. This Call Reports are also formally known as the FFIEC 031 (used for banks with both domestic (U.S.) and foreign (non-U.S.) offices) and FFIEC 041 (used for banks with domestic (U.S.) office only) regulatory filings. From these Call reports, all main variables in the analysis are sourced. We can find detailed information from the Call Reports, such as banks' income statements, balance sheets, and off-balance sheet data. Other macroeconomy data set mainly comes from Thomson Reuters DataStream. In this analysis, as we are testing the effect of three rounds of Federal Reserve QE, the time period under consideration would be the same with the main period of LSAPs, from 2008Q1 up until 2014Q1. There are more than 190 thousand observations in our data set. And the total number of banks included in this chapter is over 7500 on average.

4.4.2 Empirical Strategy

In this part, we will discuss the empirical methodology. In order to identify the effect of QE on bank lending standards and bank risk-taking, we set the main regression specification as follows:

$$y_{i,t} = \alpha + \beta(\frac{MBS}{TotalAssets})_{i,t} postQE^{j} + \theta X_{i,t} + \gamma_i + \tau_t + \varepsilon_{i,t} \qquad (4.4.1)$$

Where,

$y_{i,t}$ is the bank i's risk-taking level in period t,

$(\frac{MBS}{TotalAssets})_{i,t}$ is bank i's ratio of MBS holding to total assets in period t,

QE^{j} is a post-treatment dummy of the j^{th} round of QE,

$X_{i,t}$ is the control variable

γ_i is the bank-fixed effects,
τ_t the time-fixed effects,

$\varepsilon_{i,t}$ is the error term.

To describe all the variables in the regression function, here, the dependent variable $y_{i,t}$, is the bank risk-taking level, measured by Z-Score, which is an inverse proxy of bank risk taking level. Z-score can be used to measures the distance from insolvency

(Roy, 1952), which is defined as a state where losses are larger than equity. A high Z-score means more stability of the bank. So, the higher Z-score is, the more monitoring effort will be paid by bank, and the less risk the bank takes. It can be calculated by the return on assets plus the equity to asset ratio divided by the standard deviation of return on assets. That is $Z = \frac{ROA+CAR}{\sigma(ROA)}$, where, ROA is the rate of return on assets, CAR is the capital assets ratio, and $\sigma(ROA)$ is an estimate of the standard deviation of return on assets. Intuitively, this measure of Z-score represents the number of standard deviations below the mean by which profits would have to fall so as to just deplete equity capital (Boyd, De Nicolò, and Al Jalal, 2006). It has been widely used to measure the bank risk taking level (e.g. Houston et al 2010, Laeven and Levine, 2009).

The independent variable $(\frac{MBS}{TotalAssets})_{i,t}$ is bank i's ratio of MBS holding to total assets in period t. While QE^j is a post-treatment dummy which is equal to 1after the implementation of the j^{th} round of quantitative easing. Moreover, our regression includes bank-fixed effects, γ_i, and time-fixed effects, τ_t, to control for fixed differences between banks and for differences over time that affect all banks. Therefore, only the interaction between the MBS share and the QE dummies is estimated while the main effects of both variables are absorbed by the fixed effects. We include bank-specific, time-varying controls to control for remaining differences between banks, which is $X_{i,t}$ in the function. It includes: equity ratio, lending, net income, total assets, and reserves.

Next, we will introduction the definition of these variables. According to the Call report, in the U.S. banking sector mortgage-backed securities include: US government agency and corporation issued obligations or guaranteed certificates of participation in pools of residential mortgages. US Government agency and corporation obligations and collateralized mortgage obligations issued by the Federal National Mortgage Association (FNMA) and the Federal Home Loan Mortgage Corporation (FDHLMCV, including real estate mortgage investment conduits - REMICS). Other domestic debt private securities (i.e., non-government issued or guaranteed) and certificates of participation in pools of residential mortgages. Other domestic debt securities that are privately issued and collateralized mortgage obligations (including REMICS). Effective March 1994, the full implementation of FASB 115 (The Financial Accounting Standards Board) states that a portion of banks' mortgage-backed securities portfolio is now reported based upon fair (market) values; previously, all mortgage-backed securities not held in trading accounts were reported at either amortized cost or lower of cost or market. Total assets are the sum of all assets owned by the institution including cash, loans, securities, bank premises and other assets. This total does not include off-balance-sheet accounts. Net interest income is the total interest income minus total interest expense. It represents the difference between interest and dividends earned on interest-bearing assets and interest paid to depositors and other creditors. Lending is total loans and lease financing receivables minus unearned income and loan loss allowances. Net income is net interest income plus total noninterest income plus realized gains (losses) on securities and extraordinary items, less total noninterest expense, loan loss provisions and income taxes. Reserves are the cash and balances due from depository institutions.

Table 4.2 Summary Statistics for The Variables

	N	Mean	St.Dev	p10	p25	Median	p75
Zscore	190459	.1719	.8392	-.1563	.0917	.209	.3239
mbstoasset	190686	.0821	.1056	0	.0015	.046	.1215
equityratio	190682	.1152	.0709	.0767	.0878	.1021	.1237
roa	190459	.538	3.8909	-.7128	.2487	.7017	1.1468
income	190459	.0069	.219	-.0005	.0001	.0005	.0014
lend	190686	.9754	15.3861	.0196	.0425	.0965	.228
reserve	190686	.1602	3.7011	.0019	.004	.0092	.0227
lgassets	190686	12.0963	1.361	10.5877	11.2303	11.9523	12.7698

The above table 4.2 shows the summary statistics for all the variables. The main variables are MBS to total assets ratio and the inverse bank risk taking level – Z-score. The mean for MBS to total assets ratio is 0.08 and the mean for Z-score is 0.17. The average MBS to total assets ratio is low, because not all banks in the U.S. market hold MBS securities. These banks without MBS securities holdings will exert downward pressure on this mean value.

Table 4.3 Correlation between Treatment and Initial Characteristics

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Zscore	1.000					
(2) mbstoasset	0.015	1.000				
(3) equityratio	0.182	0.059	1.000			
(4) income	0.047	0.009	0.005	1.000		
(5) lend	0.002	0.012	-0.002	0.668	1.000	
(6) reserve	0.002	0.006	-0.005	0.589	0.781	1.000
(7) lgassets	0.007	0.126	-0.164	0.156	0.277	0.209

From the results of the correlation between treatment and initial characteristics of banks, we can see there is a positive correlation between MBS holding to total asset ratio and the inverse bank risk taking, which intuitively represents a decrease in the

MBS holding for a bank, its risk taking level will increase, because Z-score is an inverse proxy of bank risk taking. And QE reduced the amount of MBS holding of an individual bank, as a consequence, these three rounds of quantitative easing (QE1, QE2, and QE3) lowered bank lending standards by taking more risk.

4.4.3 Results

Firstly, we run models with random effect and fixed effect with and without the dummy variable quantitative easing to exam the effect of quantitative easing on bank risk taking in these two models. However, after running and checking the results of Hausman test, the p-value turns to zero, which means we can use fixed effect model to exam the effect of quantitative easing on bank risk taking. Here are the results:

Table 4.4 Fixed Effect Regression Results

	(1) Zscore	(2) Zscore
mbstoasset	0.055***	0.041**
	(0.021)	(0.021)
equityratio	0.420***	0.327***
	(0.030)	(0.030)
income	0.218***	0.216***
	(0.006)	(0.006)
reserve	-0.002***	-0.002***
	(0.001)	(0.001)
lend	-0.004***	-0.004***
	(0.000)	(0.000)
lgassets	0.339***	0.344***
	(0.005)	(0.005)
t	-0.000***	0.002***
	(0.000)	(0.000)
qe1		-0.120***
		(0.004)
qe2		-0.091***
		(0.006)
qe3		-0.090***
		(0.009)
_cons	-3.967***	-3.962***
	(0.063)	(0.062)
Obs.	190459	190459
R-squared	0.038	0.048

Standard errors are in parenthesis
*** *p<0.01,* ** *p<0.05,* * *p<0.1*

Both of the above models are fixed effect models. The first model is estimated without the dummy variable quantitative easing, while the second model is estimated with the dummy variable quantitative easing. From the above results, we can find the MBS to total assets ratio has a significant negative effect on bank risk taking at 1% and 5% levels, in the models with and without the dummy variable quantitative easing, which means that a reduction of MBS to total assets ratio will spur bank to take more risk. The results in model 2 also show strong evidence that all the three waves of quantitative easing have a negative effect on Z-score, and in turn, a positive effect on bank risk taking. Therefore, those three rounds of quantitative easing significantly lowered bank lending standards and increased loan risk characteristics at 1% level. However, the effect of each round of QE on bank risk taking level is different. The first wave of QE has the greatest effect on bank risk taking choice. The occurrence of QE1 encourages banks to take 0.12 units more risk, which is higher than QE2 and QE3. After QE2 and QE3. Banks risk taking level has increased by 0.91 unit and 0.9 unit respectively. That results are constant with the risk taking channels we discussed in the first section, which indicates that the implementation of QE programs increases bank risk taking, by softening their lending standards.

Regarding other variables in the regression, they have a very similar effect on banks risk taking level, regardless of the existence of dummy variable quantitative easing. The equity ratio has a negative effect on the banks' appetite for risk taking. The higher bank's equity ratio is, the less risk will be taken. That is true, because a higher equity ratio means less risk and greater financial strength, compared with a lower ratio. A higher equity ratio means the banks has a lower portion of debts, which is less safe, because banks with more debt and a low portion of equity need to pay a large number of interest payments. As a result, it might result in bankruptcy.

The income factor also has a negative impact on banks risk taking behavior. The banks with higher income, they will surely reduce the risk taking level to maintain the current high income. Otherwise, if the bank with high income takes more risk, it will increase the possibility of bank's bankruptcy and worth nothing. Similarly, to the asset variable, big size of banks will generally decrease their bank risk taking level to seek long term and sustainable success.

Regarding the variables reserve and lending, both of them have a positive impact on banks risk taking. That is because, for reserve, it is a safe asset. If a bank has more reserve holding, this means the bank is holding a safer asset, and in turn to change the taking risk ability of the bank. As a result, this kind of bank would like to soften its lending standard and bear more risk. Secondly, with respect to the amount of lending, a bank increases the amount of lending will increase the risk taking level, because risk always goes with some of the lending behavior.

In the next stage, we will use an interaction term between MBS to asset ratio $(\frac{MBS}{TotalAssets})_t$ and post-treatment dummy QE^j to test the effect of QE on bank lending and risk taking behavior. In the following table, we denote the interaction term INTER1 is between MBS to asset ratio and QE1, interaction term INTER2 is between MBS to asset ratio and QE2, and interaction term INTER3 is between MBS to asset ratio and QE3. The following table shows the estimation results.

Table 4.5 Regression Results

Zscore	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
mbstoasset	0.237	0.026	9.05	0.000	0.185	0.288	***
equityratio	0.410	0.030	13.81	0.000	0.351	0.468	***
income	0.218	0.006	38.19	0.000	0.207	0.229	***
reserve	-0.002	0.001	-3.58	0.000	-0.003	-0.001	***
lend	-0.004	0.000	-11.7	0.000	-0.005	-0.004	***
lgassets	0.339	0.005	70.53	0.000	0.330	0.348	***
INTER1	-0.312	0.020	-15.4	0.000	-0.352	-0.272	***
INTER2	-0.194	0.020	-9.60	0.000	-0.234	-0.155	***
INTER3	-0.213	0.022	-9.62	0.000	-0.257	-0.170	***
Constant	-3.975	0.060	-66.5	0.000	-4.092	-3.858	***

Mean dependent var	0.172	SD dependent var	0.839
R-squared	0.039	Number of obs	190459.000
F-test	820.104	Prob > F	0.000
Akaike crit. (AIC)	150743.496	Bayesian crit. (BIC)	150845.068

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

When we include the interaction terms into the regression, the results do not change a lot, compared with the previous regression. We can see from the table 4.5, all the 3 rounds of quantitative easing had a positive effect on bank risk taking level, which means that during the 3 waves of QE, banks lowered their loan standards, and as a result, in the U.S. banking sector, banks take more risk. What is more, equity ratio, income, and bank's assets show a negative influence on bank risk taking, while bank reserve and the amount of lending still have the power to spur banks to taking more risk.

In this part, during the period of three rounds of Federal Reserve QE, does the conventional monetary policy still work to encourage bank's risk taking behavior, or not? Therefore, we will compare the effect between the unconventional monetary policy instrument, such as QE, and the conventional monetary policy instrument, short-term interest rate, e.g. FED fund rate. the following analysis is divided into two parts. In the first part, which is in the first two columns, regression (3) and regression (4), we compare the effect of these two policies on bank risk taking without interaction terms between policy instruments and QE. And in the second part, which is in the last two columns, regression (5) and regression (6), we compare the effect of these two policies on bank risk taking by involving interaction terms between policy instruments and QE. In the first comparison, we can see from the following table 4.6, the QE variable proxy – MBS to assets ratio has exactly the same effect on bank risk taking, but with a bit less effect on it, which is 0.005 less. However, the United States' short term interest rate has been lowered to the zero lower bound, and it will not change a lot. So, in this case, the quantitative easing generally takes the role of monetary policy rate during this period, which had been used before the quantitative easing to control and stimulate the economy. From the results of the second comparison, the unconventional monetary policy has a greater impact on banks risk taking level, which means, during this period, QE is an effective instrument to stimulate the economy and generally takes the role of conventional monetary policy. Moreover, the effect of short term interest rates only shows up in the very beginning of the first wave of QE, while in the following two rounds of QE, because United States' short term interest rate has been lowered to the zero lower bound, this conventional monetary policy instrument is not effective anymore.

Therefore, in this case, when we assess the effect of QE in the post-crisis period, the intensity of monetary interventions is unlikely to be measured by changes in the policy rate since most interest rates were stuck at the zero lower bound. That means that the intensity of QE programs is captured, by the size of asset purchases operated by Central Banks (e.g. relative to the assets held in the balance sheet before the crisis).

Table 4.6 Regression Results

	(3) Zscore	(4) Zscore	(5) Zscore	(6) Zscore
mbstoasset	0.048**		0.237***	
	(0.021)		(0.026)	
fedfundrate		0.053***		0.053***
		(0.001)		(0.002)
equityratio	0.407***	0.432***	0.410***	0.349***
	(0.030)	(0.029)	(0.030)	(0.030)
income	0.218***	0.218***	0.218***	0.216***
	(0.006)	(0.006)	(0.006)	(0.006)
reserve	-0.002***	-0.002***	-0.002***	-0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
lend	-0.004***	-0.004***	-0.004***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
lgassets	0.332***	0.390***	0.339***	0.361***
	(0.005)	(0.005)	(0.005)	(0.005)
INTER1			-0.312***	
			(0.020)	
INTER2			-0.194***	
			(0.020)	
INTER3			-0.213***	
			(0.022)	
INTER4				-0.141***
				(0.018)
INTER5				0.103***
				(0.023)
INTER6				0.243***
				(0.027)
_cons	-3.892***	-4.616***	-3.975***	-4.259***
	(0.058)	(0.059)	(0.060)	(0.062)
Obs.	190459	190459	190459	190459
R-squared	0.038	0.049	0.039	0.052

Standard errors are in parenthesis
**** p<0.01, ** p<0.05, * p<0.1*

4.5 Conclusion

This study documents an effect of the Federal Reserve's LSAPs on bank risk taking. We introduce five potential channels that can be used to explain how the unconventional monetary policy affects bank lending behavior. They are the signaling channel, the net worth channel, the liquidity channel, the prepayment risk channel, and the default risk channel respectively.

From the empirical analysis, we find that all three rounds of Federal Reserve's LSAPs, QE1, QE2, and QE3 have significant effects on bank lending standards. During the three rounds of QE, banks lower their lending standards and it seems that it becomes to be riskier in the U.S. banking sector, due to the implementation of Federal Reserve's LSAPs.

We also compare the effect between the unconventional monetary policy instrument, QE, and the conventional monetary policy instrument, short-term interest rate, in our models. The results show that because the United States' short term interest rate has been lowered to zero lower bound, although it still has an effect on the bank risk taking behavior, but it will keep relatively constant. And in this case, we can carefully say that quantitative easing is a more effective tool to stimulate the economy by replacing the role of monetary policy rate during this period.

Our findings can contribute to a better understanding of how unconventional monetary policy affects risk-taking behavior in the U.S. banking sector. It shows that QE did not only affect the availability of credit, but also led banks to issue relatively more risky loans with lower lending standards.

To conclude, credit risk is the most important risk for banks, the results indicate that the waves of QE increase the incentive of banks to take more risk. Even banks pay more effort to control risk taking after the recent financial crisis, it is not confirmed that if banks are still taking excessive risk, due to the low short term interest rate and the implementation of QE. So, for the bankers and policymakers, it is important to monitor the banks risk taking level regularly and frequently. And central banks also need to take into account the financial stability implications of their monetary policy decisions.

Chapter 5

Conclusion

5.1 Main Findings and Contributions

This thesis consists of three independent chapters, each addressing a specific and relevant issue regarding banks risk taking behavior and monetary policy. These essays are meant to contribute to our understanding of some new issues that emerged along with the progress of economy and information technology that, in general, have not yet received much investigation by the economic literature, especially brought by the recent financial crisis. In the first chapter, we apply financial theory models to examine the nature of the banks risk taking behavior under specific monetary policy conditions, assessing how banks' appetite for risk taking is affected by the current monetary policy, and indicating how policymakers can adjust and stabilize the financial system by change different monetary policies. In the second chapter, we prove the theoretical models in the first chapter, with empirical evidence, by adopting the U.S. banking sector database. And the results are consistent with the findings in the first chapter. In the final essay, we seek to investigate the effect of unconventional monetary policy on banks risk taking, with an empirical method, because after the use of the large-scale assets purchases, it seems to become the more important instrument for some central banks compared with conventional monetary policy.

This thesis makes several contributions to the literature in the area of monetary and bank risk-taking. Chapter 2 analyses one of the main causes of the recent financial crisis from a bank risk taking perspective, introducing three effects regarding the risk-taking channel, which are the value effect, the search-for-yield effect, and the risk-taking-channel effect. Meanwhile, we extended the combinations of banks monitoring cost function and firms loan demand function in the theoretical models, and also extend the assumptions, to compare the case which includes the assumption of limited liability for banks and the case which excludes the assumption of limited liability for banks. Chapter 3 is an empirical work adopting a unique model from chapter 2 and database including balance sheet information for listed top banks in the U.S. over the period 2000 to 2017, to check the effect of U.S. monetary policy on their banks' risk taking behavior. In this chapter, we apply a Generalised Method of Moments (GMM) to address the dynamic effect of monetary policy, and compare the effect of other factors on bank risk taking attitude, such as bank's size, time, how the bank is financed, etc. In the fourth chapter, we use U.S. banks Call Report data to document the effect of large-scale asset purchase programs (LSAPs) on banks' lending standards and risk taking. our findings in this chapter contribute to the growing literature which is about the effect on LASPs on economic activities, especially the understanding of how unconventional monetary policy affects risk-taking behavior in the banking sector. It is very important to show that QE can affect the availability of credit, meanwhile, it also leads banks to issue relatively more risky loans by lowering their lending standards.

To sum up, chapter 2 identifies the impact of the monetary policy on the behaviour of banks risk taking in theoretical foundation with different assumptions in different market structures. We analyse several cases in which different market structures, a reasonable bank monitoring cost functions and different loan demand functions exist.

By letting banks maximize their profits and achieve the equilibrium, we have the theoretical results of our model, with the assumption of unlimited liability for the bank. Firstly, for a convex monitoring cost function, and a linear loan demand function, when the capital structure is exogenous, and banks can choose loan interest rate, a lower risk-free rate unambiguously reduces monitoring and, hence, unambiguously increases bank risk taking. Secondly, for a convex monitoring cost function, and the assumed concave loan demand function, when the capital structure is exogenous, banks can also choose loan interest rate, the result is similar that banks monitoring increases with monetary policy rate. Banks will take more risk with the monetary policy rate decreases. Finally, for a convex monitoring cost function, and the assumed piecewise loan demand function, when the capital structure is exogenous, banks risk taking level is fixed according to the optimal loan interest rate and it is not affected by monetary policy rate. Some different results exist when we include the assumption of limited liability for the bank in the case of failure. Firstly, for a convex monitoring cost function, if the bank finances itself with a high equity ratio, both models with linear loan demand function and the assumed concave loan demand function, can predict a positive correlation between the risk free interest rate and bank monitoring effort. Therefore, they can also predict a negative correlation between the policy rate and bank risk taking. A low policy rate level will increase bank risk taking, and a high policy rate level will reduce bank risk taking. Secondly, for a convex monitoring cost function, the model with the assumed piecewise loan demand function, can predict a negative correlation between risk free interest rate and bank monitoring effort. Banks will take more risk with the monetary policy rate increases.

In the next two chapters, we adopt empirical analysis. The third chapter provides strong and wide evidence, via the empirical analysis, to show that a low short-term interest rate can contribute to the increase of bank risk-taking. Banks will take more risk if the monetary policy rate decreases. Bank risk taking behavior can be affected by lots of factors, such as bank's capitalization, equity ratio, season, etc. The bank risk taking level had been reduced by the recent financial crisis, and banks take less risk after the crisis, than that in the period of pre-crisis. Meanwhile, for bank's characteristics, the effect of short-term interest rates on bank risk-taking is less pronounced for poorly capitalized banks; the effect of short-term interest rates on bank risk-taking is also stronger for the banks financed with a higher portion of equity. Finally, season will change bank risk taking behavior as well, and power is especially strong at the period of pre-crisis.

In the fourth chapter, the results indicate that all three waves of quantitative easing, QE1, QE2, and QE3 had significant effects on lowing bank lending standards, which means, because of QE, it leads banks to issue relatively more risky loans with lower lending standards. We also compare the effect between the unconventional monetary policy instrument, QE, and the conventional monetary policy instrument, short-term interest rate, in the model. The results show that because the United States' short term interest rate has been lowered to zero lower bound, although it still has an effect on the bank risk taking behavior, but it will keep relatively constant. And in this case, the quantitative easing generally replaces the role of monetary policy rate during this period.

5.2 Future Research and Policy Implications

In this section, we briefly discuss future research relating to each essay in turn and some potential policy implications.

In chapter 2, regarding the theoretical models, we can extend the model by taking some other factors into consideration, for example, deposit insurance, competition between banks, etc. In chapter 3, regarding the database, we can include more banks from inside and outside the U.S. banks sector. Based on that, it will be interesting to compare the banks' risk-taking behavior in different regions and different economies. The time period of our data is another point which can be extended, as at the end of the sample period, we find an obvious upwards trend of the short term interests. Hence, investigating what happens to the banks' risk-taking attitude after 2017, will be an interesting topic to pursue in the future. Meanwhile, regarding the empirical method, other points are also worth trying, such as VAR models, Difference-in-differences (DID) method. In the fourth chapter, we can adopt some other estimation methods as well in future research, such as DID estimation with continuous treatment variable, to test compare the three waves of QE's effect on bank risk taking.

Credit risk is the most important risk for banks, the results indicate that low interest rate and the waves of QE both increase the incentive of banks to take more risk. Even banks pay more effort to control risk taking after the recent financial crisis, the risk free interest rate is still in low level, and the process of QE also spur bank's risk taking level. So, for the bankers and policymakers, it is important to monitor the banks risk taking level regularly and frequently. And central banks should take into account the financial stability implications of their monetary policy decisions.

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