The Risk-Taking Channel of Monetary Policy: Evidence from Norway

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Abstract

This thesis presents and discusses the theoretical and empirical literature that analyses the effects of monetary policy on financial stability. As a means to clarification and structure, the thesis will build on the IMF (2013) approach of separating the different effects that monetary policy may have on financial stability. These effects are divided into five different channels. In a literature review, these channels are carefully examined, and many of the most important contributions to the literature are presented. In short, the borrower balance sheet channel refers to the effects that higher monetary policy rates may have on borrowing constraints and therefore possibly on default rates. The asset price channel refers to the effects that lower monetary policy rates may have on aggregate asset prices that might lead to asset price bubbles. The exchange rate channel points to the effects that monetary policy may have on capital flows and exchange rates, and therefore on foreign borrowing. The risk-shifting channel refers to the effects that higher monetary policy rates have on the liability side of banks' balance sheets, possibly reducing banks' margins. Finally, the risk-taking channel refers to the potential effects of monetary policy on the asset side of banks' balance sheets, which may affect banks' risk-taking.

The second part of the thesis provides an empirical analysis of a potential risk-taking channel in Norway. By making use of quarterly panel data for Norwegian banks over the period 1995 to 2014, I study the effects of an increased three-month NIBOR interest rate, as a proxy for Norwegian monetary policy, on the composition of banks' risk weighted corporate lending. The results provide evidence of a risk-taking channel. Thus, the results from the analysis suggest that banks' risk-taking is negatively associated with interest rates. However, since the estimated interest rate coefficient is quite small, the economic significance seems modest. I also find evidence of a less pronounced negative relationship for banks with higher capitalization levels, which is contrary to the implications suggested by the theory as well as previous empirical findings in other countries. This literature suggests that the negative relationship is less pronounced for banks with lower capitalization levels. The results from the empirical analysis may contribute to the ongoing debate on the role of monetary policy on financial stability. However, the analysis also clearly indicates a need of further investigation.

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Contents

1 Introduction

Some researchers have blamed central banks for holding interest rates too low for too long in the run-up to the financial crisis in 2008. As Taylor (2009) argues, "[...] government actions and interventions caused, prolonged, and worsened the financial crisis". On the other hand, some have argued that monetary policy authorities only had negligible effects on the global financial crisis (Stiglitz, 2009). For these reasons, the financial crisis brought the link between monetary policy and financial stability to the forefront of the economic policy debate. It is important to emphasize that financial stability has long been an important consideration of central banks. However, after the financial crisis, there has been a particular focus on how monetary policy may potentially affect financial stability. Today, there is an increased concern about the historically low interest rates we currently observe in many countries, and whether these may be setting the stage for a next financial crisis. In this thesis I will examine the various effects that monetary policy may have on financial stability, with an emphasis on its relationship to banks' risk-taking, the so-called risk-taking channel of monetary policy. Analyzing the effects of monetary policy on banks' risk-taking could help to clarify whether accommodative monetary policy can lead to build-ups of financial imbalances, and may therefore contribute to the ongoing debate.

The purpose of this thesis is twofold. First, I will provide a review of the existing theoretical and empirical literature on the various channels through which monetary policy affects financial stability, with an emphasis on the risk-taking channel. Second, I will conduct an empirical analysis of the link between monetary policy rates and banks' risk-taking in Norway, thus potentially providing evidence of a risk-taking channel of Norwegian monetary policy. In this context monetary policy is mainly confined to the managing of key policy rates.

As a means to clarification and structure, the thesis will build on the IMF (2013) approach of separating the different effects that monetary policy may have on financial stability. These effects are divided into five distinct channels; the asset price channel, the exchange rate channel, the borrower balance sheet channel, the risk-shifting channel and the risk-taking channel. There has been a growth in theoretical and empirical literature analyzing these channels, and how they may contribute to financial stability. As argued in IMF (2013), these channels may work in opposing directions: Through the borrower balance sheet channel, *higher* interest rates can adversely affect borrowers' repayment capacity, thus contributing to higher risk of default and financial instability. Similarly, for open economies, a monetary policy tightening can attract excessive capital flows, leading to an appreciation of the exchange rate and thereby excessive borrowing in foreign currency. This may cause the financial system to become more vulnerable, as both national and international shocks may erode the repayment capacity of financial intuitions. Thus the exchange rate channel of monetary policy may increase the risk of financial instability. Moreover, higher monetary policy rates may increase banks' cost of funding, thus possibly reducing their margins. As a response, banks may choose a riskier portfolio of assets in order to restore their margins, which may lead to increased risk of financial instability. This is referred to as the risk-shifting channel. On the other hand, through the asset price channel, a *lower* interest rate may increase the risk of asset price bubbles, which can also be a contributing factor to financial instability. In addition, accommodative monetary policy might lead banks to increase their risk-taking, as a potential consequence of reduced return on banks' assets. This link is known as the risk-taking channel of monetary policy. A summary of the five channels of monetary policy is given in chart 1, taken from IMF (2013). It should be noted that in this classification the risk-taking and risk-shifting channels are treated separately, as monetary policy affects different sides of banks' balance sheets. However, some of the literature does not distinguish between the latter two channels, since they both describe mechanisms through which monetary policy affects banks' risk-taking behavior.

Annex Table 1. Monetary Policy Effects on Financial Stability[1/]

Sources of Financial Instability	Channel	Predicted Effect (↑ improves stability) ↓r	↑r	Selected Empirical Evidence	
Borrowing Constraints	Balance Sheet (default) Channel	↑	↓	Sengupta (2010)	↑r, ↓
				Jiménez and others (2009)	↑r, ↓
				Gertler and Gilchrist (1994)	↑r, ↓
				Asea and Blomberg (1998)	↑r, ↓
Risky Behavior of Financial Institutions	Risk-taking Channel	↓	↑	Jiménez and others (2009)	↓r, ↓
				Ioannidou and others (2009)	↓r, ↓
				Merrouche and Nier (2010)	X
	Risk-shifting Channel	↑	↓	Gan (2004)	↑r, ↓
				Landier and others (2011)	↑r, ↓
Externalities through Aggregate Prices	Asset price Channel	↓	↑	Altunbas and others (2012)	↓r, ↓
				Del Negro and Otrok (2007)	↓r, ↓
				IMF (2009)	X
	Exchange rate Channel	↑	↓	Hahm and others (2012)	↑r, ↓
				Merrouche and Nier (2010)	↑r, ↓
				Jonsson (2009)	↑r, ↓

Source: IMF

Notes: ↓r means a decrease of policy rates, ↑r means an increase of policy rates, "↓" means a decline instability, "↑" an improvement, and "X" no statistically significant effect.

Chart 1: The Effects of Monetary Policy on Financial Stability. Source: IMF (2013)

In order to illustrate the risk-taking mechanism described above, I also present a simple monitoring model advanced by Dell'Ariccia, Laeven and Suarez (2013), where banks operate in a context of limited liability and asymmetric information about borrower quality. In this paper the risk-taking channel refers to the effect that monetary policy has on both sides of banks' balance sheet. Therefore, in line with the risk-taking and risk-shifting channels described in the above paragraph, the model predicts two opposing effects on banks' risk-taking following an increase in the monetary policy rate. First, a higher key policy rate translates into a higher lending rate, which increases the incentives for banks to monitor their portfolios since borrower default is now more costly. Consequently, a higher key policy rate leads to lower risk-taking, referred to as the pass-through effect. Second, in the opposite direction, there is a risk-shifting effect associated with the higher cost of liabilities. Typically, banks transform short-term loanable funds such as deposits into longer-term loans. Higher key policy rates may reduce intermediation spreads and thus the value of banks' future profits, and increase risk-taking incentives. In this simple model, the capital structure of banks is exogenous, but Dell'Ariccia et al. (2013) also consider several extensions to analyze the risk-taking channel under different banking market structures and when the capital structure is endogenous. The results show that by changing important aspects of the model, additional effects will arise that will amplify or dampen the risk-taking channel.

As mentioned above, in the second part of this thesis I will conduct an empirical analysis of the link between monetary policy rates and banks' risk-taking in Norway, thus potentially providing evidence of a risk-taking channel of Norwegian monetary policy. Finding evidence of a risk-taking channel would be a small but important step for further analysis of how monetary policy might affects financial stability. To my knowledge, there has only been one previous study of the risk-taking channel in Norway. Karapetyan (2011) studied the link between expansionary monetary policy and banks' risk-taking in Norway by using macro data, but the results do not show any statistical evidence of riskier activities following expansionary monetary policy. In this thesis I will analyze the link between short-term interest rates and banks' risk-taking using data on individual Norwegian banks' corporate lending taken from an administrative record of banks' characteristics (ORBOF). I will make use of quarterly panel data on 163 Norwegian banks over the period 1995 to 2014. Following Karapetyan (2011), the three-month NIBOR interest rate is used as a proxy for the Norwegian key policy rate. The results from the analysis show statistical evidence of a negative relationship between monetary policy and banks' risk-taking. However, since the estimated interest rate coefficient is quite small, the economic significance seems modest.

Moreover, there are several concerns regarding the empirical specification that need to be addressed. I also find evidence of a less pronounced negative relationship for banks with lower leverage, which is contrary to the implications suggested by the theory as well as previous empirical findings in other countries. In line with the risk-shifting effect of monetary policy, this literature suggests that the potential negative relationship is less pronounced for banks with higher leverage.

The rest of this thesis proceeds as follows: In section 2, I will introduce definitions of financial stability and monetary policy. In Section 3, I present previous contributions to the literature that analyzes the relationship between monetary policy and financial stability, with an emphasis on the risk-taking channel. In Section 4, I will present the descriptive statistics of the main variables and the empirical methodology. In section 5, I will present the main results, discussions and policy implications of the analysis. Finally, in section 7, I reflect on the material presented and discussed in the thesis in concluding remarks.

2 Definitions

It is well established in the literature that the main objective of monetary policy is price stability, meaning to insure a stable price level or a low level of inflation (Walsh, 2014). By using the key policy rate, the central bank affects the price level and the economy through various channels, called the transmission mechanisms of monetary policy. For instance, a reduction in the key policy rate might lead to lower interest rates on bank loans leading to increased demand for credit and higher investment levels. The central bank can alter financial conditions, not only by changing the interest rate, but also by signaling their view about future economic conditions and the likely policy response.

The world has on several occasions experienced that financial instability can have negative impacts on the real economy. For instance, the banking crisis in Norway in 1988-1993 led to huge bank losses that were transmitted to lower lending and lower economic growth for several years (Norges Bank, 2004). It is, however, not obvious what characterizes financial stability. In this section, I therefore present definitions of financial stability and monetary policy to delimit and clarify the analysis.

2.1 Financial Stability

Central bankers and other policy makers have become significantly more concerned about financial stability over the last decade (Yellen, 2014). However, financial stability has also been important to central banks earlier in history. As an example, in a speech in 2004, the governor of the Swedish Riksbank noted that the central bank back in 1992 had to support the financial system in order to reduce the risk of a financial crisis (Heikensten, 2004). Despite the apparent relevance of stability in the financial system to the responsible authorities, there is no clear consensus in the literature on the definition of this notion. According to Allen and Wood (2006, p. 152) financial stability is "...about institutions not suddenly collapsing and causing economic damage to people who could not reasonable have been expected to anticipate the collapse." They also emphasize that a good definition of financial stability must be related to welfare, observable and in the hands of public authorities, and it should not be so rigorously that any kind of change is a sign of instability. Building on many of the same principles, but taking a slightly more specific and operational approach, Norges Bank (2013b, p. 6) defines financial stability as involving "...a financial system that is resilient to shocks and is capable of channeling funds, executing payments and distributing risks efficiently."

When defining financial stability, Issing (2003) claims it is important to distinguish between imbalances in the whole system and those only affecting local financial markets. An abrupt fall in the stock market does not necessarily need to be a problem of financial instability, as long as the fall in prices only leads to redistribution between economic agents without negative impacts on the real economy. Following the definitions proposed by Allen and Wood (2006) and Norges Bank (2013b), financial stability is clearly related to the systemic risk of the financial system.

Furthermore, Borio (2003) and Natvig (2011) emphasize that we can distinguish between two dimensions of systemic risk, the cross-sectional and the time dimension: The cross-sectional dimension concerns the distribution of risk across financial institutions at a given point in time, including the correlation between these institutions' exposure to risk. This further relates to how specific shock to the financial system can propagate itself and become systemic. As explained by Caruana (2010), the financial system is a network of interconnected balance sheets in which a shock hitting one institution can spread to other institutions and thus become systemic. The time dimension, on the other hand, relates to the development of systemic risk over time, and hence the mutual reinforcement between movements in macroeconomic and financial variables: Over the business cycle, the dynamics of the financial system and the real economy is connected and reinforce each other, increasing the amplitude of booms and busts (Caruana, 2010).

The above definitions of financial stability are wide and contain little practical guidance for any institution trying to contribute to the maintenance of financial stability. Therefore, it can be useful to define certain measures that historically have performed well as indicators that signal the potential build-ups of financial imbalances. As explained by Norges Bank (2013a), identifying financial imbalances can be demanding since the type of imbalance and the risks that they convey vary both between countries and over time. Lessons from earlier country-specific crises as well as economic theory will therefore guide the responsible authorities in its choice of suitable and well-preforming indicators. A list of indicators used by Norges Bank to monitor the financial system is included in the appendix section A.4.

It is important to emphasize that the scope of this thesis is to investigate whether there is existence of a risk-taking channel of monetary policy in Norway. Financial institutions seeking higher return by increasing leverage and purchasing riskier assets, may lead the financial system to become more fragile and vulnerable to shock hitting the economy.

Hence, increased risk-taking by banks, may lead to increased systemic risks, and thereby might impose risks to the financial stability.

2.2 Asymmetric Information and Limited Liability

A general problem in financial markets is the presence of financial frictions such as asymmetric information, in combination with limited liability. Agents operating under limited liability do not internalize the losses they impose on other economic agents, who can lead the former to take more risk than what is socially optimal (De Nicolo, Dell'Ariccia, Laeven and Valencia, 2010). According to Sinn (2001), this type of behavior could not occur without the presence of asymmetric information, since this leads the parties sustaining the potential losses unable to negotiate for compensation before or while the risk-taking decision is made. If the parties were able to negotiate, this would erode agents' incentives to take additional risks, since the gain of taking higher risk would be ruled out by the higher cost of the liabilities. As described in Leeper and Nason (2014), "incomplete markets imply financial market frictions that prevent economic agents from perfectly sharing risk. If these frictions did not exist, financial stability would be of no concern."

2.3 Monetary Policy Actions

The purpose of this thesis is to analyze the effects of monetary policy on financial stability. As mentioned in the introduction, our definition of monetary policy is mainly confined to the managing of key policy rates, and largely ignores other instruments. To achieve the operational target of monetary policy the Norwegian central bank's most important instrument is the key policy rate, which is the interest rate on bank deposits up to a quota in Norges Bank. This rate works as an interest rate "floor" in the Norwegian interbank money market. If the central bank makes sure that there is enough liquidity in the banking system, the short-term interbank interest rates will remain close to the central bank's policy rate (Hoff, 2010).

The policy rate expectations in the future also may be important. Norges Bank has since 2005 published forecasts for key policy rates to signal what the market should expect from central bank behavior in the future, and how the participants should expect the central bank to react to certain disturbances in the Norwegian economy. The role of interest rate expectations will be further discussed in section 3.1, where it is argued that such expectations may also be important for banks' risk-taking, and thus have implications for financial stability.

As a means to anchor the public's expectations of future monetary policy, the Norwegian central bank publishes interest rate forecasts in the form of a future interest rate path. According to Norges Bank (2012) an appropriate interest rate path should meet the following criteria; the inflation target is achieved, the inflation targeting regime is flexible, meaning that the central bank is not a strict inflation targeter, and in particular, that monetary policy takes into account considerations of financial stability. Moreover, the central bank attempts to inform the market participants about the likely response of the central bank to the different factors in its flexible inflation targeting regime. The central bank's weighing of the different factors is represented in a simplified form through a loss function of the form:

$$L = (\pi_t - \pi^*)^2 + \lambda(y_t - y_t^*)^2 + \gamma(i_t - i_{t-1})^2 + \tau(i_t - i_t^*)^2 \tag{1}$$

where λ, γ and τ represent the relative weights, $y_t - y_t^*$ is the output gap, $(\pi_t - \pi^*)$ is the inflation gap, $(i_t - i_{t-1})$ indicates that interest rate should be changes gradually and $(i_t - i_t^*)$ measure that deviation from the normal level (Norges Bank, 2012).

Following Karapetyan (2011), I will in the empirical analysis, use the three month NIBOR interest rate as a proxy for the Norwegian monetary policy stance. An effective monetary policy means that changes in the current key policy rate will be reflected in the short-term money market interest rates, while the effect on long-term interest rates will depend on the degree to which the conduct of monetary policy affects inflationary expectations, and the markets' expectations of monetary policy in the future. The NIBOR interest rate is regarded as the best possible estimate of the market rate, and shall reflect the interest rate that a bank would charge on lending in NOK to a bank that is active in the Norwegian money market (Norges Bank, 2014a). It has been shown in an empirical analysis of Norwegian money marked in the period 2007 to 2012, that the key policy rate has a broad impact on short-term interest rates: Bernhardsen (2012) estimates the equation $i - f_{styr} = a + bf_{styr} + cX$, where i is the three month money market interest rate, f_{styr} is the expected three month key policy rate and X is a vector of control variables. Bernhardsen (2012) finds that b equals approximately zero, and concludes that this may be an indication of the effectiveness of the Norwegian central bank's monetary policy.

3 Literature Review: The Effects of Monetary Policy on Financial Stability

As pointed out in section 2.1, after the financial crisis, central bankers and other policy makers have become significantly more concerned about financial stability. While earlier in history, the focus has mainly been on the financial conditions in general, after this crisis, there has been a greater focus on how monetary policy may potentially affect financial stability. As an example, in 2013, the key policy rates were held low for a long time period. The Norwegian central bank stressed that they were aware that this potentially could lead to buildup of financial imbalances, and that these considerations were taken into account in the monetary policy decision (Norges Bank, 2013c, p. 7-8). Another example is a speech by the Fed governor Janet Yellen in 2014. She emphasized that: "I am also mindful of the potential for low interest rates to heighten the incentives of financial market participants to reach for yield and take on risk..." (Yellen, 2014).

The literature has contributed to the identification of a number of channels in which policy rates can affect financial decisions and impose risks to financial stability. As mentioned in the introduction, IMF (2013) separates the different effects of monetary policy on financial stability into five distinct channels. These channels may operate simultaneously, with their strength varying with the stage of the cycle, the overall health of the financial sector, financial structure, and other country specific characteristics.

3.1 The Risk-Taking Channel

The recent global financial crisis led the debate on the link between short-term interest rates and banks' risk-taking to the forefront of the academic policy debate. This link is also known as the monetary policy's risk-taking channel, the notion that the interest rate affects not only the quantity, but also the quality of banks' balance sheets (Dell'Ariccia et al., 2013). As we will see, the empirical and theoretical literature indicate that accommodative monetary policy may lead to increased risk-taking by financial institutions. It is important to emphasize that the increased risk-taking may be an intended effect of the central bank's policy response, and therefore not a concern to the responsible authority (Yellen, 2014). On the other hand, if the increased risks substantially increase the vulnerability of the financial system to shocks, then through the risk-taking channel, monetary policy may impose risks to financial stability.

I will in this section present some of the literature that analyzes how monetary policy may affect banks' risk-taking. Mainly, the literature discusses the effects of changing the level of the key policy rates. However, monetary policy might affect banks' risk-taking incentives in other ways than just through the level of policy rates. For instance, if economic agents expect monetary policy to be eased during recessions to support the real economy and the financial system, this may also give rise to additional risk-taking incentives (IMF, 2013).[1]

3.1.1 Portfolio Effects and the Search for Yield

Most of the literature that discusses the risk-taking channel emphasizes that lower monetary policy rates lead to higher risk-taking by banks. De Nicolo et al. (2010) argue that the risk-taking channel mainly is based on the following three mechanisms: asset substitution, search-for-yield and pro cyclical leverage.[2] The asset substitution effect is related to the impact of monetary policy rates on the asset side of banks' balance sheets. Assuming that lower key policy rates are reflected into lower interest rates on safe assets, everything else equal, this may reduce the expected yield in banks' portfolios. As a consequence, De Nicolo et al. (2010) suggest that this may increase risk-neutral banks' demand for risker assets, hence in aggregate reducing the yield, until in equilibrium the returns on both types of assets are again equalized. Thus, lower monetary policy rates may lead to reallocation in banks' portfolios toward more risk exposure. A second and related mechanism, is the search-for-yield effect, originally advanced by Rajan (2006), that is especially relevant for financial intermediaries with long-term commitments, for example pension funds. These intermediates often need to match the yield they promised on their liabilities, with what they obtain on their assets. Lower monetary policy rates will only affect the asset-side of the balance sheets, as the intermediates have to pay the same interest on their liabilities regardless of changes in the monetary policy stance. As a consequence, De Nicolo et al. (2010) argue that if the intermediaries stay with safe but low return assets, they are likely to default for sure, while if they invest in riskier but higher return assets, they still have some chance of not defaulting on their commitments. On the other hand, when interest rates are high, the intermediates can generate the necessary revenue by investing in safe assets since they are more likely to match the yield on their liabilities.

The third mechanism proposed in the paper by De Nicolo et al. (2010) is a pro cyclical

[1]This "bail out" policy expected by economic agents will lead to a time consistency problem. This is shown in a model developed by Jeanne and Korinek (2013).

[2]Bank leverage in this thesis is defined as banks' total assets to equity.

leverage effect of monetary policy, originally advanced by Adrian and Shin (2008). Since lower monetary policy rates tend to increase asset prices, this may boost the value of banks equity, which everything else equal, leads to a fall in banks' leverage. Moreover, it is argued that the banks target constant leverage ratios, and tend to buy assets rather than distributing dividends. As a consequence, following a reduction in monetary policy rates, banks react to the fall in leverage by increasing demand for assets, which will result in a more fragile banking system that may be more exposed to shocks in asset prices (De Nicolo et al., 2010).

These three mechanisms predict that there is a negative relationship between short-term interest rates and banks' risk-taking. However, at least for the asset substitution and search-for-yield mechanisms, the effects completely rely on the assumption of a positive pass-through from monetary policy rates to the yield on banks assets. Adrian and Liang (2014) suggest that it is the interaction between monetary policy and the presence of financial frictions that may lead to the moral hazard problem of risk-taking and as a result may impose risks to financial stability. As explained in section 2.2, a general problem in financial markets is the presence of limited liability and asymmetric information. De Nicolo et al. (2010) suggest that banks operating under these frictions will tend to take more risk than what is socially optimal. Furthermore, that highly leveraged banks will tend to take more risk compared to banks with low leverage, as the former do not internalize the potential losses caused on the depositors. Therefore, the more a bank potentially can lose in the case of failure, or the more "skin-in-the-game" the bank has, this will lead banks to invest more prudently.

3.1.2 The "Greenspan Put"

Finally, De Nicolo et al. (2010) suggest an effect of monetary policy on banks' risk-taking, which often is referred to as the "Greenspan put".[3] This effect arises from the expected reaction function of the central bank, and is not directly an effect of the adjustment of policy interest rates. De Nicolo et al. (2010) suggest that banks take additional risk when they expect a policy response or a "bailout" from the central bank to a negative shock. The reasoning is that expected "bailout" policies from the central bank relaxes potential binding constraints after a financial crisis, and distort the incentives of private agents to be prudent in the initial period. This might lead to a time consistency problem for the central bank. Ex ante, the central bank would like to commit to smaller than the (ex

[3] This is also advanced in Diamond and Rajan (2011).

post) optimal policy response so as to mitigate the additional risk problem. However, ex post, once the economy has entered a period with binding constraints, the central bank would like to provide the optimal bailout (Jeanne and Korinek, 2013). Still, the level of the interest rate matters for the magnitude of this effect. To the extent that there is greater room for monetary stimulus when rates are high than when they are low, higher rates will correspond to greater risk-taking.

3.1.3 A Simple Static Model of Banks' Risk-Taking

In this section, I will present a simple static model of banks' risk-taking advanced by Dell'Ariccia et al. (2013). In this model, loans are the only type of asset and they need to be monitored in order to increase the repayment probability. The bank can exert monitoring effort q, which guarantees an identical repayment probability to a cost $(1/2)cq^2$. The degree of risk-taking will, therefore depend on the bank's incentives to monitor its portfolio. The banking system is perfectly competitive and banks fund themselves by equity (κ) and deposits. Banks operate in a context of limited liability and asymmetric information, and therefore repay depositors only in case of success.

In this simple model, banks' capitalization levels are exogenous, so banks cannot adjust leverage when the real monetary policy rate, r^*, changes. For simplicity, it is also assumed that the deposit rate (r_D) equals the policy rate.[4] Equity is more costly, with a yield $r_E = (r^* + \xi)/q$, with $\xi \geq 0$ which represent the equity premium. The cost, r_E, can be interpreted as the opportunity cost for a bank of investing its equity in the bank, adjusted to reflect risk-taking through the probability of success q.

For a fixed interest rate r^*, banks choose the competitive interest rate to charge on loans, and then choose how much to monitor their portfolio. A representative bank's expected profit is given by:

$$\begin{aligned} \Pi &= \left(q\big(r_L - r_D(1-\kappa) - r_E\kappa\big) - \left(\frac{1}{2}\right)cq^2\right)L(r_L) \\ &= \left(q\big(r_L - r_D(1-\kappa)\big) - (r^* + \xi)\kappa - \left(\frac{1}{2}\right)cq^2\right)L(r_L) \end{aligned} \tag{2}$$

We can see from this equation that if the investment succeeds, the bank earns $(r_L - r_D(1-\kappa) - r_E\kappa)$ after repaying depositors. When the investment fails, however, the bank

[4] The assumption that the deposit rate equals the policy rate, implies that depositors are protected by deposit insurance, and therefore also are insensitive to risk-taking.

receives nothing and due to limited liability it must not repay the depositors. It can be shown that by maximizing equation 2 with respect to q and setting $r_D = r^*$ will give:

$$\hat{q} = min\left\{\frac{r_L - r^*(1-\kappa)}{c}, 1\right\} \tag{3}$$

By substituting equation 3 back into the profit function (equation 2), and solving for the lending rate (by imposing zero-profit in the competitive equilibrium) we find that:

$$r_L = r^*(1-\kappa) + \sqrt{2ck(r^* + \xi)} \tag{4}$$

By inserting this back to equation 3, we find the optimal monitoring rate:

$$q^* = \frac{\sqrt{(2c\kappa(r^* + \xi)}}{c} \tag{5}$$

from which it is immediate that $(\partial q^* / \partial r) > 0$. We can see from equation 3 that an increase in the reference rate, r^*, affects monitoring, and thus risk-taking, through two distinct channels. A tightening of monetary policy affects both the asset side and liability side of banks' balance sheets. On the asset side, a higher monetary policy rate affects the interest rate on loans (r_L). A higher interest rate on loans increase the incentives to monitor, since borrower default is now more costly, which is called the pass-through effect. Therefore, higher interest rates may lead to decreased risk-taking incentives. On the other hand, on the liability side, due to market imperfections, higher deposit rates decrease monitor incentives when interest rates increase, through the risk-shifting mechanism. The interest rate the bank has to pay on its deposits goes up, which (everything else equal) reduces banks' profit in case of success, and, hence the incentives to monitoring the portfolio. Therefore, higher interest rates may lead to increased risk-taking incentives. This result implies that when banks are unable to adjust their capitalization levels, we will observe differences in the risk-taking behavior depending on banks' capitalization levels. Dell'Ariccia et al. (2013) argue that for a bank entirely funded by deposits (fully leveraged) the risk-shifting effect is maximal. However, this effect goes to zero for a bank fully funded with capital. Dell'Ariccia et al. (2013) conclude that this simple model produces the following testable implication, namely that "[b]ank risk-taking is negatively associated with interest rates if banks are not capital constrained. However, this negative relationship depends on the capitalization of the bank and is *less* pronounced for poorly capitalized banks."

3.1.4 The Role of Leverage and Market Structure

In Dell'Ariccia, Leaven and Marquz (2010) this simple model is extended by assuming that banks choose the capitalization levels that maximize profits. The assumption of deposit insurance is also relaxed, so depositors will now demand a deposit rate depending on expected risk-taking. Depositors know that a highly leveraged bank will have a smaller incentive to monitor, so the demanded interest rate equals $r_D = r^*/E(q|k)$. Therefore, when the monetary policy rate increases, the banks take into account that by reducing some of their leverage, depositors will demand a lower interest rate. It follows that as the policy rate increases, so does the benefit from lower leverage, the only commitment device available to the bank. As a consequence, bank leverage decreases with the monetary policy rate. Dell'Ariccia et al. (2010) argue that when banks optimally choose their capitalization levels, the aggregated effect of higher monetary policy rates is that banks would be less leveraged and take less risk. Conversely, reductions in r^* would lead to more highly levered banks and reduced monitoring effort.

Finally, Dell'Ariccia et al. (2010) explore the idea that the type of market structure in the loan market matters for risk-taking. Two banking structures are examined; a perfectly competitive credit market where banks take the lending rate as given, and a market featuring a monopolist facing a loan demand function that is perfectly inelastic up to some fixed loan rate R (the reservation level). The assumption of deposit insurance is still relaxed and banks' capitalization levels are exogenous. Intuitively, the pass-through from monetary policy rates to lending rates is higher the more competitive is the market. Therefore, irrespective of banks' level of leverage, risk-taking will decrease with the policy rate. On the other hand, when a profit-maximizing monopolist dominates the banking market, there might be a positive relationship between banks' risk-taking and monetary policy. Assuming that the profit-maximizing monopolist will in this case set the lending rate at the maximum value, monetary policy will only affect the liability side of the bank's balance sheet. Therefore, only the risk-shifting effect will be present. As a result, risk-taking will increase in the policy rate since higher policy rates will reduce the monopolist's margins, and hence reduce the incentive to monitor. This illustrates that the effect of monetary policy on banks' risk-taking may depend on the structure of the banking system, and as a consequence, that the relationship may not be universally negative.

3.1.5 Risk-taking and Volatility of Monetary Policy

De Groot (2013) examines how monetary policy affects the riskiness of the financial sector by using a DSGE model with nominal frictions. In this model, the banking sector can issue both outside equity and debt, making banks' exposure to risk an endogenous choice and dependent on the policy environment. The main interest in the paper is the composition of the liability side of banks' balance sheets. De Groot (2013) argues that:

"The recent financial crisis highlighted the importance of financial intermediaries' balance sheets, demonstrating that the extent to which financial intermediaries leverage themselves, and the extent to which financial intermediaries make use of debt finance, affect the probability of future financial crisis occurring and the amount of damage a negative shock ... does to the economy." (De Groot 2013, p 115)

It is assumed that banks have three available sources of funding: inside equity, outside equity (external equity issuance) and external debt (household deposits). Building on the claim that leverage and the share of debt finance are sources to financial instability, the model shows that periods of tranquility in the economy can generate build-up of risks since financial institutions increase the size and leverage of their balance sheets, and rely more heavily on debt financing. Moreover, De Groot (2013) argues that, if the bank is heavily reliant on debt, which is a non-state-contingent claim on the bank, then any fluctuations in the asset return will have to be absorbed by bank's net worth. On the other hand, since the return on outside equity is state contingent and linked to the return on assets, it provides a valuable hedge for banks' net worth when uncertainty is high. As a result, according to this framework, the optimal composition of banks' balance sheets will depend on the stochastic nature of asset returns, and one of the determinants is the policy environment. De Groot (2013) suggests that banks would like to stabilize volatility in the shadow value of their net worth. If monetary policy acts to achieve this, then banks may have less incentive to resort to outside equity finance and may leverage up their balance sheets.

3.1.6 Empirical Literature

After the financial crisis in 2008, there has been a growth in the empirical literature that studies the risk-taking channel of monetary policy, and I will in this section present the results from some of these studies. As an example, Jiménez, Ongena, Peydro and Saurina (2014), use loan-level data from the Spanish credit registry and provide evidence that banks increase lending to riskier borrowers when interest rates are low. Oannidou, Ongena and Peydro (2009) report similar results with data from Bolivia. The conclusions are further confirmed by Dell'Ariccia et al. (2013) and Maddaloni and Peydro (2010) in a study of the U.S. loan market.

Evidence of a Risk-Taking Channel in the United States

Dell'Ariccia et al. (2013) studied the link between short-term interest rates (the federal funds rate) and ex ante risk-taking over the period 1997-2011 by making use of loan-level data on individual U.S. banks' loan ratings from the Federal Reserve's Survey on Terms of Business Lending (STBL). In the survey, all loans approved by banks are risk rated on a scale from 1 (minimal risk) to 5 (high risk). The main interest of the paper is the relationship between this risk-rating and monetary policy. The results point to a significantly negative relationship between short-term interest rates and banks' risk-taking, which is consistent with a risk-taking mechanism. In addition, the relationship seems to be weaker for poorly capitalized banks. They also find evidence that the strength of this relationship is stronger when interest rates are held low for extended periods.

The authors emphasize that the empirical results should not be interpreted as implying that the additional risk associated with lower rates is excessive. To further investigate if they have actually identified the effect of interest rates on banks' risk-taking, several robustness checks are conducted.[5] The results from these robustness checks provide additional evidence that they have identified the existence of a risk-taking channel of monetary policy.

A key assumption underlying the identification approach is that a lower monetary policy rate is exogenous to bank risk-taking. Dell'Ariccia et al. (2013) argue that since the analysis is mostly conducted ahead of the financial crisis, it is fair to say that financial stability considerations played a limited role in the setting of monetary policy, and that this was primarily the job of supervisory and regulatory authorities. Further, to shed light on the relevance of these considerations, the minutes of the Federal Open Market Committee meetings are analyzed, searching for keywords associated with financial stability.

Maddaloni and Peydro (2010), also use survey data, and find that low interest rates led to an excessive softening of lending standards to firms and households in both the U.S.

[5] They perform several sample splits to address specific endogeneity concerns. As an example, they run regressions in subsamples of loans from local banks, where they argue that these banks are less influenced by national economic activity. They still find a significant, negative relationship between interest rates and loan risk rating.

and in the Eurozone. Further, they find that the effect were stronger when interest rates had been long for extended periods, supervision was weaker and securitization activity greater. Maddaloni and Peydro (2010) also studied risk-taking related to long periods of negative Taylor-rule residuals, and found that negative residuals for long periods of time led to excessive risk-taking by banks. They also argue that these findings were a key contributing factor of the last financial crisis.

Evidence of a Risk-Taking Channel in Spain, Bolivia and Norway

As mentioned above, Jiménez et al. (2014) and Oannidou et al. (2009) report similar results using loan-level data from respectively Spain and Bolivia. Despite that the authors access data from different countries, different time periods and employ different methodologies, they both find evidence of a negative relationship between monetary policy and banks' risk-taking.

Jiménez et al. (2014) analyzed the impact of the monetary policy stance (overnight rates) on the level of risk of individual bank loans, using register (micro) data over the period 1984 to 2009 from the banking supervisor in Spain. Since Spain is part of the Eurozone, monetary policy is said to be fairly exogenous. The results indicate that a lower overnight interest rate induces banks to engage in higher risk-taking. Further, a lower overnight interest rate leads lowly capitalized banks to grant more loan applications to ex ante risky firms than highly capitalized banks and that, when granted, the committed loans are larger in volume and are more likely to be uncollateralized.

Using loan-level register data from Bolivia over the period 1999 to 2003, Oannidou et al. (2009) analyzed the impact of monetary policy on banks' risk-taking and pricing of new bank loans. During this period the local currency, Bolivian Peso, was pegged to the US dollar and the banking system was almost fully dollarized, and as a consequence, monetary policy was dependent on U.S. monetary policy. In this paper, several loan-specific measures of banks' risk-taking are studied. The risk measures considered are: time to individual loan default, current or past borrower default, and internal credit ratings at origination. The results indicate that when interest rates are low, not only do banks increase the number of risky loans but they also reduce the rates they charge to riskier borrowers relative to what they charge to less risky ones. In addition, banks with more liquid assets and less funds from foreign financial institutions (and therefore more robust balance sheets) take more risk when rates are low and they price the additional risk even more negatively than other banks.

In Norway, there has only been one pervious study that investigates the potential existence of a risk-taking channel of monetary policy. Karapetyan (2011) analyzed the impact of expansionary monetary policy on a measure of bank portfolio risk in the period 1979 to 2010. The measure of a bank's risk-taking was the share of troubled loans, where trouble loans are those where payments for more than 90 days are not made. Using aggregated (macro level) data there is no evidence of a risk-taking channel, but Karapetyan (2011) suggests that this question should be investigated at a micro level.

3.2 The Risk-Shifting Channel

As seen from the simple model in section 3.1.3, there may be a risk-shifting effect of monetary policy that works in the opposite direction of the pass-through and leverage effects. Thus, that there might be a positive relationship between monetary policy and risk-taking. According to IMF (2013), the risk-shifting effect enters from the liability side of banks' balance sheets, and is particularly relevant for banks' that fund themselves short-term at variable rates, but lend long-term at fixed rates. Consequently, following a monetary policy tightening, banks' margins fall, which may lead lenders to seek more risk. Indeed, lower margins may induce movement intro riskier assets and toward higher leverage to maintain return (IMF, 2013). Using loan level data, Landier and Sraer (2011) provide evidence of this channel by examine the lending behavior of a large subprime mortgage originator (New Century Financial Corporation) starting in 2004.

Landier and Sraer (2011) studied the behavior of the subprime originator after a monetary policy tightening implemented by the Fed in the spring of 2004, which destroyed a significant fraction of the originator's shareholder value. They further observe that New Century reacted to this by massively offering "interest-only" loans, which are not only riskier, but the returns were also designed more sensitive to real estate prices than standard contracts. Interest-only loans means that borrowers pay interest only in a teaser period, which in this case was 24 months. After this period, refinancing is in many cases necessary since monthly payments increase dramatically, as the borrower begins to repay the principal. To refinance, the borrower must have built some wealth the last 24 months, so this wealth could be used to borrow at a lower rate. Therefore, the refinancing might require an increase in real estate prices. In a weak real estate market, refinancing with better terms can become impossible, and therefore, some borrowers have no other choice but to default. According to Landier and Sraer (2011), originating these loans was a bet on the appreciation of real estate prices.

3.3 The Asset Price Channel

A potential source of financial instability is sharp increases in asset prices, as a consequence of an accommodative monetary, which often are referred to as the asset price channel (IMF, 2013). After the financial crisis in 2008, policy authorities in the affected countries have been criticized for holding monetary policy rates too low for long periods, leading to massive increases in asset prices, which in some cases can be referred to as an asset price bubble.

Lower monetary policy rates tend to increase asset prices on for example houses and stocks, increasing the net worth of borrowers and lenders. As described in Bjørnland and Jacobsen (2010), housing has a dual role of being both a store of wealth and a durable consumption good. Hence, expansionary monetary policy might raise household wealth, which again raises consumption spending and aggregate demand. In addition, house prices influences banks' balance sheets. If real estate prices rise because of a monetary expansion, then banks' loan losses may decrease, which increases bank capital and thus lending. Therefore, accommodative monetary policy may raise both the supply and demand for credit, which will increase asset prices even further. As a consequence, there may be a feedback loop between eased financial constraints and rising asset prices, which is referred to as a "financial accelerator" mechanism advanced in Bernanke, Gertler and Gilchrist (1999).

Mishkin (2001) also illustrates the asset price mechanism by using Tobin's q theory. The Nobel Prize winning economist James Tobin proposed that firms base their investment decisions on the following ratio:

$$q = \frac{\text{Market Value of Capital}}{\text{Replacement Cost of Capital}} \tag{6}$$

If q is high, then the market price of firms is high relative to the replacement costs, and new capital is cheap relative to the market value of firms. Companies can then issue stocks, and get a high price for it relative to the cost of capital. Investment spending will rise, since firms can buy capital with only a small issuance of stocks. Expansionary monetary policy, which lowers interest rates, makes bonds less attractive relative to stocks and result in increased demand for stocks that bids up their price (Mishkin, 2001).

The financial amplification effects described above may be related to pecuniary externalities (higher asset prices) when atomistic agents do not internalize that their individual actions lead to relative price movements that reinforce shocks in the aggregate (Jeanne and Korinek, 2013). As a result, we may end up with a more fragile economy and financial system that is more exposed to shocks.

3.3.1 Empirical Literature

IMF (2009) tried to shed some light on the validity of the criticism of monetary policy being too loose from 2002 to 2006, which in turn contributed to the house price booms and subsequent busts the previous decade. The authors argue that if monetary policy was a cause of the house price booms, there would be a systematic relationship between monetary policy conditions and changes in house prices across economies. By studying the relationship between average real policy rates and changes in real house prices for a range of advanced economies, they find no association between measures of monetary policy and house price increases in the full sample[6].

In Norway, there have also been a few studies of the link between monetary policy and asset price movements. Bjørnland and Jacobsen (2010) analyzed the role of house prices in the monetary transmission mechanism in three small open economies, Norway, UK and Sweden. They find that, following an increase of the monetary policy rate of one percentage point, house prices fall by 3-5 percent. Robstad (2014) also aims to quantify the effect of a monetary policy shock on household credit and house prices in Norway. Overall, the evidence supports the findings of Bjørnland and Jacobsen (2010), and the results further suggest that the effect of monetary policy on house prices is quite large.

Negro and Otrok (2007) analyzed the relationship between monetary policy rates and house price increases in the United States, and turned to data on house price growth from 1986 to 2005. In the beginning of the 21th century some metropolitan areas in the U.S. experienced a dramatically increase in house prices, however, this was not homogenous across different states. Some states, for example California, New Jersey and Rhode Island

[6]The full sample consists of the following countries: Australia, Austria, Belgium, Canada, Switzerland, Denmark, Germany, Spain, United Kingdom, Greece, Finland, France, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, Sweden, United States.

experienced house price growth rates at above 10 percent per year, while other states, like Texas and Ohio, only had a house price growth at about 2 percent per year. Therefore, Negro and Otrok (2007) investigate whether the increase in house prices reflected a national phenomenon (for example monetary policy) or if it was due to "local bubbles". The results indicate that through the sample period (1986 to 2005), movements in house prices were mainly driven by the components at the local level. However, when the relationship is studied at specific periods form the beginning of the 21th century, the results show that the pattern was different. For a number of states that experienced a large increase in house prices, a substantial fraction of these increases was attributable to the national factor. Therefore, Negro and Otrok (2007) investigate to what extent monetary policy was behind this co-movement. The results indicate that the impact of monetary policy shocks on house prices is non-negligible, but overall fairly small in comparison with the magnitude of the price increase. Therefore, the authors conclude that expansionary monetary policy was not an important factor behind the boom in house prices.

3.4 The Borrower Balance Sheet Channel

3.4.1 Theoretical literature

Higher monetary policy rates may have an impact on borrowing constraints and might increase the risk of financial instability. As an example, higher monetary policy rates might increase the repayment burden for variable rate borrowers, increasing the probability for borrower default. Thus, the borrower balance sheet channel promotes a positive relationship between monetary policy and the risk of financial instability. According to Gertler and Gilchrist (2009), the balance sheet channel is typically existent under the presence of agency problems between borrowers and lenders[7]. These imperfections will lead to a wedge between the cost for firms to raise capital externally and the opportunity cost of capital for the firm, which in the literature is referred to as the external finance premium. The balance sheet channel is based on the theoretical prediction that this premium will depend on the borrower's financial position. In particular, the greater the borrower's net worth - defined as the sum of the liquid assets and marketable collateral - the lower the external finance premium (Bernanke and Gertler, 1995). Consequently, the cost of raising external funds is lower for high net worth agents, since a borrower with more "skin in the game" has greater incentives to make well-informed investment choices. As a

[7]As we saw in section 2.2, asymmetric information about borrower‘s quality and limited liability is often precent in financial markets.

result, lenders assume less risk when lending to high net worth agents, and agency costs are lower. Therefore, since the borrower's financial position affects the external finance premium, and thus the amount of credit he faces, fluctuations in the balance sheet will affect spending and investments.

As described in section 3.3, monetary policy may have an influence on asset prices, such as houses and shares. Related to the external finance premium, this can reduce the amount of credit available for the firm and increase the costs of short-term funding. Again, this can lead to increased probability of borrower default. Increased interest rates may also indirectly affect firms' balance sheets. A higher interest rate may lower the overall spending in the economy, thereby also reducing the demand for the firm's products. In turn, this may reduce the firm's revenue. The reduction in revenue might erode the firm's net worth and credit-worthiness over time. Therefore, tighter policy may result in higher default rates, lower banking profits, and larger share of non-performing loans (IMF, 2013).

3.4.2 Empirical Literature

Sengupta (2010) showed that tighter monetary policy in the Unites States after 2004 increased the debt service burden on adjustable rate mortgages (ARM), leading to a sharp rise in defaults of Alt-A mortgages[8]. By using loan-level data on securitized Alt-A originations from 1998 to 2007, the data provides evidence that for most years in the sample period, adjustable rate mortgages registered higher default rates[9] than fixed rate mortgages (FRM). Furthermore, by studying the percentage delinquent after the first 18 months, the difference was greater for ordinations between 2005 and 2007. Sengupta (2010) suggests that the low interest rate environment during the early part of the decade following a monetary tightening in the second half of 2004, might explain the rise in default rates on adjustable interest rate mortgages.

Bernanke and Gertler (1995) investigated empirical evidence of a link between monetary policy and the financial position of firms, by studying the "coverage ratio" as a measure of firms' financial position.[10] The results suggest that there is a close relationship between this ratio and the federal funds rate. Consequently, an increase in the funds rate may lead

[8] Alt-A mortgages is a class of mortgage bank securities (typically a large pool of mortgages that are used as collateral to issue securities) that involves loans to borrowers with good credit.

[9] Default on mortgages is in this paper is defined as a 90-day delinquency event at any point in the repayment history.

[10] The ratio of interest payments by non-financial corporations to the sum of interest payments and profits. Source: Bernanke and Gertler (1995)

to a higher coverage ratio, meaning that higher interest rates depress the financial position of firms. To get a clearer picture of the impact of monetary policy on the components of firms' cash flows, data from 1965 to 1994 from the U.S. is used to estimate a VAR-model. The results show that a tightening of monetary policy squeezes firms' cash flows. Bernanke and Gertler (1995) emphasize that the implications for economic behavior of the firm will depend on the firms' ability to smooth this drop. Firms that have relatively poor access to credit markets will typically cut production and employment, as a response to declining cash flow, while firms with good access will face less financial pressure.

3.5 Exchange Rate Channel

Over the past half-century, there has been an evolution of financial integration in the world economy, and the financial openness is argued to be an irresistible long-run trend (Rey, 2013). In a small open economy, monetary policy may have an impact on capital flows and exchange rates. According to Mishkin (2001) a tighter monetary policy (higher interest rates) relative to other countries means that investors may get a higher yield on domestic assets relative to other countries, tending to make the domestic assets more attractive. Increased demand for domestic assets might lead to an increased value of the domestic currency. As a consequence, a tighter monetary policy may reduce the price of imports, and reduce the demand for exports, which therefore might lead to a current account deficit (IMF, 2013). A current account deficit is matched by net capital inflows, as foreign investors build up claims in the domestic economy. Merrouche and Nier (2010) describe several consequences of high capital inflows that might impose risks to financial instability. High capital inflows may reduce the cost of wholesale funding for domestic banks. This might lead banks to excessively borrow in foreign markets, and take on additional leverage. As a consequence, the financial system may become more vulnerable, as both national and international shocks may erode the repayment capacity of financial intuitions. High capital inflows may also increase the total supply of credit in the domestic economy, possibly causing asset prices to rise. Thus, through the exchange rate channel, a higher monetary policy rate may lead to increased risks of financial instability.

Merrouche and Nier (2010) investigated the drivers on financial imbalances ahead of the global financial crises, and argue that rising global imbalances (capital flows) might have been a contributing factor. The panel data regressions are performed for OECD countries over the period 1999 to 2007. The main result of the analysis shows that for small advanced countries the net capital inflows (which may steam from a rise in the policy rate) can contribute to the build-up of financial imbalances, as measured by the ratio of credit to deposits. Conversely, a loose monetary policy stance, can contribute to current account surpluses and capital outflows that may fuel build-ups of financial imbalances elsewhere in the world. The conclusions from the paper by Merrouche and Nier (2010) are further supported in IMF (2013), where it is argued that the exchange rate channel was particularly relevant ahead of the recent financial crisis. As an example, in Iceland the high interest rate differential between foreign and domestic financial markets prior to the crisis, led the banking sector in Iceland to excessively increase foreign funding, which fueled capital inflows, and led to a sharp appreciation of the currency and overheating of the economy. As a response, the central bank raised policy rates in order to reduce inflationary pressures, but this attracted even more capital, generating an adverse feedback loop (IMF, 2013).

4 Evidence of a Risk-Taking Channel in Norway: An Empirical Analysis

Although the model regarding banks' risk-taking discussed in section 3.1 is simple, it produces testable hypotheses about a possible relationship between banks' risk-taking and the monetary policy rate. Most of the theoretical implications in section 3.1 suggest a negative relationship between banks' risk-taking and the policy interest rate, but that the strength of this relationship depends on the capitalization structure of the bank. In this section, I present my approach to testing the predicted behavioral responses of banks to changes in the monetary policy stance as implied by the model, and how these responses depend on banks' leverage. The analysis will be conducted using quarterly panel data of 163 individual Norwegian banks over the period 1995 to the second quarter of 2014.

In order to construct a measure of banks' risk-taking behavior, I make use of an administrative record on banks' and financial intermediaries' characteristics (ORBOF) reported to Norwegian authorities.[11] The construction of this measure will be further explained in section 4.1. The approach taken in the analysis is to investigate whether the three-month NIBOR interest rate, as a proxy for Norwegian monetary policy, affects the composition of banks' lending to different risk weighted industries. If the theoretical predictions implied by the model are of any relevance, then banks should invest in riskier industries when this interest rate decreases.

4.1 The Risk Measure

Because there are possibly many factors determining risk, successfully identifying banks' risk-taking is not straightforward. Given this empirical challenge, I have constructed a risk measure, making use of data on banks' losses on loans divided into nine defined industries. The risk measure for a given bank in a given time period is defined as the ratio of the sum of total risk-weighted lending to all the classified industries to its total lending to the nine industries. Mathematically the risk-measure is given by the following

[11] In this setting, the authorities are Statistics Norway, Norges Bank and the Norwegian Financial Supervisory Authority.

formula:

$$y_{it} = \frac{\sum_{j=1}^{9} \gamma_j L_{itj}}{\sum_{j=1}^{9} L_{itj}}, \text{ for all i, t} \tag{7}$$

where γ_j is the risk-weight associated with bank loans based on average historical losses to industry j and L_{itj} denotes loans from bank i to industry j in a given quarter t. The interpretation of y_{it} is that if bank i increases the portion of loans to higher risk-weighted industries so that y_{it} increases, this may indicate higher risk-taking.

To construct the risk-weights, γ_j, I make use of annual data on aggregate bank losses from 1997 to 2013 reported to Norges Bank and the Norwegian Financial Supervisory Authority, by all Norwegian banks excluding branches of foreign banks. Bank losses, are in this particular case, defined as defaulted loans in the various industries as a percentage of total lending to the respective industry. Defaulted loans are defined as loans where payments due for more than 90 days are not made.[12] I take the average over the whole sample for each industry. This is in line with the definition proposed in Solheim and Kragh-Sørensen (2014) who argue that data on historical losses give a good basis for measuring the probability of losses on bank loans. The risk-weights, represented by the average in each industry, are given in table 1. According to the data, the industry associated with the highest risk-weight is the shipping sector. This is reasonable to expect, because loans to the shipping sector are usually large and the sector is highly exposed to disturbances in both the national and the international economy. A bit surprising, following the same arguments, is that the oil and gas industry is associated with the lowest risk-weight. However, one reason might be that oil companies are relatively large, governments are often partly involved, and therefore, firms in this industry rarely default on loans. Furthermore, in the period considered, 1997 to 2014, the oil sector has mainly been growing, and therefore not been associated with loan losses.

The risk measure is not ideal and may capture other effects than banks' risk-taking. Also, due to data limitations, an ex ante measure of banks' risk-taking is not feasible to construct. Ideally, we would have a measure of the ex ante risk-taking based on banks' assessment of risk at the time the loan was made. When using an ex post risk measure,

[12] In the dataset, the definition of defaulted loans changes in 2010 where losses then are defined as loans where payments due for more than 30 days are not made.

Table 1: Average Percentage Losses on Bank Loans

Variable	**Risk-weight (mean)**
Agriculture, forestry and fishing	0,5457
Extraction of oil and gas	0,0375
Manufacturing and mining industry	0,6388
Construction activities and water- and electricity supply	0,4245
Retail, accommodation and food service	0,5097
Real estate activities and other financial services	0,2297
Various tertiary industries	0,3882
Shipping	0,6863
Transportation and communicaton	0,5719

we might also capture the risk that banks never intended to take, and were just caught off guard. The disadvantages and limitations of the risk-taking measure used in this thesis will be discussed in more detail in section 5.3.1.

4.2 Data Description

The main dataset used in this thesis is an administrative record including bank lending for Norwegian registered financial institutions (ORBOF). The authorities in Norway request banks to provide monthly and annual information on lending standards distinguishing between different types of loans. The dataset includes various variables on bank characteristics related to banks' equity, deposits, and corporate lending divided into respective industries. The aggregated results from this self-reporting are published at the website of Statistics Norway.[13] However, the overall sample at the individual bank level is confidential. The reporting is compulsory and applies to all banks, credit institutions and other financial institutions registered in Norway, including branches of foreign banks and financial institutions, as well as governmental lending institutions and Norges Bank. The Norwegian corporate loan market is primary dominated by banks.[14] Although the sample covers the whole financial sector, I restrict the analysis to consider only banks and their industrial lending.

[13]For data source: see appendix A.5.

[14]A chart of the division of gross domestic lending in Norway can be found in Norges Bank (2014b), chart 2.

All issuances of banks' corporate loans are divided into different industries based on the Norwegian Standard Industrial Classification. This classification provides unique definitions for industrial classification, and its primary objective is to provide rules and guidelines to be used in Norway's Official statistics (SSB, 2008). The classification system is revised every few years, because new industries appear and the structure of industries changes. The system was revised in the mid of 2002 and 2009, but in this thesis the data is transformed back to the SIC1994 classification. According to SSB (2008), the system of classification aims at satisfying two criteria. First, the units classified in the same class have to produce a significant share of total production that characterizes the group in question. Second, as a whole, the units in an industrial subclass shall be as homogeneous as possible with respect to the technical organization of production and the product's nature and field of utilization. Banks' business loans are divided into nine industries:[15]

- Gross loans to agriculture, forestry and fishing.
- Gross loans to extraction of oil and gas.
- Gross loans to manufacturing and mining industry.
- Gross loans to construction activities and water- and electricity supply.
- Gross loans to retail, accommodation and food service.
- Gross loans to real estate activities and other financial services.
- Gross loans to shipping and pipelines.
- Gross loans to transportation and communication.
- Gross loans to various tertiary industries.

There are several challenges when analyzing data from a relatively long time-period, due to potential changes in the banking structure and the number of operating banks. Between 1995 and 2014, several banks have merged and some banks have been renamed. In some cases, when banks are renamed, they are reported twice. Because of the renaming, banks are reported both as the "new" bank, and as the "old" bank with zero lending. In these particular cases, I merge the observations. Banks that simply do not have any lending

[15] More details and explanations of the different industries can be found in the appendix A.1.

activity during the considered period are deleted from the dataset. Due to confidentiality, the names of the affected banks are not reported in the thesis.

The data on different measures of individual banks' capitalization levels are taken from the ORBOF dataset, while the data used to construct risk-weights are taken from statistics used in Norges Bank's Financial Stability Report. Data on the three-month NIBOR interest rate can be found at the online database of Norges Bank, while data on the gross value added in the different industries can be found at the online database of Statistics Norway.[16]

4.2.1 Descriptive Statistics

Table 2 yields the descriptive statistics of the dependent and explanatory variables, including standard deviations, minimum and maximum values and mean values. The panel is unbalanced. First, there seems to be sufficient variation both *between* and *within* the included variables in the data set. High *between* variation supports the inclusion of bank fixed effects, controlling for observed and unobserved variables varying across banks, but not time. The risk measure varies between 0.173 and 0.639 with an average risk of 0.4195 and a standard deviation of 0.0623.[17]

The summary statistics of the variables used in the construction of the dependent variable, are reported in table 3. The bank loan data is reported quarterly at the aggregated industry level for each bank. As seen in this table, the number of observations on the loan data is varying across the different industries. It is especially the observations on loans to the shipping industry and the oil industry that are considerably lower than the number of observations in the other industries. As mentioned earlier, banks' loan losses are defined as defaulted loans in the various industries as a percentage of total lending to the respective industry. As seen in table 3, the standard deviations of some of these variables are large. In addition, as seen from the minimum values, some of the observations take negative values. The reason is that loans that previously were considered as defaulted, starts repaying, and as a consequence are no longer considered as defaulted.

[16] For data sources: see appendix A.5.

[17] As seen from section 4.1, by construction the maximum value of the risk measure will always be smaller than one.

Table 2: Summary Statistics

Variable		Mean	Std. Dev.	Min.	Max	Obs.
Risk measure	Overall	0.4195	0.0623	0.1731	0.6391	N = 11027
	Between		0.0542	0.2605	0.5239	n = 162
	Within		0.0350	0.0851	0.6373	T-bar = 68.0279
3-month NIBOR (%)	Overall	4.2365	1.9558	1.6698	8.0408	N = 12714
	Between		0	4.2365	4.2365	n = 163
	Within		1.9558	1.6698	8.0408	T-bar = 78
Tier-1 capital ratio	Overall	0.1655	0.0645	0.0156	1.9540	N = 10544
	Between		0.0536	0.0156	1.9540	n = 152
	Within		0.0401	-0.0080	1.7799	T-bar = 69.37
Total capital ratio	Overall	0.1726	0.0600	0.0306	1.9540	N = 10544
	Between		0.0462	0.0840	0.3996	n = 152
	Within		0.0411	-0.0009	1.7870	T-bar = 69.37
Leverage ratio	Overall	0.1023	0.0409	0.0102	1.9667	N = 10544
	Between		0.0300	0.0527	0.2258	n = 152
	Within				0.6373	T-bar = 69.37
Bank total assets	Overall	15.9887	87.92822	0.0201	1773.548	N = 11127
(mill NOK)	Between		68.9089	0.0857	793.8638	n = 162
	Within		49.9622	-640.1029	955.6727	T-bar = 68.6852
Value added	Overall	0.0034	0.6798	-1.1256	1.4723	N = 12551
agriculture	Between		0	0.0034	0.0034	n = 163
(growth rate)	Within	0.6798	0.6798	-1.1256	1.4723	T-bar = 77
Value added	Overall	0.0222	0.1252	-0.3260	0.3371	N = 12551
oil and gas	Between		0	0.0222	0.0222	n = 163
(growth rate)	Within		0.1252	-0.3260	0.3371	T-bar = 77
Value added	Overall	0.0176	0.0710	-0.2045	0.2155	N = 12551
shipping	Between		0	0.0176	0.0176	n = 163
(growth rate)	Within		0.0799	-0.2045	0.2155	T-bar = 77
Value added	Overall	0.0090	0.0702	-0.1517	0.1431	N = 12551
manufacturing	Between		0	0.0090	0.0090	n = 163
(growth rate)	Within		0.0702	-0.1517	0.1431	T-bar = 77
Value added	Overall	0.0125	0.0813	-0.1069	0.1700	N = 12551
retail	Between		0	0.01246	0.0125	n = 163
(growth rate)	Within		0.0813	-0.1069	0.1700	T-bar = 77
Value added	Overall	0.0176	0.0800	-0.2045	0.2155	N = 12551
transportation	Between		0	0.1759	0.0176	n = 163
(growth rate)	Within		0.0800	-0.2045	0.2155	T-bar = 77
Value added	Overall	0.0205	0.0744	-0.1675	0.2096	N = 12551
financial services	Between		0	0.0205	0.0205	n = 163
(growth rate)	Within		0.0744	-0.1675	0.2096	T-bar = 77
Value added	Overall	0.0165	0.0734	-0.1651	0.1894	N = 12551
tertiary industries	Between		0	0.0165	0.0165	n = 163
(growth rate)	Within		0.0734	-0.1651	0.1894	T-bar = 77
Value added	Overall	0.0169	0.1162	-0.2506	0.2612	N = 12551
water supply	Between		0	0.0169	0.0169	n = 163
(growth rate)	Within		0.1162	-0.2506	0.2612	T-bar = 77

Table 3: Summary Statistics Variables Used in Construction of the Dependent Variable

Variable		Mean	Std. Dev.	Min.	Max	Obs.
Loans agriculture	Overall	368.038	1299.55	0	21948.63	N = 10597
(mill NOK)	Between		1072.71	0	9436	n = 159
	Within		644.28	-7103	12880.67	T-bar = 66.6478
Loans oil and gas	Overall	323.89	906.32	0	8418.02	N = 2199
(mill NOK)	Between		427.94	0	2988.31	n = 92
	Within		570.82	-2228.25	5753.60	T-bar = 23.90
Loans manufacturing	Overall	397.37	2027.64	0	34151.35	N = 10801
(Mill NOK)	Between		1731.056	1.28	17109.77	n = 159
	Within		878.20	-10033.92	17438.96	T-bar = 67.93
Loans water supply	Overall	380.78	2259.27	0	54037.8	N = 10845
(mill NOK)	Between		1522.87	1.24	16789.75	n = 160
	Within		1580.21	-14700.49	37628.84	T-bar = 67.7813
Loans retail	Overall	442.89	2040.80	0	31974.72	N = 10900
(Mill NOK)	Between		1798.98	0.02	19436.6	n = 162
	Within		809.61	-9964.71	12981.01	T-bar =
Loans shipping	Overall	1390.27	4042.56	0	31288.68	N = 2573
(Mill NOK)	Between		2281.4	0	16484.45	n = 84
	Within		2118.90	-7856.76	16194.5	T-bar = 30.63
Loans transportation	Overall	242.84	1121.62	0	19006.72	N = 10248
and communication	Between		917.34	0.47	8575.28	n = 161
(Mill NOK)	Within		564.85	.8332.44	10674.28	T-bar = 63.65
Loans financial services	Overall	2227.12	11397.32	0	181144.2	N = 10862
(Mill NOK)	Between		8848.94	0	91751.61	n = 162
	Within		6428.82	-69177.34	91619.67	T-bar = 67.05
Loans various tertiary industries	Overall	170.90	701.56	0	11731	N = 10697
(Mill NOK)	Between		583.18	0.42	5936.38	n = 161
	Within		363.43	-4277.70	5965.52	T-bar = 66.44
Loss agriculture	overall	0.546	1.716	-2.17	6.08	17
Loss oil and gas	overall	0.038	0.76	-1.668	1.7	17
Loss manufacturing	overall	0.639	0.498	-0.28	1.75	17
Loss water supply	overall	0.424	0.422	-0.18	1.72	17
Loss retail	overall	0.51	0.344	0.085	1.376	17
Loss shipping	overall	0.686	0.741	-0.09	2.1	17
Loss transportation and communication	overall	0.572	0.544	-0.201	1.434	17
Loss financial services	overall	0.23	0.394	-0.192	1.55	17
Loss various tertiary industries	overall	0.388	0.426	-0.111	1.57	17

4.3 The Econometric Model

Again, I will make use of quarterly panel data including 163 individual banks over the period 1995 to the second quarter of 2014, to test the predictions from the theoretical section regarding the risk-taking channel. The aim is to investigate the notion that monetary policy affects the quality of banks' balance sheets, by analyzing the effect of the NIBOR interest rate on the composition of banks' lending to risk-weighted industries in Norway. Based on the set-up of Dell'Ariccia et al. (2013), the baseline econometric model takes the functional form of equation 8. Banks are represented by subscript i, quarters by subscript t and industries by subscript j.

$$y_{i,t} = \alpha_i + \beta_1 i_t + \beta_2 K_{i,t-1} + \gamma K_{i,t-1} i_t + \beta_3 X_{i,t} + \beta_4 y_{i,t-1} + \beta_5 i_{t-1} + \sum_{j=1}^{9} \beta_{5+j} Z_{j,t} + \varepsilon_{i,t} \quad (8)$$

$y_{i,t}$ is the risk measure for a given bank i in a given quarter t, i_t is the three-month NIBOR interest rate and $\varepsilon_{i,t}$ is the error term.[18] A full set of bank fixed effects, α_i, is also included to control for unobserved bank characteristics that vary across banks, but not time. This variable will capture some of the effects from omitted variables that differ between banks. The lagged risk measure is included because it may be a good proxy for other shocks to banks' risk-taking that are serial correlated (Romer and Romer, 2010). Since the data is quarterly, it is reasonable to assume that the previous quarter's interest rate is correlated with risk-taking in the next period. Therefore, in order to capture lagged responses of the NIBOR interest rate on banks' risk-taking, a lag of the NIBOR interest rate is included. Because an increase in the dependent variable may indicate higher risk-taking, or lower quality of banks' lending, the main coefficient of interest, β_1, is expected to be negative.

$K_{i,t-1}$ is the capital-asset ratio (the inverse of bank leverage) for bank i at the end of quarter $t-1$.[19] As pointed out in section 3.1, banks' risk-taking is expected to be dependent on banks' capitalization levels. In the data set, the capital asset ratios are measured by end of quarter. For this reason, it is the previous quarters' capital ratio that is included as a control variable.

$X_{i,t}$ is a set of bank specific control variables not including bank leverage. The motivation to control for bank characteristics is that lending behavior may vary across banks and

[18] As discussed in section 2.3, previous studies support the use of the three month NIBOR interest rate as a proxy for key policy rates.

[19] The capital-asset ratio is defined as the Tier-1 capital to risk weighted assets in period $t-1$.

time. Following Dell'Ariccia et al. (2013), a measure of bank size, the growth rate in bank total assets, is included in the regression, since it can be expected that larger banks have other risk-preferences compared to smaller banks.[20] Controlling for bank size reduces a possible omitted variable bias in the interest rate coefficient, as changes in the growth rate of total assets and interest rates is likely to be correlated. I also include dummy variables for different types of banks, since these often specialize in different segments of financial markets. I run the regressions in subsamples specified by three bank types, (*i*) savings banks, (*ii*) commercial banks and (*iii*) branches of foreign banks.[21] The motivation for splitting the sample is that in the Norwegian banking market, commercial banks are the largest banks measured by bank total assets, and in addition, some of the commercial banks are accounted as the largest corporate loan originators (Norges Bank, 2014b). Therefore, splitting the sample might give additional information.

As described in the section 3.1, the strength of the effect of monetary policy on banks' risk-taking may depend on banks' capitalization levels. As advanced in the simple model by Dell'Ariccia et al. (2010), due to the risk-shifting effect, the strength of the relationship may be weaker for banks with higher leverage. Therefore, in equation 8, I have included an interaction term, $K_{i,t-1}i_t$, between the interest rate and the Tier-1 capital ratio, as a proxy for banks' capitalization levels. The estimated coefficient, $\hat{\gamma}$, is expected to be negative, as this would imply a stronger negative effect of higher interest rates for well-capitalized banks, compared to lower capitalized banks.

I also control for the macroeconomic environment by including industry specific control variables, where $Z_{j,t}$ is the gross value added in each of the nine industries considered.[22] As an example, increased growth rates in the oil industry is also likely to increase demand for loans in this industry, which might affect our dependent variable. Therefore, as an attempt to disentangle the effect of monetary policy conditions on banks' credit supply and other economic features, the growth rates in the different industries are included as control variables.

[20]In section 3.1 we discussed the time-consistency problem for central banks. It is reasonable to assume that larger banks might expect more bail-out by governments, since these banks impose a larger risk to financial stability.

[21]The division of different bank types is based on the concession register from the Financial Supervisory Authority in Norway.

[22]Gross value added is the sum of firms sales minus value of input factors.

4.3.1 An Alternative Specification

An alternative specification is shown in the equation below, where time fixed effects are included.[23] The time fixed effects are expected to influence all banks since they vary at the country level. The reason for not including time fixed effects in equation 8 is that when time fixed effects are included, other variables that vary at the national level are dropped. This also includes the NIBOR interest rate, which varies over time, but is the same for all banks. Nevertheless, including time fixed effects enables us to check the robustness of the estimated interaction between the interest rate and banks' capitalization levels in the previous specification. Time fixed effects will capture changes in economy-wide conditions, such as current and future expectations of GDP growth, inflation, exchange rates and other overall shocks to the economy, that may be related to the NIBOR interest rate. This may reduce the potential inconsistency of the estimator of the interaction term in the above specification. The alternative specification including time fixed effects, λ_t, and bank fixed effects, α_i, is represented in the below equation. In this specification, the main coefficient of interest is γ, which still is expected to be negative.

$$y_{i,t} = \alpha_i + \lambda_t + \beta_2 K_{i,t-1} + \gamma K_{i,t-1} i_t + \beta_3 X_{i,t} + \beta_4 y_{i,t-1} + \varepsilon_{i,t} \tag{9}$$

4.4 Estimation Issues, Reversed Causality and Specification Tests

An important assumption underlying the identification approach is that monetary policy authorities do not respond to banks' risk-taking when setting the key policy rate. If the central bank reacts to financial stability considerations, which in this case is increased risk-taking, there will be potential reversed causality issues. Dell'Ariccia et al. (2013) argue that prior to the financial crisis, financial stability considerations played a limited role in the setting of the monetary policy rate. In line with the Dell'Ariccia et al. (2013) paper, this thesis is largely based on the period before the financial crisis, and it therefore seems reasonable to assume that the key policy rate was set without to much influence from the financial stability environment. In addition, the primary objective of the Norwegian central bank is to set the key policy rate to achieve the inflation target. Furthermore, the Norwegian Financial Supervisory Authority is the main responsible authority considering financial stability issues. For these reasons, it is assumed that such a reversed causality problem is of limited importance.

[23] Jiménez, Ongena, Peydró and Saurina (2012) refer to this model as the various fixed effects model, since both bank fixed effects and time fixed effects are included.

It has long been recognized in time-series analysis that estimated regression relationships of macroeconomic flow data can be distorted by non-stationarity in the data. Therefore, what appears to be a strong estimated relation can be entirely spurious due to underlying characteristics of the time-series process rather than actual connections among the variables (Green, 2008). A stationary variable is a variable that is non-explosive, not trending or wandering aimlessly around (a random walk) without returning to its mean. Checking for unit roots can test the presence of non-stationarity for all the included variables, because a shock to a variable with unit roots will have permanent effects (Hill, Griffiths and Lim, 2012). By using the Dickey-Fuller test for panel data, I find strong evidence that the log of bank total assets is the only variable with presence of unit roots. This is taken account for by taking the first difference, which still gives a valid economic interpretation. Conducting the same test for the new variable, which is now the growth rate in total assets, I find strong evidence that the variable is stationary. The results from the Dickey-Fuller tests are included in the appendix A.2.

Another important question when it comes to panel data is the question of whether to pool or not to pool the data. In the pooled regression model, it is assumed that there is no observed or unobserved heterogeneity between the individual banks, and that the least square estimator including a common intercept is consistent (Green, 2008). On the other hand, the fixed effects approach takes the constant term to be group-specific in the regression model. We can test for bank fixed effects by running an OLS regression with dummies for each bank, and then conduct a general F-test under the null hypothesis that the constant terms are all equal. Under the null hypothesis, the pooled regression estimates provide consistent and efficient estimates of the common intercept and slope coefficient (Green, 2008). In this thesis, however, it is reasonable to assume that there exist heterogeneous effects between banks. This is further supported in table 4 and table 5, which yield the test results from the F-test. As we can see from these tables, the null hypothesis is rejected for all the included regressions. Likewise, in some of the included regressions the absence of random bank effects is rejected by the Breusch-Pagan Lagrange multiplier test for random effects.[24] Furthermore, I also test for random versus fixed effects by using a Hausman test. The results strongly suggest the fixed effects approach in all the included regressions. As a result, all the reported regressions in this thesis are including individual bank fixed effects.

[24]Unlike the fixed effects approach, in the random effects approach it is assumed that the unobserved individual heterogeneity is uncorrelated with the included variables (Green, 2008)

I also test each of the regressions for serial correlation and heteroskedasticity in the error terms. All the test results show strong evidence for both, and therefore, all the standard errors are clustered by bank at the quarterly level.[25] Test results are reported in table 4 and table 5. In the last specification equation, time fixed effects are also included. When I test for time fixed effects, I find that it is strongly suggested to include such in the regressions, see table 6.

Table 4: Specification Test Results of Regressions Reported in Table 7 and Table 8

Model	Fixed effects Standard F-test H_0: No Fixed effects statacmd: test	Random effects Breush-Pagan LM H_0: No Random effects statacmd: xttest0	Fixed vs Random Hausman-test H_0: No systematic difference statacmd: hausman fixed random	Autocorrelation H_0: No serial correlation statacmd: xtserial	Heteroskedasticity H_0 :No heteroskedasticity statacmd: xttest3
Model 1	p-value 0.000	p-value 0.000	chi2(1) -13.34	p-value 0.000	p-value 0.000
Model 2	p-value 0.000	p-value 0.000	chi2(1) -2.12	p-value 0.000	p-value 0.000
Model 3	p-value 0.0000	p-value 1.000	chi2(1) 0.000	p-value 0.000	p-value 0.000
Column 1 Commercial	p-value 0.000	p-value 1.000	chi2(1) 0.000	p-value 0.000	p-value 0.000
Column 2 Savings	p-value 0.0015	p-value 1.0000	chi2(1) 0.000	p-value 0.000	p-value 0.000
Column 3 Foregin	p-value 0.0000	p-value 1.0000	chi2(1) 0.0016	p-value 0.000	p-value 0.000

[25]Cluster standard errors will take care of the idiosyncratic autocorrelation and heteroskedasticity in the error terms.

Table 5: Specification Test Results of Regressions Reported in Table 9

Model	Fixed effects Standard F-test H_0: No Fixed effects statacmd: test	Random effects Breush-Pagan LM H_0: No Random effects statacmd: xttest0	Fixed vs Random Hausman-test H_0: No systematic difference statacmd: hausman fixed random	Autocorrelation H_0: No serial correlation statacmd: xtserial	Heteroskedasticity H_0 :No heteroskedasticity statacmd: xttest3
Column 1 Tier-1 capital interaction	p-value 0.0000	p-value 1.0000	chi2(1) 0.000	p-value 0.000	p-value 0.000
Column 2 Total capital interaction	p-value 0.0000	p-value 1.0000	chi2(1) 0.000	p-value 0.000	p-value 0.000
Column 3 "Inverse leverage" interaction	p-value 0.0000	p-value 1.0000	chi2(1) 0.000	p-value 0.000	p-value 0.000

Table 6: Testing for Time Fixed Effects for the Regressions Reported in Table 10

Model	Test Statistics of a Standard F-test (statacmd: testparm) H_0: No Time-Fixed Effects	p-value
Column 1	F (76, 151) = 14.70	0.0000
Column 2	F (76, 151) = 14.52	0.0000
Column 3	F (76, 151) = 14.59	0.0000

5 Empirical Results

In this section, I will present the main results from the regression analysis described in the previous section, regarding the relationship between short-term interest rates and banks' risk-taking, and the effect of banks' capitalization on this relationship.

5.1 Empirical Results Baseline Regression

Table 7, reports the results from estimating the baseline model, equation 8. In this table all the models include bank fixed effects, and the standard errors are clustered quarterly at the bank level. In model 1, neither bank specific nor industry specific control variables are included in the regression. The results from this estimation suggest that a one percent increase in the NIBOR interest rate is positively associated with risk-taking, and the estimated coefficient, $\hat{\beta}_1$, equals 0.00674, which is also highly statistically significant. A positive relationship between banks' risk-taking and interest rates is not consistent with most of the theoretical suggestions of the risk-taking channel proposed in section 3.1. However, as we will see, the effect varies across models including different control variables, as well as across different bank types.

In model 2, when industry specific and bank specific controls are included, the estimated interest rate coefficient remains approximately the same. Note however, that the estimate in model 2 is slightly more precise than in model 1, as the standard error falls. Evident from this model is that the estimated coefficient of the tier-1 capital ratio, $\hat{\beta}_2$, seems to be positively associated with risk-taking. This would imply that lower leverage is associated with higher risk-taking, and the estimated effect is therefore not consistent with the theoretical literature. Following the argument by De Nicolo et al. (2010), banks with more "skin-in-the-game" or lower leverage, invest more prudently compared to higher leveraged banks. Intuitively, an explanation might be that banks with lower leverage might tolerate higher losses, and therefore takes higher risk.

In model 3, when a lag of the dependent variable and interest rate variables are added, the estimated interest rate coefficient, $\hat{\beta}_1$, reduces prominently. Furthermore, the estimated coefficient of the lagged dependent variable is highly significant and also has about the same magnitude as the common autoregressive coefficient.[26] Therefore, including

[26]When running an xtregar regression, correcting for the AR(1) serial correlation in the disturbances with no lagged risk-taking measure included, the AR(1) coefficient has about the same magnitude as the estimated coefficient of the lagged risk measure, $\hat{\beta}_5$, as the estimated AR(1) coefficient equals, $\rho = 0.9591$.

the lagged dependent variable will likely take care of the serial correlation in the disturbances.[27] As a result, I will proceed by including the lagged risk-taking measure. In this model the estimated coefficient, $\hat{\beta}_1$, turns negative and is also highly statistically significant. Hence, a one percent increase in the NIBOR interest rate is negatively associated with banks' risk-taking, and the estimated coefficient, $\hat{\beta}_1$, equals -0.0039. The estimation results in this model imply that, ceteris paribus, there is a negative relationship between interest rates and banks' risk-taking. This may be interpreted as the quality of banks' lending improves when the interest rate increases, which is consistent with the theoretical suggestions in section 3.1 and previous studies in other countries. Clearly, from table 7, the results in the three columns indicate that the relationship between the short-term interest rate and banks' risk-taking is ambiguous, and dependent on the inclusion of different control variables, as the estimated coefficient, $\hat{\beta}_1$, varies between -0.00039 and 0.00674.

[27] As seen in table 4, when testing for serial correlation in the error terms by using the xtserial test, H_0 is rejected, indicating that there still is serial correlation in the disturbances. Therefore, the standard errors are still clustered quarterly at the bank level.

Table 7: Bank Risk-Taking and the 3-Month NIBOR Interest Rate

Variable	**Model 1**	**Model 2**	**Model 3**
	All banks	All banks	All banks
3-month NIBOR	0.00674***	0.00656***	-0.00039**
	(0.00040)	(0.00038)	(0.00018)
Growth rate bank size		0.00461	0.00359
		(0.00757)	(0.00520)
Tier-1 capital ratio $(t-1)$		0.07780*	0.00957*
		(0.04326)	(0.00539)
Risk measure $(t-1)$			0.94872***
			(0.00631)
3-month NIBOR $(t-1)$			0.00076***
			(0.00019)
Constant	0.39063***	0.37824***	0.01762***
	(0.00172)	(0.00758)	(0.00243)
R-sqr	0.137	0.184	0.917
Degrees of freedom	161	151	151
Observations	11027	10357	10352
Bank fixed effects	yes	yes	yes
Industry specific controls	no	yes	yes
Clustered standard errors	yes	yes	yes
* p<0.10, ** p<0.05, *** p<0.01			

In model 1, the NIBOR interest rate is the only included explanatory variable. In model 2, bank specific and industry specific variables are included. In model 3, a lag of the dependent variable and the interest variable are also included. Bank size is measured by log of total assets. Dependent variable: Risk measure. Standard errors are reported in brackets.

Table 8 yields the results from regressions on different subsamples of bank types. In this table, bank specific and industry specific controls are included as well as the lagged dependent and lagged interest rate variables. In column 1, the sample is restricted to include commercial banks. The results indicate that a one percent increase in the interest rate is negatively associated with banks' risk-taking, and the estimated interest rate coefficient equals -0.0018, which is also highly statistically significant. Compared with the results from model 3 in table 7, when restricting the sample to commercial banks, the estimated effect of a higher interest rate is greater. In addition, the estimated coefficient of the Tier-1 capital ratio is negative and highly statistically significant. A negative estimated coefficient on proxies for banks' capitalization levels indicates that lower leverage is associated with lower risk-taking, which is consistent with the "skin-in-the-game" argument in De Nicolo et al. (2010). In column 2 and column 3, the results from regressions on subsamples of savings banks and branches of foreign banks are reported, respectively. In both columns, the estimated interest rate coefficients are negative, but statistically insignificant even at a ten percent level. Moreover, for both bank types, the estimated coefficients of the tier-1 capital ratio are positive, and statistically significant.

As seen in table 8, running regressions on different subsamples of banks seems to yield different results, in both the estimated interest rate and capital ratio coefficients. A potential explanation might be that commercial banks, which are the largest operator in the Norwegian corporate lending market[28], may have more sensitive investment strategies to different shocks, when deciding the composition of their loan portfolio. Also, branches of foreign banks are regulated subject to their home country's requirements, which might also explain the differences (Ministry of Finance Norway, 2011). Although the estimated interest rate coefficients differ in magnitude and in statistically significance, they all indicate a negative relationship between banks' risk-taking and short-term interest rates.

[28]Source: chart 1.5 in Norges Bank (2014b) page 11.

Table 8: Bank Risk-Taking and the 3-Month NIBOR Interest Rate for Different Bank Types

Variable	**Column 1**	**Column 2**	**Column 3**
	Commercial banks	Savings banks	Foreign banks
3-month NIBOR	-0.00180**	-0.00024	-0.00075
	(0.00068)	(0.00018)	(0.00158)
Growth rate bank size	0.02945***	-0.00679**	0.01067
	(0.00670)	(0.00313)	(0.02667)
Tier-1 capital ratio $(t-1)$	-0.01427***	0.02240***	0.06420*
	(0.00448)	(0.00588)	(0.02290)
Risk measure $(t-1)$	0.88468***	0.95404***	0.70337***
	(0.03631)	(0.00570)	(0.06220)
3-month NIBOR $(t-1)$	0.00270***	0.00058***	0.00021
	(0.00091)	(0.00019)	(0.00129)
Contant	0.04032***	0.01365***	0.11517**
	(0.01297)	(0.00192)	(0.02693)
R-sqr	0.859	0.925	0.660
Degrees of freedom	16	130	3
Observations	816	9382	154
Bank fixed effects	yes	yes	yes
Industry specific controls	yes	yes	yes
Clustered standard errors	yes	yes	yes
* p<0.10, ** p<0.05, *** p<0.01			

In this table, both bank specific and industry specific control variables are included, as well as a lag of the dependent variable and the NIBOR interest rate.
In column 1, only commercial banks are included, in column 2, only savings banks are included, and in column 3, only branches of foreign banks are included. Bank size is measured by log of total assets. Dependent variable: Risk measure. Standard errors are reported in brackets.

As shown in the simple model in section 3.1, we might observe differences in banks' risk-taking responses following from an increase in the monetary policy rate, depending on banks' capitalization levels. In table 9, the regressions in all columns include an interaction term between the interest rate and different proxies for banks' capitalization levels. The focus is now on the coefficient of the interaction term, $\gamma K_{i,t-1} r_t$, which is expected to be negative. This is consistent with the simple model in section 3.1, as a negative sign of the estimated interaction term coefficient, $\hat{\gamma}$, would indicate a stronger negative effect of an increased interest rate on banks' risk-taking for well-capitalized banks. Column 1 yields the estimation results when including an interaction term between the tier-1 capital ratio and the NIBOR interest rate. The estimated coefficient is positive and statistically significant at a ten percent level. I also check the robustness of this result by estimating the coefficients of interaction terms for other proxies of banks' capitalization levels. In column 2, an interaction term between the total capital ratio and the interest rate is included. The total capital ratio is the regulatory capital (tier-1 plus tier-2 capital) to risk-weighted assets (Norges Bank, 2014b). The estimated coefficient of the interaction is still positive and highly statistically significant. In column 3, the "inverse leverage ratio" is included as a proxy for banks' capitalization levels. The "inverse leverage ratio" is in this case defined as the tier-1 capital to total assets (Norges Bank, 2014b). The estimated effect remains positive, but is now statistically insignificant, even at a ten percent level.

As seen from table 9, the estimated coefficients of the different interaction terms between banks' capitalization levels and short-term interest rates do not confirm the theoretical suggestions in section 3.1. Given a negative relationship between interest rates and banks' risk-taking, a positive estimated coefficient of the interaction terms imply that the negative relationship is less pronounced for banks with lower leverage, which does not support the risk-shifting effect described in the simple model. Although the estimated coefficients for the three proxies of banks' capitalization levels are not consistent with the model, the estimation results are robust across the different measures. The estimated interaction effect is positive and approximately equal, irrespective of the proxy of capitalization used.

Table 9: Bank Risk-Taking and the 3-Month NIBOR Interest Rate Including Interaction Terms

Variable	**Column 1**	**Column 2**	**Column 3**
	All banks	All banks	All banks
3-month NIBOR	-0.00078***	-0.00088***	-0.00062**
	(0.00025)	(0.00026)	(0.00026)
Growth rate bank size	0.00401	0.00422	0.00218
	(0.00512)	(0.00507)	(0.00559)
Tier-1 capital ratio $(t-1)$	-0.00112		
	(0.00712)		
Tier-1 capital ratio*NIBOR	0.00235*		
	(0.00122)		
Total capital ratio $(t-1)$		-0.00517	
		(0.00658)	
Total capital ratio*NIBOR		0.00290**	
		(0.00122)	
"Inverse leverage ratio" $(t-1)$			0.02292
			(0.01463)
"Inverse leverage ratio"*NIBOR			0.00173
			(0.00195)
Risk measure $(t-1)$	0.94832***	0.94908***	0.94486***
	(0.00638)	(0.00632)	(0.00680)
3-month NIBOR $(t-1)$	0.00076***	0.00075***	0.00077***
	(0.00019)	(0.00019)	(0.00019)
Constant	0.01954***	0.01991***	0.01868***
	(0.00273)	(0.00277)	(0.00264)
R-squard	0.917	0.917	0.917
Degrees of freedom	151	151	151
Observations	10352	10352	10352
Bank fixed effects	yes	yes	yes
Industry specific controls	yes	yes	yes
Clustered standard errors	yes	yes	yes
* p<0.10, ** p<0.05, *** p<0.01			

In this table, all control variables in equation 8 is included. Bank size is measured by log of total assets. In column 1, an interaction term between the tier-1 capital ratio and the NIBOR interest rate is included. In column 2, an interaction term between the total capital ratio and the NIBOR interest rate is included, and in column 3, an interaction term between the "inverse leverage ratio" and the NIBOR interest rate is included. Dependent variable: Risk-taking measure. Standard errors are reported in brackets.

5.2 Empirical Results - Including Time Fixed Effects

Table 10 yields the results from estimating the various fixed effects model, specified in equation 9, where both time fixed effects and bank fixed effects are included. The coefficient of interest is still the coefficient of the interaction term between the interest rate and banks' capitalization levels. As explained in section 4.3.1, the NIBOR interest rate is not included in this specification because the it varies over time, but not across banks, and will therefore be captured in the time fixed effects. As seen from this table, the estimated coefficients of the three different interaction terms are positive. However, it is only the interaction term between the total capital ratio and the interest rate that is statistically significant at a ten percent level. It should be noted that the estimated coefficients of the different interactions between interest rates and banks' capital ratios in table 9 and 10 are very similar, which suggests that the baseline estimated interaction coefficients are robust to controlling for economy-wide variation that is not captured by the short-term interest rate, as argued by Dell'Ariccia et al. (2013).

Table 10: Bank Risk-Taking and the 3-Month NIBOR Interest Rate Including Time Fixed Effects

Variable	**Column 1**	**Column 2**	**Column 3**
	All banks	All banks	All banks
Tier-1 capital ratio $(t-1)$	-0.00780		
	(0.00475)		
Tier-1 capital ratio*NIBOR	0.00153		
	(0.00103)		
Total capital ratio $(t-1)$		-0.01050**	
		(0.00479)	
Total capital ratio*NIBOR		0.00200*	
		(0.00111)	
"Inverse leverage ratio" $(t-1)$			-0.00763
			(0.01023)
"Inverse leverage ratio"*NIBOR			0.00194
			(0.00174)
Growth rate bank size	0.00330	0.00342	0.00291
	(0.00385)	(0.00384)	(0.00399)
Risk measure $(t-1)$	0.90165***	0.90153***	0.90173***
	(0.00917)	(0.00917)	(0.00915)
Constant	0.03819***	0.03860***	0.03769***
	(0.00366)	(0.00365)	(0.00370)
R-sqr	0.930	0.930	0.930
Degrees of freedom	151	151	151
Observations	10352	10352	10352
Bank fixed effects	yes	yes	yes
Time fixed effects	yes	yes	yes
Clustered standard errors	yes	yes	yes
* p<0.10, ** p<0.05, *** p<0.010			

In this table, all control variables are included, also a lag of the NIBOR interest rate and a lag of the dependent variable.Bank size is measured by log of total assets.
In column 1, an interaction term between the tier-1 capital ratio and the NIBOR interest rate is included. In column 2, an interaction term between the total capital ratio and the NIBOR interest rate is included. In column 3 an interaction term between the "inverse leverage ratio" and the NIBOR interest rate is included. Dependent variable: Risk-taking measure. Standard errors are reported in brackets. The quarterly time dummies are not included in the output.

5.3 Discussion

5.3.1 Limitations of the Analysis

As pointed out in earlier sections, there might be several potential drawbacks and limitations of the empirical analysis. In this section, I will present and discuss some of these concerns.

An important assumption underlying the empirical strategy is that the average of the percentage bank losses gives a good indication of the risk that banks consider when deciding the composition of their lending portfolios. However, this assumption might fail for several reasons. First, as seen in table 3, there is a lot of variation in the loan default data. This can also be seen from the charts in the appendix A.3. The problem related to the variation in bank loan losses, is that the averages might not represent the risk that a bank considers in a given time when deciding to supply a loan. To illustrate, suppose that a representative bank when deciding to supply a loan, considers losses in the two preceding years as the indicator of risk. In some of the industries, there have been several periods with substantial bank losses for some periods of time. Therefore, this bank may invest in other industries associated with lower losses during the recent periods. However, due to the high variation, the latter industries still might be associated with high average risk. Consequently, according to the measure used in the analysis, the bank's risk-taking behavior has rather increased than decreased. Nevertheless, it may be reasonable to assume that banks are more long sighted, and as a consequence, the overall averages might give a good indication of risks considered by banks.

Second, as mentioned earlier, Solheim and Kragh-Sørensen (2014) argue that the data on historical average losses give a good basis for measuring the probability of losses on bank loans. However, a potential concern, also advanced in Solheim and Kragh-Sørensen (2014), is that the data (over the period 1997 to 2013) do not include any serious banking crisis. It seems reasonable to assume, that losses in a crisis will differ from losses in normal periods. As a result, the risk weights used in this thesis, might be misleading as the averages not including any banking crisis, might be different from averages including a banking crisis. Third, another concern following from the way of defining a risk measure in this thesis is that there might be other factors affecting banks' perception of risk in an industry than previous losses. For example, expected future demand for an industry's products can possibly also have an influence on the assessment of risks associated with a given industry. However, it is reasonable to assume that these considerations possibly differ largely between banks, and therefore, this concern may not be easily addressed. Fourth and finally, another concern related to the risk measure is the potential presence of negative correlation between the risk weights. If the losses in the different industries are negatively correlated, it might be that a risk-averse bank hedge the risk in its portfolio by supplying loans to two negatively correlated industries. I therefore check the correlation between the risk weights in all nine industries. The correlation matrix shows that, with one exception, the correlations between all industries are positive.[29] The exception is the correlation between the shipping industry and the agricultural industry, but the correlation is fairly small. I therefore do not consider this issue as an important drawback with the empirical analysis.

As illustrated above, there are several potential drawbacks concerning the construction of the banks' risk-taking measure. A way of checking for robustness of the results and address some of the above concerns is to use the risk-weights defined by DnB, a large Norwegian bank, reported in the paper by Solheim and Kragh-Sørensen (2014). Due to both limited data and time, this is not further explored in this thesis.[30]

The aggregation of the loan data at the industry level for each bank might also have implications for the estimated results. It might be that banks rely more heavily on firm characteristics, rather than industry characteristics when deciding to supply loans. For example, it is reasonable to expect that firms in a given industry differ in their characteristics associated with risks, observable for banks. A way of addressing the relevance of this issue could be to run the regressions of subsamples of local banks. Intuitively, it might be that local banks compared to national banks in a larger degree rely on firm characteristics instead of the overall industry characteristics. Another issue is the possible measurement errors in the data, a well-known problem related to using administrative records. The ORBOF data is self-reported by banks, and it might be that banks wrongly report their characteristics. However, if these errors are not systemic and only affecting the dependent variable, this will not cause problems with the estimated coefficient (Studenmund, 2006).

An important assumption in the empirical analysis is that the NIBOR interest rate is a good proxy for the stance of monetary policy. In a paper by Bernhardsen (2012) it was shown that the key policy rates had a broad impact in the Norwegian money market. As

[29]The correlation matrix can be found in the appendix A.6.

[30]The industrial classification used in Solheim and Kragh-Sørensen (2014) is not the same as used in this thesis, and it would required a lot of time to transform the risk-weights to the same classification standard.

mentioned earlier, when including time fixed effects, the NIBOR interest rate is omitted from the regression as it vary at the economy-wide level. Therefore, it might be that instead of the NIBOR interest rate, the banks' deposit rates could potentially be a good proxy for the key policy rates since these varies at the bank level, and therefore could be included in the alternative specification. However, this relies on the assumption of a positive pass-through from the key policy rates to banks' deposit rates. In addition, such a strategy would introduce new endogeneity problems since the deposit rates could depend on risk-taking. Another concern following from the econometric specification is that it can be difficult to separate the effects of monetary policy conditions and other economic features on banks' risk-taking. It might be that in periods of low economic growth in some industries, demand for loans in these industries are lower, which might affect the composition of banks' portfolios. Fully controlling for these issues is a challenge that is not easily resolved. However, including time fixed effects controlling for time varying observed and unobserved variables, and including the growth rates in the industry specific gross value added, might control for this demand effect.

The goal of empirical studies in economics is to establish causal relationships, thus how changes in one variable *causes* a change in another variable (Wooldrigde, 2002). Therefore, simply finding two variables to be correlated is rarely enough. For nearly half a century, there has been a widespread consensus that the best kind of non-experimental data for making causal inference is longitudinal data (Allison, 2005). In panel data, it is possible to take care of some of the individual heterogeneity that varies across individuals but not time. Also, it is possible to take care of omitted variables that varies across time but is affecting all individuals. However, there still might be other types of omitted variables, or other issues regarding the empirical strategy, that erodes the possibility to establish a causal relationship.

5.3.2 Discussion and Policy Implications

To summarize, the estimated effect of the short-term interest rate on banks' risk-taking varies, and is not stable when including different control variables. As seen in table 7, the baseline estimation results not including any controls indicate that, ceteris paribus, there is a positive relationship between banks' risk-taking and the three-month NIBOR interest rate, as a proxy for monetary policy interest rates. However, when the suggested controls are included, the estimated relationship between banks' risk-taking and interest rates becomes negative, which is consistent with the predictions of the literature described in section 3.1. Thus, the quality of banks' issuance of loans improves when the interest rate increases. However, the various estimated interest rate coefficients are quite small, varying between -0.00024 including only savings banks to -0.0018 when only including commercial banks. Therefore, although the estimated coefficients are statistically significant, the economic significance of the effect seems modest.

Moreover, before estimation I expected a negative estimated coefficient of the interaction terms for different proxies of banks' capitalization levels and the short-term interest rate. When the estimated relationship between the interest rate and banks' risk-taking is negative, a negative coefficient on the interaction term would imply a stronger negative relationship for higher capitalized banks compared to banks with lower capitalization levels. This is consistent with the risk-shifting effect suggested in section 3.1. At the total opposite, the estimated coefficients of the interaction terms were positive for a range of measures of banks' capitalization, which was robust to the inclusion of time fixed effects. This indicates a weaker negative relationship for well-capitalized banks, or banks with lower leverage. Again, an alternative interpretation of this result may be that well capitalized banks have more capacity to carry risk.

The aim of the empirical analysis was to investigate whether there exist evidence of a negative relationship between the NIBOR interest rate (as a proxy for the monetary policy stance) and Norwegian banks' risk-taking. The analysis suggests that, when the proposed controls are included, there is evidence of such a negative relationship. To the extent that the proposed specifications shed a correct light on the possible existence of a risk-taking channel in the Norwegian banking market, the estimation results would suggest that the central bank should take these considerations into account in the monetary policy decision. As the section above also clearly indicates, there are several potential drawbacks with the analysis that need to be taken care of. In addition, it does not follow immediately that a potential effect of policy rates on banks' risk-taking is unintended. An extension of the empirical analysis could be to test whether the relationship strengthens when interest rates are held low for extended periods, as done in both Maddaloni and Peydro (2010) and Dell'Ariccia et al. (2013). This extension could give a better indication of the possible policy implications for the central bank. However, I have not pursued this idea further, but consider it an area for future research.

Despite the limitations, the analysis still provides some evidence of a potential risk-taking channel of monetary policy in Norway. In addition, the analysis is a good benchmark for future research, and may be a small but important step for further investigation of the existence of a risk-taking channel in Norway. Also, as suggested in the above section, further exploring the consequences of including different risk-weighs, have more disaggregated data or including additional controls might give additional information regarding the relationship between monetary policy and banks' risk-taking.

6 Concluding Remarks

The purpose of this thesis has been to present the existing theoretical and empirical literature regarding the effects of monetary policy on financial stability, as well as to investigate the potential existence of a risk-taking channel of monetary policy in Norway. The first part of the thesis provides a literature review, including a description of the theoretical arguments and previous empirical findings related to the five channels of monetary policy on financial stability. Naturally, as to establish a background for the empirical part of the thesis, the main focus of the literature review has been on the risk-taking channel. Related to this channel of monetary policy, there are several theoretical arguments suggesting a negative relationship between monetary policy and banks' risk-taking, and also, that the strength of the relationship depends on banks' capitalization levels.

The theoretical literature presented in section 3.1 suggests that this negative relationship results from the effects that monetary policy has on the asset side of banks' balance sheets. Higher monetary policy rates might increase the expected return of banks' portfolios. As a consequence, banks may reduce their demand for risky assets or increase the monitoring of their portfolios. Therefore, higher monetary policy rates might lead to lower banks' risk-taking. In the opposite direction, argued in the paper by Dell'Ariccia et al. (2013), there might be a risk-shifting effect of monetary policy, as higher monetary policy rates also affect the costs of banks' liabilities. Higher monetary policy rates that are translated into higher deposits rates may reduce banks' margins and the expected profit in case of success. Therefore, banks operating in a context of limited liability and asymmetric information may increase their demand for riskier assets or lower the monitoring of their portfolios in an attempt to restore profits. This partial effect of monetary policy suggests a positive relationship between central bank interest rates and banks' risk-taking. Due to this risk-shifting effect of monetary policy, we might also observe differences in banks' risk-taking depending on their capitalization levels: Indeed, banks with higher leverage will experience a higher direct increase in funding costs, compared to banks with lower leverage, and the former will therefore be prone to more risk-taking.

The second part of the thesis provides an empirical analysis of a potential risk-taking channel in Norway. The results from this analysis suggest that banks' risk-taking is negatively associated with interest rates. By using quarterly data on individual banks' aggregate lending to nine different industries in Norway, covering all banks and their corporate lending, the analysis is conducted over the period 1995 to the second quarter of

2014. The results from the analysis suggest that when the purposed control variables are included, there is evidence of a negative relationship between the three-month NIBOR interest rate and banks' risk-taking in Norway. However, the effect is quite small, and therefore the economic significance seems modest. Moreover, the model predictions of a stronger negative relationship for well-capitalized banks are not confirmed. Rather, my results provide evidence of a weaker negative relationship for well-capitalized banks, contrary to the implications suggested by the theory as well as previous empirical findings in other countries.

The Norwegian central bank has already on several occasions emphasized that the possibility of a low monetary policy rate leading to buildups of financial imbalances could influence the monetary policy decision (Norges Bank, 2012). Given this, the empirical evidence presented in this thesis may suggest that the Norwegian central bank should take these considerations into account, and under some circumstances keep the key policy rate higher than they otherwise would. However, the estimated effect seems to be of limited economic significance, since the relevant regression coefficient is relatively small. Furthermore, as was discussed in detail in section 5.3.1, there are several potential drawbacks of the analysis that may invalidate the policy implications of the results. In addition, it does not follow immediately that a potential negative effect of policy rates on banks' risk-taking is unintended. Therefore, both the existence and consequences of a risk-taking channel in Norway need further investigation, in order to be relevant to the central bank's monetary policy decisions.

References

Adrian, T. and Liang, N. (2014). Monetary Policy, Financial Conditions, and Financial Stability, *Federal Reserve Bank of New York Staff Reports, No 690* .

Adrian, T. and Shin, H. S. (2008). Liquidity and leverage, *Federal Reserve Bank of New York Staff Reports, No 328* .

Allen, W. and Wood, G. (2006). Defining and achieving financial stability, *Journal of Financial Stability, No 2* pp. 152–172.

Allison, P. D. (2005). Causal inference with panel data, *University of Pennsylvania* .

Anh, V. T. Q. (2011). Countercyclical capital buffer proposal: an analysis for Norway, *Staff Memo Norges Bank, No 2* .

Bernanke, B. and Gertler, M. (1995). Inside The Black Box: The Credit Channel of Monetary Policy Transmission, *NBER Working Paper Series, No 5146* .

Bernanke, B., Gertler, M. and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework, *Handbook of Macroeconomics, No. 1* .

Bernhardsen, T. (2012). Sammenhengen mellom styringsrenten og pengemarkedsrentene: 2007-2012, *Akutell kommentar Norges Bank, No 2* .

Bjørnland, H. and Jacobsen, D. H. (2010). The Role of House Prices in the Monetary Policy Transmission Mechansim in Small Open Economies, *Journal of Financial Stability, No. 6* .

Borio, C. (2003). Towards a macroprudential framework for financial supervision and regulation?, *BIS Working Papers, No. 128* .

Caruana, J. (2010). Systemic risk: how to deal with it?, *Bank for International Settlements* .

De Groot, O. (2013). The Risk Channel of Monetary Policy, *International Journal of Central Banking* .

De Nicolo, G., Dell'Ariccia, G., Laeven, L. and Valencia, F. (2010). Monetary Policy and Bank Risk Taking, *IMF Staff position Note* .

Dell‘Ariccia, Laeven and Suarez (2013). Bank Leverage and Monetary Policy‘s Risk-Taking Channel: Evidence from the United State, *IMF Working Paper, No. 142* .

Dell‘Ariccia, Leaven and Marquz (2010). Monetary Policy, Leverage, and Bank Risk-Taking, *IMF Working Paper, No. 276* .

Diamond, D. and Rajan, R. (2011). Illiquid banks, financial stability, and interest rate policy, *NBER Working Paper No. 16994* .

Gertler, M. and Gilchrist, S. (2009). Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms, *The Quarterly Journal of Economics, Vol 109. No. 2* .

Green, W. (2008). *Econometric analysis*, Pearson International Edition.

Heikensten, L. (2004). The riskbank and risks in the financial system, Speech at the Risk Management Conference, Stockholm.

Hill, C., Griffiths, W. and Lim, G. (2012). *Principles of Econometrics*, fourth edition edn, Wiley.

Hoff, E. (2010). Likviditetsstyringen i norge og utviklingen i bankenes likviditet, *Staff Memo Norges Bank, No. 10* .

IMF (2009). Lessons For Monetary Policy From Asset Price Fluctuations, *World Economic Outlock* .

IMF (2013). The Interaction of Monetary and Macroprudential Policies, *International Monetary Fund* .

Issing, O. (2003). Monetary Policy and Financial Stability: Is there a Trade-off?, *Conference on Monetary Stability, Financial Stability and the Business Cycle* .

Jeanne, O. and Korinek, A. (2013). Macroprudential regulation versus mopping up after the crash, *NBER Working Oaoer No. 18675* .

Jiménez, G., Ongena, S., Peydró, J.-L. and Saurina, J. (2012). Credit supply and monetary policy: Identifying the bank balance-sheet channel with loan applications, *American Economic Review* **102**(5).

Jiménez, Ongena, Peydro and Saurina (2014). Hazardous Times for Monetary Policy: What Do Twenty-Three Million Bank Loans Say About The Effect Of Monetary Policy on Credit Risk-taking?, *Econometrica, Vol. 82, No. 2* .

Karapetyan, A. (2011). Credit, house prices, and risk taking by banks in norway, *Staff Memo Norges Bank, No. 13* .

Landier, A. and Sraer, D. (2011). The Risk-Shifting Hypothesis: Evidence from Sub-Prime Originatiors, *12th Jacques Polak Annual Research Conference* .

Leeper, E. M. and Nason, J. M. (2014). Bringing financial stability into monetary policy, *Prepared for Sveriges Riksbank* .

Maddaloni and Peydro (2010). Bank Risk-taking, Secutitization, Supervision and Low Interest Rates, *European Central Bank Working Paper Series, No. 1248* .

Merrouche, O. and Nier, E. (2010). What Caused the Global Fiancial Crisis? - Evidence on the Drivers of Financial Imbalances 1999-2007, *IMF Working Paper, No. 265* .

Ministry of Finance Norway (2011). Bedre rustet mot finanskriser, *Norges offentlig utredninger* .

Mishkin, F. (2001). The Transmission Mechanism and the Role of Asset Prices in Monetary Policy, *Working Paper, No. 8617* .

Natvig, G. (2011). Om interaksjon mellom pengepolitikk og tidsvarierende makroregulering av om interaksjonen mellom pengepolitikk og tidvarierende makroregulering av finanssektoren, *Staff Memo Norges Bank, No. 11* .

Negro, M. D. and Otrok, C. (2007). 99 Luftballons: Monetary Policy and The House Price Boom Across U.S. States, *Journal of Monetary Economics, No. 54* .

Norges Bank (2004). Norske finansmarkeder – pengepolitikk og finansiell stabilitet, *Occasional Paper Norges Bank No. 34* .

Norges Bank (2012). Monetary policy report 1/12, *Reports from the Central Bank of Norway No. 1/2012* .

Norges Bank (2013a). Criteria for an appropriate countercyclical capital buffer, *Norges Bank Papers No. 1* .

Norges Bank (2013b). Financial Stability Report 2013, *Reports from the Central Bank of Norway No. 5-2013* .

Norges Bank (2013c). Monetary policy report with financial stability assessment 3/13, *Reports from the Central Bank of Norway No. 3-2013* .

Norges Bank (2014a). Appendix to letter of 26.5.14 to finanstilsynet: Weaknesses in NIBOR.

Norges Bank (2014b). Financial stability report 2014 - vulnerabilities and risks.

Oannidou, Ongena and Peydro (2009). Monetary Policy, Risk-Taking and Pricing, *CentER Discussion Paper* .

Rajan, R. G. (2006). Has Finance Made the World Riskier?, *European Financial Management, Vol. 12, No. 4,* .

Rey, H. (2013). Dilemma not trilemma: The global financial cycle and monetary policy independence, *Kansas City FED* .

Robstad, Ø. (2014). House Prices, Credit and the Effect of Monetary Policy in Norway: Evidence from Structural VAR Models, *Norges Bank Working Paper 05,* .

Romer, C. D. and Romer, D. H. (2010). The macroeconomic effects of tax changes: Estimates based on a new measure of fiscal shocks, *American Economic Review No. 100* .

Sengupta, R. (2010). Alt-A: The Forgotten Segment of the Mortgage Market, *Federal Reserve Bank of St. Louis Review 92(1)* .

Sinn, H.-W. (2001). Risk Taking, Limited Liability and the Competition of Bank Regulators, *NBER Working Paper 8669* .

Solheim, H. and Kragh-Sørensen, K. (2014). Kanaler fra høy gjeld i husholdningene til tap i bankene, *Staff Memo Norges Bank, No. 09* .

SSB (2008). Standard Industrial Classification - Official Statistics of Norway D 383.

SSB (2014). Definitions of the credit indicator.

Stiglitz, J. E. (2009). The Anatomy of a Murder: Who Killed America‘s Economy?, *Critical Review: A Journal of Politics and Society* .

Studenmund, A. (2006). *Using Econometrics - A Practical Guide*, Pearson International Edition.

Taylor, J. (2009). Getting Off Track: How Government Actions and Interventions Caused, Prolonged, and Worsened the Financial Crisis, *Hover Press* .

Walsh, C. E. (2014). Goals and rules in central bank design, *Prepared for the Reserve Bank of New Zealand and International Journal of Central Banking Congerence*.

Wooldrigde, J. M. (2002). *Econometric Analysis of Cross Section and Panel Data*, The MIT Press.

Yellen, J. (2014). Monetary policy and financial stability, *Speech at the 2014 Michel Camdessus Central Banking Lecture, IMF* .

A Appendix

A.1 Detailed Description of the Standard Industrial Classification

Table 11: Detailed Description of The Classified Industries

Variable	**Description**
Agriculture, forestry and fishing	Agriculture, hunting, game preservation, forestry and services related to forestry, fishing and hatchery
Extraction of oil and gas	Extraction and drilling related to oil and gas
Manufacturing and mining industry	Mining industry and extraction manufacturing and production of ships and boats
Water- and electricity supply and construction activities	Water-, gas,- steam- and hot water supply, renovation and sewer systems, real estate development, and construction.
Retail, accommodation and food service activities	Retail, accommodation and food service activities
Real estate activities and other financial activities	Sales and management of real estate, professional and financial services and business services
Other tertiary industries	public services, health, education and other activities
Shipping and pipeline	Shipping and transportation of pipelines
Transportation and communication	transportation, communication and information

A.2 Dickey-Fuller Test Results

Table 12: Dickey-Fuller test results

Fisher-type unit-root test for the included dependent and independent variables based on the augmented Dickey-Fuller tests. Stata-command: xtunitroot.
H_0 = All panels contain unit roots.
H_a = At least one panel is stationary

Variable	Description	Statistics	p-value
3-month NIBOR	Inverse chi-squared(326)	705,5691	0,0000
	Inverse Normal	-15,3365	0,0000
	Inverse logit t(819)	-14,3847	0,0000
	Modified inv. Chi-squared	14,8651	0,0000
Tier -1 capital ratio (Tier-1 capital to total risk-weighted assets)	Inverse chi-squared(304)	664,3404	0,0000
	Inverse Normal	-7,1186	0,0000
	Inverse logit t(764)	-10,1469	0,0000
	Modified inv. Chi-squared	14,6137	0,0000
Total capital ratio (Regulatory capital to total risk-weighted assets)	Inverse chi-squared(304)	752,1238	0,0000
	Inverse Normal	-9,7913	0,0000
	Inverse logit t(764)	-13,3056	0,0000
	Modified inv. Chi-squared	18,1738	0,0000
Leverage ratio (Tier-1 capital to total assets)	Inverse chi-squared(306)	841,2709	0,0000
	Inverse Normal	-10,2736	0,0000
	Inverse logit t(764)	-14,6447	0,0000
	Modified inv. Chi-squared	21,637	0,0000
Growth rate agriculture	Inverse chi-squared(326)	1,18E+04	0,0000
	Inverse Normal	-103,7444	0,0000
	Inverse logit t(819)	-253,8628	0,0000
	Modified inv. Chi-squared	447,4074	0,0000
Growth rate oil and gas	Inverse chi-squared(326)	4880,4708	0,0000
	Inverse Normal	-63,6034	0,0000
	Inverse logit t(819)	-105,4422	0,0000
	Modified inv. Chi-squared	178,3668	0,0000

Table 13: Dickey-Fuller test results

Growth rate shipping	Inverse chi-squared(326)	9208,918	0,0000
	Inverse Normal	-90,9027	0,0000
	Inverse logit t(819)	-198,9527	0,0000
	Modified inv. Chi-squared	347,8819	0,0000
Growth rate retail	Inverse chi-squared(326)	1,18E+04	0,0000
	Inverse Normal	-103,7444	0,0000
	Inverse logit t(819)	-253,8628	0,0000
	Modified inv. Chi-squared	447,4074	0,0000
Growth rate transportation and communication	Inverse chi-squared(326)	9208,9403	0,0000
	Inverse Normal	-90,9028	0,0000
	Inverse logit t(819)	-198,9584	0,0000
	Modified inv. Chi-squared	347,8828	0,0000
Growth rate other services	Inverse chi-squared(326)	1,18E+04	0,0000
	Inverse Normal	-103,7444	0,0000
	Inverse logit t(819)	-253,8628	0,0000
	Modified inv. Chi-squared	447,4074	0,0000
Growth rate financial services	Inverse chi-squared(326)	1,12E+04	0,0000
	Inverse Normal	-101,2241	0,0000
	Inverse logit t(819)	-242,5335	0,0000
	Modified inv. Chi-squared	426,8711	0,0000
Growth rate manufacturing	Inverse chi-squared(326)	1,17E+04	0,0000
	Inverse Normal	-103,7378	0,0000
	Inverse logit t(819)	-253,8325	0,0000
	Modified inv. Chi-squared	447,3526	0,0000
Growth rate water- and electricity supply	Inverse chi-squared(326)	1,18E+04	0,0000
	Inverse Normal	-103,7444	0,0000
	Inverse logit t(819)	-253,8628	0,0000
	Modified inv. Chi-squared	447,4074	0,0000
Risk	Time trend is included		
	Inverse chi-squared(324)	677,128	0,0000
	Inverse Normal	-8,9282	0,0000
	Inverse logit t(809)	-10,1741	0,0000
	Modified inv. Chi-squared	13,8722	0,0000
Bank size (log of total assets)	Inverse chi-squared(324)	406,547	0,0012
	Inverse Normal	3,7853	0,9999
	Inverse logit t(809)	2,4082	0,9919
	Modified inv. Chi-squared	3,2428	0,0006
Growth rate bank size	Inverse chi-squared(324)	4798,8571	0,0000
	Inverse Normal	-59,7541	0,0000
	Inverse logit t(809)	-103,9887	0,0000
	Modified inv. Chi-squared	175,789	0,0000

A.3 Banks' Losses on Loans as a Percentage of Lending to the Respective Industries

Chart 2: Pecentage Losses Manufacturing

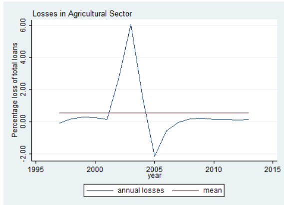

Chart 3: Pecentage Losses Agriculture

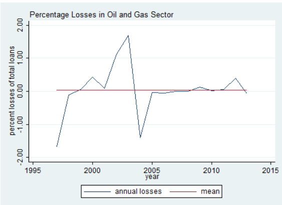

Chart 4: Percentage Losses Oil and Gas

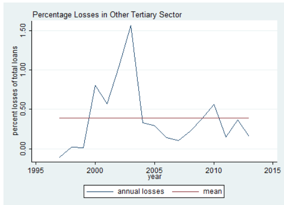

Chart 5: Percentage Losses Tertiary Industries

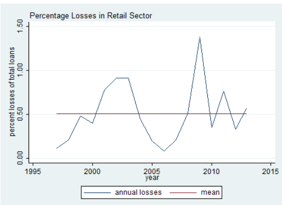

Chart 6: Percentage Losses Retail

Chart 7: Percentage Losses Shipping

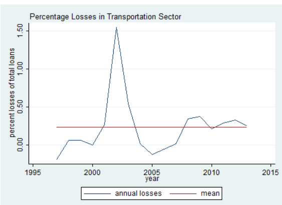

Chart 8: Percentage Losses Financial Services

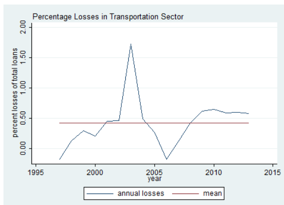

Chart 9: Percentage Losses Water Supply

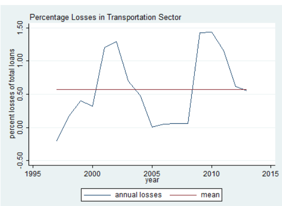

Chart 10: Percentage Losses Transportation

A.4 Norges Bank's Indicators of Financial Imbalances

- The ratio of total credit [31] to mainland GDP.

  Based on Norwegian data Anh (2011) finds that this indicator historically has shown a particularly sharp rise ahead of financial crises, and therefore has a good performance in terms of its ability to signal a financial crisis.

- The ratio of house prices to household disposable income.

  Property prices will have an influence on agents' borrowing preferences and their access to credit since real estate is used both as an asset and as collateral. A sharp decline in house prices might lead to an increase in banks' loan losses, both directly, related to higher default rates on loans, and indirectly, due to a fall in total demand caused by rising unemployment and lower economic activity as real estate construction slows down.

- Commercial property prices.

  In Norway, commercial property have historically exposed banks to the largest loan losses (Norges Bank, 2013a)

- The wholesale funding ratio of Norwegian credit institutions.

  A rise in banks' share of wholesale funding indicates that the lending growth is higher than the deposit growth. This ratio is an indicator of the potential build-up of financial imbalances since banks' access to wholesale funding often dries up or funding costs increase substantially in turbulent times.

[31] The two credit indicators C2 and C3 measure total credit. C2 is an approximate measure of the magnitude of the gross domestic debt of households, non-financial enterprises and municipalities in NOK and foreign currency, while C3 gives an indication of the total gross debt, i.e. the sum of the public's gross domestic and gross external debt (SSB, 2014).

A.5 Data Sources

- **Aggregated data and description of the OBBOF reporting**
  Name: ORBOF reporting (In Norwegian only)
  Webpage: `http://www.ssb.no/innrapportering/naeringsliv/orbof`

- **Value added in different industries in Norway**
  Name: Value added at basic prices. Current prices (NOK million)
  Table: 09171
  Webpage: `https://www.ssb.no/statistikkbanken/SelectVarVal/Define.asp?MainTable=KNRProduksjonInnt&KortNavnWeb=knr&PLanguage=0&checked=true`

- **3-month NIBOR interest rate in Norway**
  Name: Three month NIBOR interest rates
  Webpage: `http://www.norges-bank.no/en/Statistics/Historical-monetary-statistics/Short-term-interest-rates/`

- **Concession Register in Norway**
  Name: Concession Register from The Financial Supervisory Authority of Norway
  Webpage: `http://finanstilsynet.no/no/Venstremeny/Konsesjonsregister/`

A.6 Correlation Matrix of Bank loan Losses

Table 14: Correlation Matrix

	Agriculture	Oil	Manufac.	Water s.	Retail	Shipping	Transpo.	Financial	Tertiary
Agriculture	1.000								
Oil	0.5452	1.000							
Manufac.	0.7112	0.5791	1.000						
Water s.	0.7609	0.6257	0.6754	1.000					
Retail	0.4822	0.4671	0.6160	0.6191	1.000				
Shipping	- 0.0300	0.1692	0.1133	0.3348	0.3438	1.000			
Transpo.	0.2960	0.3987	0.5323	0.5129	0.7565	0.5407	1.000		
Financial	0.5668	0.6268	0.7438	0.4371	0.6235	0.2190	0.6010	1.000	
Tertiary	0.7862	0.7492	0.7542	0.7426	0.5044	0.0070	0.4500	0.6056	1.000