Monetary Policy and Financial Stability: A Vector Autoregressive Approach

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I also certify that the thesis is an original piece of research and has been written by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged.

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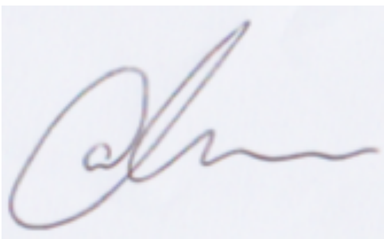

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Abstract

Applying vector autoregression (VAR) techniques, this paper investigates the effects of monetary policy on financial stability in the United Sates, using monthly data for 1990-2014. Alternative indicators of monetary policy are used to assess the dynamic responses of a key set of financial stability variables. By building upon a disaggregation made in the literature, the financial stability transmission channels of monetary policy are also analysed.

This study finds that the net effect of monetary policy on financial stability is rather small. Weak evidence is found for the hypothesis that monetary expansions contribute to financial vulnerabilities; or conversely, that monetary contractions reduce vulnerabilities. However, evidence is found that suggests monetary contractions deteriorate financial conditions as well. In addition, the effects of monetary policy on financial stability are found not to be uniform across transmission channels. In particular, little evidence was found for a financial instability channel in asset markets, while the shadow banking sector displayed the most significant evidence. Overall, these results lend support to a policy framework where monetary policy primarily targets price stability and macroprudential policies target financial stability.

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Chapter 1

Introduction and Motivation

Since the 2007-08 Global Financial Crisis (GFC), the relationship between monetary policy and financial stability has come under renewed focus and debate. The crisis was a timely reminder that price stability is not a sufficient condition for financial stability, that financial crises have large negative effects on the economy, and that the costs of cleaning up after bust bubbles are not always small. Thus, the 'lean versus clean' debate has been rekindled. Specifically, policy makers and researches have reexamined whether monetary policy should proactively act to 'lean against' crisis risk, or merely 'clean up' after a crisis. Resolving this debate, however, largely depends on an often-overlooked question. Namely, what is the effect of monetary policy on financial stability?

Despite a large proportion of the debate focusing on whether monetary policy should lean or clean, our current knowledge of the relation between monetary policy and financial stability is insufficient to the task at hand. In particular, our understanding of the channels through which monetary policy affects financial stability is severely limited. There is no theoretical consensus, and little empirical work has been conducted. In fact, most of our knowledge originates from a slightly older literature that investigates the effects of financial variables on the transmission of monetary policy (IMF, 2015). Hence, while a new literature is growing, research in this area remains a key priority.

The gap in our knowledge is understandable. Financial stability is notoriously difficult to define or measure, while financial crises, as 'tail-risk' events, are infamously troublesome to model. Furthermore, the effects of monetary policy on financial variables exhibit an intertemporal nature, and change depending on initial conditions. Nevertheless, addressing this gap is of fundamental importance for the conduct of monetary policy.

Determining the effects of monetary policy on financial stability is of essential importance for a number of interrelated reasons. Firstly, avoiding future crises requires an understanding of why economies grow vulnerable over time. In particular, a number of pundits have postulated the existence of a 'tradeoff' between price and financial stability. It follows that the extent to which the monetary stance preceding the crises contributed to the buildup of financial vulnerabilities, and the extent to which the current stance is contributing to a future crisis, is fundamentally connected to the relationship between monetary policy and financial stability.

Secondly, if the price-stability-orientated monetary policy framework is sub-optimal, how should it be altered to contain financial stability risks? The 'Jackson Hole Consensus', which prevailed prior to the GFC – that monetary policy should have a relatively narrow mandate of price stability and stabilising resource utilization around a sustainable level (Smets, 2014) – has come under renewed criticism. However, the extent to which monetary policy frameworks should take into account financial stability objectives is contingent upon how significant the impact of monetary policy is on financial stability. From a perspective of practicality, what weight should the monetary policy authority ascribe to financial stability objectives in the policy rule?

Lastly, the newly emerging paradigm posits that monetary policy should primarily target price stability, while macroprudential policies should target financial stability. In theory, macroprudential polices are able to target specific sources of vulnerabilities and hence offer the potential to offset the tradeoff between price and financial stability. Their effectiveness, however, largely depends upon the ability to accurately identify the transmission channel through which monetary policy is engendering financial vulnerabilities. Therefore, improving our understanding of the transmission mechanism between monetary policy and financial stability is integral to the success of macroprudential policies.

This paper thus offers two contributions to the debate. Firstly, most of the literature considers financial variables individually[1], in the sense that they restrict themselves to investigating a specific aspect of financial stability. The limitation of such an approach is that it has little to say about the net effect of a monetary policy shock on financial stability. However, there is strong reason to suspect that the effects of monetary policy on financial stability are heterogeneous. For instance, a monetary expansion may engender financial vulnerabilities by increasing bank leverage, at the same time that it strengtheners financial conditions by reducing delinquency rates. The net effect is thus ambiguous. Consequently, this paper makes a tentative first step at quantifying the net effect of monetary policy on financial stability. While we abstract from interconnections between financial variables, this paper nonetheless investigates a broad set of financial variables in a unified framework. As such, it offers a more complete picture of the effect of monetary policy on financial stability than previously considered in a single study.

The second contribution relates to the transmission channels going from monetary policy to financial stability. By building upon a disaggregation made in the literature, financial variables are grouped into four sectors – the asset market, the banking sector, the shadow-banking sector, and the nonfinancial sector – thus allowing individual transmission channels to be analysed. As a

[1] For example see Rigoban and Sack (2002), Bernanke and Kuttner (2004), De Nicolo et al (2010), Mian and Sufi (2009) and Nelson, Pinter and Theodoridis (2015).

result, the transmission channels can be compared and contrasted in order to inform the conduct of macroprudential policy.

The remainder of the paper is organized as follows. Section two provides a literature review of the relationship between monetary policy and financial stability, particularly focusing on the transmission channels of monetary policy and the potential buildup of financial vulnerabilities. Section three discusses the methodology and the alternative indicators of monetary policy that are employed. Section four provides the results. Section five confronts some criticisms and discusses limitations. Section six concludes.

Chapter 2

Literature Review

2.1 Financial Stability

A starting point for understanding the relationship between monetary policy and financial stability is the notion of financial stability per se. Unfortunately, financial stability is notoriously difficult to define or measure. Narrow definitions characterise a financial system "as stable in the absence of excessive volatility, stress or crisis" (Irving Fisher Committee, 2009). Alternatively, a system is considered 'imbalanced' in the presence of "a sustained and substantial deviation from historical norms, for which there is no compelling analytical explanation" (White, 2012). However, narrow formulations fail to encompass the complex interconnectedness of the financial system with itself, and the real economy.

Broader definitions of financial stability are more abstract, and take into account the system's ability to fulfil its purpose in the wider economic context. Schinasi (2004) suggests that financial stability can be broadly conceived in terms of the financial system's ability "(a) to facilitate the efficient allocation of economic resources… and other economic processes (such as wealth accumulation, economic growth, and ultimately social prosperity); (b) to assess, price allocate, and manage financial risks; and (c) to maintain its ability to perform these key function – even when affected by external shocks or a build up of imbalances – primarily through self corrective mechanisms" (Schinasi, 2004 p.8). Thus, Schinasi advocates the following formulation:

> "A financial system is in a range of stability whenever it is capable of facilitating (rather than impeding) the performance of an economy, and of dissipating financial imbalances that arise endogenously or as a result of significant adverse and unanticipated events" (Schinasi, 2004 p.8)

This definition has several key components. First, the phrase 'a range of stability' indicates that financial stability can be conceived in terms of a continuum of equilibria. Thus, invoking the conception of a financial system "being in a perpetual state of flux and transformation while its ability to perform its key functions remains well within a set of tolerable boundaries" (Schinasi, 2004 p.8). These boundaries entail a set of variables that attempt to quantify, albeit imperfectly, how well the financial system is performing.

The second key component is the phrase 'facilitating (rather than impeding) the performance of an economy'. Essentially, this phrase stresses the role of financial conditions in supporting the macroeconomy. In particular, that financial conditions are conductive to economic activity, instead of inhibitive.

Lastly, the term 'dissipate financial imbalances' implies that the system is capable of withstanding shocks and the unraveling of financial imbalances. It suggests that the system has a certain amount of resilience to the amplification of adverse shocks by financial vulnerabilities. Specifically, that the quantity of financial vulnerabilities do not pose an intolerable risk to the stability of the system.

As a result, these key components imply some practical implications that must be taken into account when investigating financial stability. The most salient being that financial stability cannot be summarised in a single quantitative indicator. This reflects the multifaceted nature of financial stability as it relates to both financial conditions and vulnerabilities. Instead, a broad set of factors need to be considered, that are ultimately judged on their relation to the real economy.

Another important implication is that financial stability is inherently difficult to forecast. Assessing the quantity of financial vulnerabilities can provide an indication of the potential for systemic risk; however, they provide a less accurate indication for the realisation of systemic risk. Largely, this is due to contagion effects and nonlinearities in the relationships between various parts of the financial system. In addition, realisations of financial stability risks often reflect the far-reaching consequences of 'tail events'. Thus, there is considerable uncertainty surrounding the actual shape of the probability distribution.

Lastly, the intertemporal nature of financial stability needs to be emphasised. In part, the intertemporal characteristic reflects tensions between financial conditions and financial vulnerabilities. Often short-term stability, in the form of improved financial conditions, may come at the cost of longer-term instability, in the form of increased financial vulnerabilities. This intertemporal tradeoff is a fundamental issue in determining the net effect on financial stability.

2.2 Conceptual Framework

The relationship between monetary policy and financial stability is complex and ambiguous. "Accommodative monetary policy eases financial conditions, but may also contribute to the buildup of financial vulnerabilities and hence increase risks to financial stability" (Adrian & Liang, 2014 p.1). Conversely, monetary policy contractions may dampen the buildup of financial vulnerabilities, but also agitate financial conditions thus inducing financial instability. Consequently, it is difficult to determine the net effect for a given economy at a particular point in time.

This paper draws heavily on the conceptual framework of Adrian and Liang (2014) in organising our thinking about the effects of monetary policy on financial stability. In particular, this paper follows Adrian and Liang's disaggregation of the financial stability transmission mechanism of monetary policy into four key sectors, but extends upon it by attempting to quantify the individual effects of the sectors. Adrian and Liang summarise the four sectors of the monetary transmission channels as follows:

> "Asset markets: Easier monetary policy improves financial conditions by lowering the risk-free term structure, but also compresses risk premiums.
>
> Banking sector: Easier monetary policy increases loan supply, but also contributes to higher leverage of banks and greater risk taking (more credit to riskier firms).
>
> Shadow banking: Easier monetary policy increases dealer-intermediated leverage that facilitates maturity and credit risk transformation, and securitisation, without an explicit government backstop, but contributes to higher leverage and lower risk premiums.
>
> Nonfinancial sector: Easier monetary policy eases borrowing constraints and boosts credit growth, but reduces underwriting quality and increases debt burdens of riskier borrowers." (Adrian & Liang, 2014 p.2)

The relationship between monetary policy and financial stability is thus characterised by a tradeoff between financial conditions and financial vulnerabilities. The opposing forces of the credit channel and the risk-taking channel exemplify this tradeoff. The credit channel posits that, "interest rate changes affect loan supply through credit market frictions, such as asymmetric information between borrowers and lenders that gives rise to an external finance premium" (Adrian & Liang, 2014 p.2). The size of the external finance premium is inversely related to the balance sheet health of the borrower, which has a negative relationship with the level of interest rates. Hence, when a monetary contraction engenders a fall in asset values, borrowers are less able to borrow (balance sheet channel), and banks struggle to replace deposits with non-deposit funding, leading to a reduction in the supply of loans (bank lending channel). As a result, interest rate rises tend to deteriorate financial conditions, while interest rate cuts tend to improve them.

On the other hand, the risk-taking channel holds that accommodative monetary policy will engender an increase in risk-taking by financial institutions and agents that will boost economic activity, but also increase the vulnerability of the financial system to shocks. As the vulnerability of the financial system to shocks increases, it becomes increasingly unstable and prone to collapse. For instance, low interest rates incentivise investors to reach for yield and assume more risk as they target higher returns than are available on safe assets (search for yield channel). Thus, interest rate rises tend to decrease the risks to financial stability, while interest rate cuts tend to increase the risks.

To further complicate matters, the intertemporal nature of the tradeoff between financial conditions and vulnerabilities means that the costs and benefits of each are likely to be realised in different time periods. For example, Adrian and Liang postulate "accommodative policy eases current financial conditions, allowing business to borrow immediately at lower rates. However, if borrowing were to continue at a rapid rate, borrows and lenders would over time become more leveraged and more vulnerable to an adverse shock" (Adrian and Liang, 2014 p.4). Hence, the benefits to financial conditions from a monetary easing tend to materialise before the buildup of financial vulnerabilities becomes apparent. In addition, monetary policy affects financial conditions, and hence economic outcomes, via expected economic outcomes. In contrast, it affects the buildup of vulnerabilities that increases the potential systemic risk that may only be realised in certain states of the world.

2.3 Asset Markets

The connection between asset markets and financial stability is generally established via the relationship between monetary policy and asset prices. In fact, the asset price mechanism is one of the primary channels through which monetary policy affects the aggregate economy (Shin, 2005). In general, the literature supports the hypothesis of a negative relationship between interest rates and asset prices. That is, interest rate cuts lead to increases in asset prices. The relationship between asset prices and financial stability, however, is more complex and involves a tradeoff with a strong intertemporal dimension.

2.3.1 Asset Price Bubbles

In narratives of financial crises, asset price bubbles usually occupy center stage. Furthermore, the literature tends to focus on the optimal response of monetary policy to bubbles. However, this attention on bubbles per se can be misleading. While there is a widely recognised potential for loose monetary policy to inflate asset price bubbles, "widespread financial distress typically arises from the unwinding of financial imbalances that build up disguised by benign economic conditions" (Borio and Lowe, 2002). Hence, bubbles are just one of many symptoms that can arise from financial instability in asset markets, and the lack of an obvious bubble does not necessary suggest that all is well. In addition, the conventional wisdom on bubbles has been challenged. In particular, Gali (2013) provides evidence that increases in interest rates tend to increase the size of the bubble, rather than deflate them. Consequently, restricting analysis of financial stability in asset markets to examining bubbles does not provide a holistic picture.

Despite the limitations of focusing on bubbles, monetary policy has widely documented impacts on the pricing of risk assets, such as equity, credit and housing. This channel is particularly important as fluctuations in the pricing of these assets can have large impacts, both benign and adverse, on the aggregate economy. For example, Mishkin (2001) outlines how expansionary monetary policies can boost aggregate output and hence financial conditions, via equities, through four transmission mechanisms: (1) stock market effects on investment (Tobin, 1969), (2) firm balance sheet effects, (3) household wealth effects, and (4) household liquidity effects. In contrast, Taylor (2015) asserts that the Federal Reserve's deviation from the 'Taylor Rule' from 2003 to 2005 (in particular, keeping interest rates too low for too long) was a major contributing factor to the housing bubble at the center of the GFC.

Similarly to Taylor, Jarocinski and Smets (2008) also focus on the relationship between monetary policy and house prices in the lead up to the GFC. Using a Bayesian Vector Autoregressive (BVAR) model of the US housing market, they document that monetary policy has significant effects on residential investment and house prices. In addition, Siaz (2014) finds that fundamentals, such as housing supply elasticities and land shares, predicated only 50% of the variance in price growth during the sub-prime mortgage boom. Hence, interest rates appear to play a significant role in the housing market, with proven potential to contribute to bubbles.

2.3.2 Risk Premia

The relationship between monetary policy and asset prices is complex. On one hand, accommodative monetary policy can promote financial stability and improve financial conditions by increasing asset prices and generating stronger economic growth, primarily by lowering the risk-free rate. On the other, low interest rates can lead to a buildup of financial vulnerabilities and engender financial instability by increasing the probability for an abrupt price reversal that may extract large economic costs. Hence, the link between monetary policy and asset prices does not necessarily suggest that low interest rates increase risks to financial stability. According to Adrian and Liang (2014), "for that to happen, risk premiums would have to become compressed" (Adrian and Liang, 2014 p.6). Thus, along with bubbles, compressed risk premiums are another symptom of financial vulnerabilities in asset markets.

In the case of credit markets, Stein (2013) posits that a prolonged period of low interest rates can contribute to overheating, primarily through a compression of risk premia. In particular, he states that a prolonged period of low interest rates represents "a change in the economic environment that alters the risk-taking incentives of agents making credit decisions" (Stein, 2013).

A similar relationship is also documented for equity markets. Interest rate cuts induce stock price increases because of improved corporate profits, reduction in equity risk premium and lower discount rates used to calculate the present value of future profits. Rigoban and Sack (2003), for instance, employ a VAR model that is identified by the heteroscedasticity that exists in high frequency data and find that an unexpected 25-basis point increase in the short-term interest rate engenders a 1.7% decline in the S&P index. In addition, Bernanke and Kuttner (2005) conduct an event-study analysis by constructing a daily window around FOMC decisions and tracking the associated movement in stock prices. They find that an unexpected 25-basis point cut leads to a 1% increase in stock indexes on that same day. Furthermore, they show that the increase is engendered primarily through decreases in risk premium, with very little of the effect coming from changes in the risk–free rate.

In the case of Treasury securities, Hanson and Stein (2012) document evidence that "monetary policy shocks induce time-variation in real term premia" (Hanson and Stein, 2012 p.3). They argue that this effect arises because of 'yield-oriented' investors, who put weight in their objective functions on current income over holding-period returns. Hence, a reduction in interest rates causes these investors to rebalance their portfolios towards longer-term bonds, in order to prevent too much of a decline in their overall yield. This in turn boosts the price of long-term bonds, and hence decreases term premiums.

More broadly, interest rate cuts may compress risk premiums by altering the risk-taking behaviour of financial institutions and investors. In particular, Rajan (2005, 2006) postulates that low interest rates compress risk premia because they "induce an additional degree of procyclical risk taking into financial markets" (Rajan, 2006 p.517). This occurs as low interest rates create additional incentives for institutions to 'reach for yield' and engage in 'risk shifting', thereby reducing risk premia. These incentives arise because financial intermediaries often operate with constraints, such as fixed rate commitments produced by their liabilities, or the compensation structures of asset managers are based on returns in excess of a minimum nominal return. Allen and Gale (2000) advance similar arguments in models of bubbles in real estate markets.

Changes in monetary policy may also affect risk-taking behavior and compress risk premiums by influencing financial institutions' cost of leverage. For instance, Drechsler, Savov and Schnabl (2014) present a dynamic heterogeneous-agent asset pricing model in which monetary policy affects the risk premium component of the cost of capital. Specifically, "lowering the nominal interest rate reduces the cost of leverage, which increases risk taking and decreases risk premia" (Drechsler Savov and Schnabl, 2014 p.56). Adrian, Etula, and Muir (2012) and Adrian, Moench, and Shin (2010) also posit that expansionary monetary policy increases the ability of intermediaries to take on leverage, which in turn impacts the pricing of risk.

In summary, in the short-term, monetary expansions tend to improve financial stability by increasing the value of assets held by households and financial institutions. These effects strengthen the financial conditions of households and firms, possibly leading to decreases in delinquencies and increased aggregate demand, contingent upon balance sheet effects. In the medium-term, however, financial vulnerabilities are likely to grow as compressed risk premia induce a 'search for yield' support by increased leverage.

2.4 Banking Sector

The banking sectors connection to financial stability is generally established via the link between the stance of monetary policy and the risk-taking behaviour of banks. Broadly speaking, the literature tends to support the hypothesis of a negative relationship between bank risk-taking and monetary policy. Specifically, loose monetary policy tends to be associated with higher risk taking, at least for new loans[2]. De Nicolo et al (2010), however, show that the relationship is more complex than typically believed. Forces, such as 'search for yield' and asset effects, imply a negative relationship between the policy rate and risk taking. While forces, such as risk shifting by banks protected by limited liability, operate in the opposite direction. De Nicolo et al argue that the net effect depends on the health of the financial system and the degree to which banks have 'skin in the game'.

2.4.1 Portfolio Effects and the Search for Yield

The mechanisms by which accommodative monetary policy promotes bank risk taking can be broadly categorized under four headings: asset substitution, search for yield, procyclical leverage, and the external finance spread.

The asset substitution argument holds that, under relatively general conditions (in particular, a positive pass-through between the policy rate of the central bank and the real yield on safe assets), low interest rates cause banks to decrease the relative weight of safe assets in their portfolios. As a result, risk-neutral banks will increase their demand for risky assets, and hence reduce the yield of risky assets in aggregate, until equilibrium between safe and risky returns is re-established. A similar portfolio reallocation occurs for risk-averse banks under most utility functions. Fishburn and Porter (1976), however, propose a set of conditions under which income effects could dominate asset substitution effects and result in a decrease in bank holdings of risky assets.

[2] See De Nicolo et al (2010) for a brief summary of the preliminary empirical evidence.

Nevertheless, asset substitution suggests that monetary easing generates an increase in bank risk.

Rajan (2005) suggests a closely related mechanism, called the 'search (or reach) for yield' phenomenon. Financial institutions with long-term commitments (such as pension funds and insurance companies) need to match the yield they promise on their liabilities with what they obtain on their assets. It follows that in a high interest rate environment, they can generate the required revenue by investing in safe assets. In contrast, in a low interest rate environment, there is an incentive to invest in riskier assets in order to match the yield on their liabilities. Like the asset substitution effect, this mechanism assumes that there is a positive relationship between the short-term policy rate and the yield on longer-term safe assets. Continued investment in safe assets during a prolonged period of low interest rates (and hence low yield on safe assets) will likely diminish a financial institutions ability to meet its long-term commitments. Ultimately, this would increase the financial institutions likelihood of default. Alternatively, "a switch to riskier assets (and higher yields) may increase the probability that it will be able to match its obligations (De Nicolo et al, 2010). Consequently, a low interest rate environment increases the incentive for financial institutions to reach for yield and take on risk.

Lastly, monetary policy easing can induce risk taking via the leverage channel, as advanced by Adrian and Shin (2009, 2014). Adrian and Shin document that bank leverage is endogenous and highly procyclical, due to the manner in which risk management is conducted. They present evidence that in the event of an adverse shock "adjustments in leverage primarily take place through expansions or contractions of the balance sheet rather than through the raising or paying out of equity" (Adrian & Shin, 2009 p.4). This implies that monetary policy easing can indirectly affect the risk taking of financial institutions, to the extent that there is a negative relationship between interest rates and asset prices. The logic of this is as follows: interest rate cuts boost asset prices, which increases the equity of financial institutions. Subsequently, financial institutions respond to the fall in leverage by increasing their demand for assets. This reaction is selfreinforcing as demand for assets feeds back into the initial increase of asset values, and so on. "The result is a more fragile banking system that is more exposed to negative shocks to asset values and thus riskier[3]" (De Nicolo et al, 2010).

2.4.2 Limited Liability and Risk Shifting

Under the conditions of asymmetrical information and limited liability, banks tend to operate with more risk than is socially optimal. "Risk-neutral leveraged banks behave like risk-loving agents, since they do not internalize the losses they impose on depositors and bondholders" (De Nicolo et al, 2010). As a result, leveraged banks have an incentive to pursue risky investments that yield high private returns in the case of a positive outcome – but also large losses that fall on others (usually depositors) in the case of a negative outcome – over more prudent investments that offer a higher net present value (Keeley, 1990). This is essentially a moral hazard problem that results from asymmetrical information. If investors were able to correctly price the risk taking of banks at the margin, then the incentive to invest in riskier (higher yielding) assets would be offset by the higher cost of bank liabilities. However, as investors are unable to observe bank portfolios, and banks operate under limited liability, excess risk-taking ensures.

To the extent that the limited liability condition is essentially a moral hazard problem, it can offset by 'skin-in-the-game' effects. The general idea of these effects is that "the more the bank has to lose in the case of a failure, the less severe the moral hazard problem" (De Nicolo et al, 2010). Accordingly, these effects tend to arise from prudential banking regulation such as capital requirements and increasing shareholder liability, and from a banks franchise value (the net present value of the banks future profits). For example, in the case of banks' franchise value, a high value implies a higher value of future profits and

3 Acharya and Naqvi (2010) find a similar effect for the incentives of banks to take risks when asset prices influence market liquidity.

hence more to lose from excessive risk taking. In contrast, a zombie bank (one whose losses are close to or exceed future profits) has a greater incentive to take large risks to gamble for resurrection.

Monetary policy may thus affect bank risk-taking through the effects of interest rate changes on bank profits, as shown by Dell'Ariccia, Laeven and Marquez (2010). An increase in bank profits increases the franchise value of the bank, which dampens moral hazard and hence reduces the incentive for bank risk-taking. Dell'Ariccia, Laeven and Marquez argue that, contingent upon a negatively sloped demand for loans, a cut in the policy rate engenders lower deposit rates, which are only partially passed through to lending rates. Thus, the value of bank assets and future profits increase, while the attractiveness of risk-taking are reduced.

2.5 Shadow Banking

Shadow banking is an ill-defined sector of the financial system that is subject to much debate. The Financial Stability Board (2012), for example, takes an institutional view of shadow banking and defines it as "credit intermediation involving entities and activities (fully or partially) outside the regular banking system". In contrast, Claessens and Ratnovski (2013) take an operational approach and define it as "all financial activities, except traditional banking, which rely on a private or public backstop to operate" (Claessens and Ratnovski 2013). While Adrian and Liang (2014) take a functional perspective and define shadow banking as "maturity transformation, liquidity transformation, and credit risk transfer outside of institutions with direct access to government backstops" (Adrian and Liang, 2014 p.9).

It is important to note that, despite their differences, financial intermediaries of the shadow banking system are often closely intertwined with traditional banks and insurance institutions. These interlinkages involve lines of credit, implicit guarantees and asset management subsidiaries (Brunnermeier & Pedersen, 2009; Adrian and Ashcraft, 2012). Thus, from the perspective of financial stability, a distinction can appear arbitrary. Specifically, their interconnectedness means that contagion can quietly spread to from the shadow banking system to the traditional banking system. Nonetheless, in order to discern the different transmission channels between monetary policy and financial stability, this paper follows Adrian and Liang's function definition.

2.5.1 Role and Purpose

The shadow banking system was a major contributor to systemic risks in the lead-up to the GFC and was a renowned source of financial instability. For example, Bernanke (2013), for example, asserts "shadow banking… was an important source of instability during the crisis". Furthermore, the definitions that emphasize that shadow banking exists outside of the regulators remit stress the uninsured nature of shadow bank funding sources and thus their susceptibility to runs. However, it is also important to note that shadow banking arose to satisfy a genuine demand for 'riskless' assets and thus contributes to financial conditions.

A supply side perspective focuses on how the shadow banking system arose to exploit 'regulatory arbitrage' (Pozsar et al., 2010). Shadow banks, by operating in environments with either low or nonexistent levels of regulatory standards and supervisory oversight, are less constrained than their traditional counterparts. As a result, they are able to engage in a larger degree of risk taking, evident in higher leverage ratios, and greater maturity and liquidity transformations. Such a strategy, however, increases the potential for systemic risk. In particular, the heavy reliance of shadow banks on short-term funding, coupled with their absence of access to government backstops, exposes them to 'bank runs' (Duffie, 2010).

In contrast, a demand side perspective emphasises how shadow banking arose to fill a vacuum (Pozsar, 2011). "This vacuum is best thought of as a result of a limited supply of government-guaranteed money market instruments on the one hand… , and an aversion to unguaranteed exposures to the traditional banking system via uninsured deposits on the other (Pozsar, 2011 p. 87). Hence, shadow banking meets this demand for safe assets by supplying privately guaranteed instruments protected by layers of 'risk stripping'. While this perspective does not dismiss the financial vulnerabilities inherent to the system, it does acknowledge that shadow banking fulfils a demand of the financial system that positively affects financial conditions.

In order to analyse the net effect of shadow banking on financial stability, it is necessary to explore the role that it performs. Essentially, the shadow banking system engages in a 'money creation' process through transforming risky, long-term loans into seemingly riskless, short-term, money-like instruments. Hence, shadow bank liabilities substitute for cash-proof liquid assets (e.g. deposits or Treasury-backed repos) in the private sector's asset allocation.

The shadow bank system creates safe assets by stripping pools of long-term, risky loans of their component risks. This 'risk-stripping' is accomplished via a credit intermediation process that involves credit, maturity, and liquidity transformation, funded on a short-term basis. "Unlike the traditional banking system that conducts credit intermediation 'under one roof' – that of a bank – in the shadow banking system, it is performed through a daisy-chain of nonbank financial intermediaries in a multi step process" (Pozsar et al., 2010). These steps are undertaken in a sequential order with each step performed by a specific type of shadow bank and through a specific funding technique. Pozsar et al. (2010) succinctly summarises these steps in table 2.

The shadow banking system thus bolsters financial conditions by distributing risks across the financial system to those who are most willing and able to assume them. It is also an import source of liquidity in the financial system and plays a significant role in the expansion and contraction of credit in the economy. For instance, Gallin (2013), using data from the Flow of Funds Accounts of the United States, shows that the shadow banking system was a significant supplier of funding to the real economy in the lead-up to the GFC. Furthermore, Caballero and Farhi (2014) identify a shortage of safe assets as a structural drag on the economy. Hence, to the extent that shadow banking fulfils the demand for safe assets and effectively distributes risks, it has a benign effect on financial conditions.

Table 1. Shadow Bank Credit Intermediation Chain

	Function	**Shadow Banks**	**Shadow Banks' Funding***
Step (1)	Loan Origination	Finance companies	CP, MTNs, bonds
Step (2)	Loan Warehousing	Single and multi-seller conduits	ABCP
Step (3)	ABS Issuance	SPVs, structured by broker-dealers	ABS
Step (4)	ABS Warehousing	Hybrid, TRS/repo conduits, broker-dealers' trading books	ABCP, repo
Step (5)	ABS CDO Issuance	SIVs, structured by broker-dealers	ABS, CDOs, CDO-squareds
Step (6)	ABS Intermediation	LPFCs, SIVs securities arbitrage conduits, credit hedge funds	ABCP, MTN, repo
Step (7)	Wholesale Funding	2(a)-7 MMMFs, enhanced cash funds, securities lenders, etc	$1 NAV shares (shadow bank 'depsoits')

Notes: * funding types highlighted in red denote securitized funding techniques. Securitized funding techniques are not synonymous with secured funding.

Source: Pozsar et al. (2010)

2.5.2 Financial Vulnerabilities of Shadow Banking

While shadow banking tends to have a positive effect on financial conditions, it is also a significant source of financial vulnerabilities. Shadow bank credit intermediation, for example, distributes risks across the financial system but also creates a "lack of transparency, underestimation of risk, and cluelessness about how new financial products might behave when subjected to significant stress" (Roubini, 2010 p.67). Intermediation also allows the economy to operate at higher levels of risk taking and with greater leverage relative to an economy with only traditional banking (Adrian, Covitz & Liang, 2013).

The leverage of shadow banking institutions also tends to be more pro-cyclical than traditional banks. For example, Adrian and Shin (2010) document the pro-cyclical leverage of broker-dealers, and highlight that financial crises correspond to extremities in this leverage cycle. In particular, the leverage cycle functions as an amplification mechanism for adverse shocks. In times of benign financial conditions, leverage tends to build, boosting asset prices and compressing risk premia. When financial conditions deteriorate, however, shadow banking institutions tend to deleverage, generating endogenous rises in risk premia and volatility. Given the maturity mismatch of credit intermediation, such deleveraging may potentially trigger fire sales.

The reliance of shadow banks on wholesale short-term funding is another source of financial vulnerabilities. Wholesale short-term funding markets are inherently fragile and susceptible to runs because they allow credit intermediation without direct sources of liquidity or backstops. Thus they act as potential amplifying mechanisms for adverse shocks. Moreover, the absence of a direct backstop makes the value and 'safeness' of shadow bank liabilities state contingent. Moreira and Savov (2014) argue that while shadow bank securities are money-like in normal times, they become illiquid when uncertainty rises. Furthermore, Caballero and Farhi (2014) note that "the world supply of safe assets collapsed from 37% of world GDP in 2007 to about 18% by 2012" (Caballero & Farhi, 2014 p.112), driven primarily by the sudden reassessment of the riskiness of shadow bank securities.

Meeks, Nelson and Alessandri (2013) present a dynamic general equilibrium in which a traditional commercial banking sector and a shadow-banking sector interact through the market for securitised assets. They find that securitisation can have beneficial effects on the macroeconomy, acting as a stabilising force for aggregate activity and credit supply. However, "when securitisation is accompanied by high leverage in the shadow banking system…the economy instead becomes excessively vulnerable to aggregate disturbances" (Meeks, Nelson & Alessandri, 2013).

2.5.3 Monetary Policy and Shadow Banking

The literature generally supports a counter-cyclical impact of monetary policy shocks on shadow banking activity. Specifically, contractionary monetary policy shocks increase the asset growth of shadow banks and securitisation activity (Nelson, Pinter & Theodoridis, 2015; Den Haan & Sterk, 2011; and Loutskina, 2011). This result is surprising because it is in contrast to monetary policies' relationship with the traditional banking sector. Nelson, Pinter and Theodoridis suggest that this 'waterbed' effect may result from commercial banks circumventing tighter funding liquidity constraints following an interest rate hike by increasing their securitisation activity. Therefore, contractionary monetary policy leads "to a migration of lending activity beyond the regulatory perimeter to the shadow banking sector" (Nelson, Pinter & Theodoridis, 2015 p.9).

The hypothesis of the 'waterbed' effect is supported by evidence of the relationship between monetary policy and securitisation. Estrella (2002), for instance, finds that securitisation has lowered the interest elasticity of output and thus mitigated the impacts of monetary policy on banking activity. Furthermore, Loutskina and Strahan (2009) and Loutskina (2011) provide extensive micro-evidence that securitisation offers banks an alternative source of funding, thus reducing the sensitivity of banks to cost of funds shocks, and thereby emasculating the efficacy of monetary policy on banks lending activity.

2.6 Nonfinancial Sector

The primacy of the sub-prime mortgage boom for the GFC, illustrates the importance of the nonfinancial sector for financial stability. The relationship between monetary policy and the nonfinancial sector is often established via the balance sheet channel, otherwise known as the 'financial accelerator'. This transmission mechanism emphasises the impact of policy on the net worth of borrowers, and the importance of borrowers balance sheets for macroeconomic stability.

Evidence on the balance sheet channel is extensive. For example, Bernanke and Gertler (1989), in the seminal contribution, developed a simple model of the business cycle in which the condition of borrowers' balance sheets is a major source of macroeconomic fluctuations. In addition, Iacoviello (2005) introduces financial frictions, in the form of nominal loans and collateral constraints tied to housing values, and shows that home equity has a larger effect on household borrowing and spending than the conventional wealth effect. Thus, the balance sheet channel often acts as a first-order transmission channel for the realisation of financial risks to the real economy.

Excessive credit growth in the nonfinancial sector is a renowned leading indicator for the buildup of systemic risk. Through the balance sheet channel, monetary expansions increase net worth, which increases access to credit. The presence of financial frictions in financing markets, however, can lead to excessive debt growth, which increases the probability that borrowers will default.

Debt increases the vulnerability of household balance sheets. As households leverage against high and rising asset prices (e.g. real estate and stock markets), they become exposed to abrupt price reversals. As shown by Filardo (2008), in monetary policy model that features asset prices and household debt, "if asset prices prove to be largely unsustainable, households could find themselves saddled with debt overhangs and heavy debt servicing costs" (Filardo, 2008 p.31). Moreover, at the aggregate level, such vulnerabilities have externalities that can amplify adverse shocks.

The nonfinancial sector is prone inefficient equilibrium allocation at the aggregate level, which can act as an amplifying mechanism. In particular, borrowers tend not to take into consideration the aggregate effects of deleveraging and thus accumulate an inefficient level of debt. For example, in a model of deleveraging, Korinek and Simsek (2014) demonstrate that the failure of borrowers to take into account externalities leads to excess leverage. Specifically, when hit by adverse shock, financial frictions, in the form of limited access to outside funds, can trigger fire sales as borrows race to raise liquidity. Such fire sales, however, feed back into the net worth of the nonfinancial sector and cause sharp falls in aggregate demand. A deficiency of aggregate demand may then reinforce the effects of the initial shock as it leads to mounting losses at financial institutions.

In addition, research has shown that aggregate household leverage is a strong predicator of recession severity. Mian and Sufi (2009) show that household leverage preforms remarkably well in explaining the sharp rise in household defaults, the drop in house prices, the fall in consumption, and the increases in unemployment during the GFC in the U.S.

Furthermore, the role of monetary policy in affecting household debt is empirically well documented. Studies tend to find that debt levels decrease following a monetary contraction. For example, studies generally find that debt decrease by about 0.7 percent to 2 percent, after a monetary contraction (Diaz Kalan et al. 2015; as cited by the IMF, 2015).

2.7 Literature on Monetary Policy Shocks

Since the seminal work of Sims (1980), a substantial part of the literature on monetary policy has been devoted to determining the effects of shocks on the macroeconomy[4]. Over time, an agreement has built up that has proven robust to different identification schemes, estimation methods, lag structures and time periods. Christiano et al. (1998) document this agreement as follows: "after a

[4] See for example Strongin, 1995; Leeper, Sims & Zha, 1996; Bernanke & Mihov, 1998.

contractionary monetary policy shock, short term interest rates rise, aggregate output, employment, profits and various monetary aggregates fall, the aggregate price level responds very slowly, and various measures of wages fall, albeit by very modest amounts" (Christiano et al., 1998 p.6). Hence, this agreement can be taken as a consensus of the effects of monetary policy.

Subsequent papers have extended this literature beyond traditional macroeconomic variables to provide a more holistic picture of the effects of monetary policy. Kuttner (2000), for example, estimates the impact of monetary surprises on bill, note and bond yields, while Rigoban and Sack (2002) use an 'event-study' approach to determine the effects of monetary policy on a range of asset prices, including stock market indexes, treasury yields and Eurodollar future rates. Consequently, there is ongoing literature quantifying the effects of monetary policy shocks beyond traditional channels.

Recently, there has been growing interest concerning potential unintended negative side effects of monetary policy. In particular, pundits posit that monetary stimulus could engender financial and real imbalances, which may lead to boom-bust processes that would threaten financial stability (Borio and White, 2003; White, 2012; Borio, 2014). Despite the attention given to the relationship between monetary policy and financial stability, few studies have provided a quantitative analysis of this relationship. The exceptions tend to focus on a particular aspect of financial stability, such as the banking sector, rather than on financial stability per se. For instance, Angeloni, Faia, and Lo Duca (2013) employ an orthogonalized VAR model to assess the impact of monetary policy shocks on bank risks. They find that a monetary expansion increases bank leverage and risk. In addition, Den Haan and Sterk (2011) use the Cholesky decomposition to quantify the effects of monetary policy shocks on home mortgages and consumer credit before and during the Great Moderation. They find that the behaviour of consumer loans has remained remarkably stable over the time periods, while the dynamics of home mortgages has changed. Specifically, following a monetary tightening, bank mortgages declined in the period before the Great Moderation but increased during it. Finally, Nelson, Pinter and Theodoridis (2015) look at the relationship between monetary policy and shadow banking, and find that a contractionary shock increases the asset growth of shadow banks and securitization activity. Hence, there is a gap in the literature concerning the effect of monetary policy on financial stability per se.

Chapter 3

Methodology

3.1 Overview

This paper employs a VAR approach to model the effects of monetary policy on financial stability. Three alternative indicators or monetary policy are used: the effective federal funds rate, non-borrowed reserves, and 'orthogonalized' non-borrowed reserves. Two time periods are considered: the full sample (1990m02-2014m07) and a pre-GFC subsample (1990m02-2007m11). Moreover, two key identifying assumptions are made:

(i) Policy variables react contemporaneously to non-policy variables, while the converse does not hold.

(ii) The contemporaneous restrictions on the policy block of the model reflect the operational procedures implemented by the monetary authority.

The variables considered in this study can be classified as follows:

Non-policy variables:

- Macroeconomic:
  - Economic activity
  - Inflation
  - Commodity prices
- Financial stability:
  - House prices
  - Stock market
  - Credit
  - Equity premium
  - Risk premium
  - Bank credit

Policy variables:

- Federal funds rate
- Non-borrowed reserves
- Total reserves

A benchmark six-variable VAR model is estimated to build confidence for our specification and identification. This model is standard in the literature and consists of the vector of non-policy, macroeconomic variables; and the vector of policy variables. We then specify a series of seven-variable VAR models by adding one financial stability variable at a time to the baseline model to assess the impact of monetary policy shocks on financial stability.

We employ monthly data with the starting date determined by the availability of particular variables. All models are estimated in levels. All variables are converted to logarithms apart from the effective federal funds rate, unless otherwise noted.

3.2 Benchmark Model

Ideally, given the interconnected nature of the financial system, we would prefer to include all of the variables in our analysis in one large unrestricted VAR and report the resulting system of impulse response functions. However, this strategy is not feasible, as standard VARs struggle to handle much more than half a dozen variables, given standard sample sizes. In particular, including all the variables that we wish to analyze in one large unconstrained VAR would invite overfitting and undermine the credibility of the VAR estimates (Killian, 2011). On the other hand, including too few variables in the VAR could expose the model to significant omitted variable bias (Christiano, Eichenbaum & Evans 1996). As a result, a balance between the tradeoffs must be struck.

In light of the above considerations, we follow Blanchard and Perotti (2002), Fragetta et al. (2011), and Christiano, Eichenbaum and Evans (1996) among others, and employ the following intermediate strategy. Starting with a benchmark six-variable VAR, we specify a series of seven-variable VAR models by adding one variable at a time to the baseline model to asses the effects of monetary policy shocks on a set of key variables of financial stability. As a result, while this paper abstracts from interrelationships between financial variables, it nonetheless investigates the effects of monetary policy on financial stability within a unified framework. In addition, this approach allows the financial stability transmission channels of monetary policy to be assessed.

The benchmark model is a VAR system that has become the standard reference model of the U.S. monetary transmission channel (Strongin 1995, Bernanke and Mihov 1995, Christiano, Eichenbaum & Evans, 1996; Leeper, Sims & Zha 1996). It consists of a vector of macroeconomic non-policy variables and a vector of policy variables. The vector of macroeconomic non-policy variables includes a measure of economic activity, domestic inflation and the commodity price level. While the vector of policy variables includes the federal funds rate, the amount of non-borrowed reserves and the quantity of total bank reserves.

The purpose of the benchmark model is to build confidence that we have identified shocks to monetary policy and that our financial stability models rest on firm foundations. In particular, Lucas (1980) suggested "[t]he more dimensions on which the model mimics the answers actual economies give to simple questions, the more we trust its answers to harder questions" (Lucas, 1980). Hence, assessing the extent to which the benchmark model is congruent with the literature on the effects of monetary policy shocks helps determine the reliability of the financial stability models.

The variables used in the baseline model are defined as follows[5]:

Non-policy variables:

- Economic activity: three-month moving average of the Chicago Fed National Activity Index (CFNAI_MA3);
- Inflation: log difference of the Consumer Price Index for all Urban Consumers, all items less food and energy, seasonally adjusted (INF);
- Commodity price index: log of the IMF's non-fuel world commodity price index (NFPI).

Policy variables:

- Federal funds rate: Effective federal funds rate, per cent per annum (EFF);
- Non-borrowed reserves: log of non-borrowed reserves, adjusted for reserve requirements (NBR);
- Total reserves: log of total reserves, adjusted for reserve requirements (TR).

3.2.1 Non-Policy Variables

Chicago Fed National Activity Index (CFNAI)

Use of the three-month moving average of the Chicago Fed National Activity Index (CFNAI) as a measure of economic activity, is motivated by our decision to use of monthly data and it success at tracking economic expansions and

[5] See Appendix for additional details.

contractions ('Background on the CFNA', 2013). Unfortunately, traditional measures of economic activity, such as real GDP, are not published at monthly frequencies. While an approach in the literature has been to interpolate quarterly real GDP based on the fluctuations in monthly indicators, such strategies "are likely to distort the structural impulse responses to be estimated" (Kilian, 2011). Furthermore, common proxies, such as industrial activity, are also problematic. For example, industrial output accounts for only a fraction of total output, while the Federal Reserve is concerned with a broad measure of economic activity. Hence, such proxies are economically unlikely to represent the policy reaction function of the Federal Reserve. In this regard, the CFNAI is a superior measure of monthly economic activity, and has a proven track record for identifying whether the economy has moved into and out of a recession.

Inflation (INF)

Including a measure of price is standard in macroeconomic VAR models. Following Dungey and Pagan (2000), this paper uses the inflation rate instead of the price level. 'Core CPI' is used because food and energy (which are excluded in the 'Core CPI') have very volatile prices, and it is well known that the Federal Reserve prefers underlying measures of inflation.

Commodity price index (NFPI)

The commodity price measure is included to mitigate the infamous 'price puzzle'. This is the result of an "anomalous response of a rise in prices following a contractionary monetary policy shock" (Lin et al., 2013). This phenomenon has been documented in a large number of empirical studies using the VAR modeling framework (see Sims, 1992 and Eichenbaum, 1992). Commodity prices are thought to account for the forward looking nature of the central bank, and act as an information signal regarding future inflation.

3.2.2 Policy Variables

Effective federal funds rate (EFF)

The federal funds rate is a standard measure of the central banks policy instrument. This choice is motivated by institutional arguments such as in Bernanke and Blinder (1992) and Sims (1986, 1992). Furthermore, the Federal Reserve expresses its current monetary policy through the federal funds rate. This study includes the effective federal funds rate because it is the rate at which depository institutions trade federal funds with each other, and is widely recognized as a basic measure of overnight U.S. interest rates.

Non-borrowed reserves (NBR)

Non-borrowed reserves are another common measure of the policy instrument. This choice is motivated by arguments due to Christiano, Eichenbaum and Evans, (1996), who argue that "innovations to non-borrowed reserves primarily reflect exogenous shocks to monetary policy, while innovations to broader monetary aggregates primarily reflect shocks to money demand" (Christiano, Eichenbaum & Evans, 1996). Furthermore, anecdotal evidence suggesting that non-borrowed reserves capture the unconventional monetary policies that were implemented after the federal funds rate became constrained by the zero-lower-bound (ZLB)[6].

Total reserves (TR)

Total reserves are a key component of the model of the market for commercial bank reserves. Thus, the series is essential for capturing the different operating procedures of the Federal Reserve (Strongin, 1995 and Bernanke & Mihov, 1998). In particular, total reserves are essential for identifying 'orthogonalized' non-borrowed reserves[7].

3.3 Financial Stability Models

[6] See section 3.4.1.
[7] See section 3.4.1.

As outlined above, we augmented the benchmark model by adding one variable at a time to the non-policy vector. Thus, the financial stability models are a series of seven-variable VARs that allow us to examine the effects of monetary policy shocks on a key set of financial stability variables.

The general framework of the financial models is as follows:

Non-policy variables:

- Economic activity: three-month moving average of the Chicago Fed National Activity Index (CFNAI_MA3);
- Inflation: log difference of the Consumer Price Index for all Urban Consumers, all items less food and energy, seasonally adjusted (INF);
- Commodity price index: log of the IMF's non-fuel world commodity price index (NFPI);
- Financial stability: a set of variables that capture various aspects of financial stability (FS).

Policy variables:

- Federal funds rate: Effective federal funds rate, per cent per annum (EFF);
- Non-borrowed reserves: log of non-borrowed reserves, adjusted for reserve requirements (NBR);
- Total reserves: log of total reserves, adjusted for reserve requirements (TR).

The set of financial stability variables is drawn from the literature and aims to quantify the effects of monetary policy on financial stability. In particular, the set contains two general types of variables. The first are financial conditions indexes that attempt the gauge the overall impact of a monetary policy shock on financial stability. The second are variables that attempt to discern the particular transmission channels through which monetary policy affects financial stability. Following the conceptual framework discussed in the literature review, there are four specific sectors through which monetary policy shocks can lead to buildups of financial vulnerabilities: asset markets, the banking sector, the shadow-banking sector, and the nonfinancial sector. Consequently, this paper employs variables that correspond to particular sectors, allowing us to distinguish the precise channels through which monetary policy impacts the financial system.

3.3.1 Financial Conditions Indices[8]

Chicago Fed's National Financial Conditions Index (NFCI)

The NFCI was introduced in 2006 and is a coincident indicator of financial activity. The index is constructed as a weighted average of 100 indicators of risk, credit and leverage. Since economic conditions are correlated with financial conditions, an adjusted national financial conditions index (ANFCI) is also provided to measure financial conditions uncorrelated with economic conditions. In addition, the NFCI has four sub-indexes, which allow for a more detailed examination of the source of financial vulnerabilities. The risk sub-index captures volatility and funding risk in the financial sector; the credit sub-index is composed of measures of credit conditions; and the leverage sub-index consists of debt and equity measures (Brave & Butters, 2010). The non-financial leverage sub-index, in particular, is characteristic of the financial accelerator and has performed well as a leading indicator of financial instability in the U.S. (Brave & Butters, 2012). Positive values of the NFCI, ANFCI or the sub-indexes, indicate tight financial conditions that are associated with above-average risk and below average credit and leverage, while negative values are associated with the opposite.

Kansas City Financial Stress Index (KCFSI)

The KCFSI was developed in 2009, and is a principal-components measure of 11 standardized indicators (Hakkio & Keeton, 2009). In particular, it focuses on six key features of financial stress: increased uncertainty about fundamental value of assets, increased uncertainty about behavior of other investors, increased asymmetry of information, decreased willingness to hold risky assets

[8] As the indices are scaled at the source to have a mean of zero, 3-month moving averages are taken instead of logs.

(flight to quality), and decreased willingness to hold illiquid assets (flight to quality). A positive value of the KCFSI indicates that financial stress is above the long-run average, while a negative value indicates the opposite.

3.3.2 Asset Markets[9]

Term premium (TP):

The term premium is based on the Adrian, Crump, Moench (2013) term structure model. It represents deviations from the term structure of interest rates and, hence, is a measure of the risk premium of Treasury securities. Thus, compressed term premiums can induce a reach for yield, supported by leverage, which may give rise to systemic financial instability.

Equity prices (S&P 500):

The S&P 500 index is an U.S. stock market index based on the market capitalizations of 500 large companies. This paper uses the growth rate of the S&P500. Fast growth rates are symptomatic of asset price bubbles driven by irrational exuberance. Due to the increased likelihood for an abrupt reversal, asset price bubbles pose a potential threat to financial stability.

Residential real estate prices (HP):

The S&P/Case Shiller U.S. National Home Price Index is a composite of single-family home price indices for the nine U.S. Census divisions. It measures the underlying change in housing market prices, given a constant level of quality. This paper employs the growth rate of house prices, which has been found to be an acceptable predictor of crisis in the literature[10]. High values may reflect an asset price bubble and indicate an increased probability of an abrupt reversal. Thus, high growth rates represent an increase in financial vulnerabilities.

[9] All variables enter the model as logs.
[10] See IMF (2015).

Implied Equity Risk Premium (ERP):

The ERP is based on the Shiller (2005) dividend discount model (DDM) of the equity risk premium. Like the term premium, compressed ERP can induce a reach for yield, supported by leverage, which may give rise to systemic financial instability.

Credit spread (CRED_S):

The Baa/10-year Treasury spread reflects the credit spread between the two securities. Treasury securities are considered 'risk-free', while Baa-rated bonds are the lowest-rated bonds classified by Moody's as investment grade. Increases in the spread may or may not be justified by an actual increase in default risk. Instead they may result from a decreased willingness to bear risk, or represent an over-reaction to a prolonged period of excessive optimism (Hakkio & Keeton, 2009). Nevertheless, an increase in the credit spread reflects a flight to quality and liquidity, and indicates a decrease in financial stability. Moreover, higher credit spreads are symptomatic of lower risk-taking behavior, implying the potential for low spreads to engender risk-taking.

3.3.3 Banking Sector

Bank credit (B_CRED):

Bank credit growth is a popular leading indicator of financial crisis in the literature. In particular, Schularick and Taylor (2012) document that faster credit growth increases the likelihood of a future financial crisis. In addition, rapid credit growth is often associated with deterioration in the quality of credit, as underwriting standards become lax.

Delinquency rates (DEL):

Delinquency rates offer a good measure of financial conditions. Higher delinquency rates are associated with periods of financial stress and are often the catalyst for a financial crisis. In contrast, low delinquency rates are symptomatic of low financial stress.

3.3.4 Shadow-Banking Sector

Net shadow bank liabilities (NSBL):

Net shadow bank liabilities is based on the Pozzsar et al. (2012) measure of shadow-banking activity. It essentially sums all liabilities related to securitization activity, as well as short-term money market transactions that are not backstopped by deposit insurance, adjusted to avoid double counting. Thus, it is not a proxy for the net supply of credit by shadow banks per se, but rather a measure of the liabilities that are vulnerable to bank runs. Hence, an increase in NSBL indicates an increase in financial fragility and instability.

Broke-dealer net leverage (BDNL):

Broker-dealer net leverage is a ratio of total financial assets to equity capital for broker-dealers. While broker-dealers have traditionally engaged in market-making and underwriting roles in securities markets, according to Adrian, Murench and Shin (2010), their importance in the supply of credit has increased in proportion to the increase in securitization. Furthermore, broker-dealers fund part of their liabilities through short-term borrowing and thus are sensitive to capital market conditions. As a result, BDNL is a good proxy for the leverage of the shadow-banking system. As increases in leverage tend to be preceded by financial crises, an increase in BDNL is interpreted as an increase in financial vulnerabilities.

3.3.5 Non-financial sector

Private credit (P_CRED):

Research has documented that excessive credit growth in the private non-financial sector is an important indicator for the buildup of systemic risk. In addition, increased credit supply has been shown to contribute to rises in household leverage and debt. Rapid credit growth also tends to create fire sale externalities, as households are less able to absorb the shock of asset declines. Thus, an increase in P_CRED is symptomatic of an increase in financial instability.

Household debt (HD):

Household debt levels are a significant source of vulnerabilities in the nonfinancial sector. High debt levels reduce the ability of households to absorb negative adverse shocks, such as a house price decline. At the aggregate level excessive debt can act as an amplifying mechanism, exuberating downturns through fire sale and aggregate demand externalities. Hence, an increase in household debt is interpreted as an increase in financial vulnerabilities.

3.4 Model Specifics

Since VAR and SVAR were introduced in the 1980s, the technique has been widely applied in the literature. In particular, they have been described as the "workhorse of empirical economics" (Demiralp, 2008 p.509), and are a popular tool in the analysis of the monetary transmission mechanism and sources of business cycle fluctuations. Hence, a technical discussion on the methodology is avoided and readers unfamiliar with the technique are encouraged to refer to Hamilton (1994) and Kilian (2011) for a rigorous exposition.

It is assumed that the structure of the U.S. economy can be described by the following equation:

$$A\begin{pmatrix} Y_t \\ M_t \end{pmatrix} = C(L)\begin{pmatrix} Y_{t-1} \\ M_{t-1} \end{pmatrix} + B\begin{pmatrix} v_t^Y \\ v_t^M \end{pmatrix} \tag{1}$$

Where Y_t is a vector of non-policy (macroeconomic and financial) variables, and M_t is a vector of policy variables controlled by the monetary authority. C(L) is a matrix finite-order lag polynomial, $v \equiv \begin{pmatrix} v_t^Y \\ v_t^M \end{pmatrix}$ is a vector of innovations to the non-policy and policy variables respectively, and A and B are coefficient matrices. Hence, the reduced-form VAR, specified for analyzing the impact of monetary policy, can be obtained by pre-multiplying (1) by the inverse of A:

$$\begin{pmatrix} Y_t \\ M_t \end{pmatrix} = A^{-1}C(L)\begin{pmatrix} Y_{t-1} \\ M_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_t^Y \\ \varepsilon_t^M \end{pmatrix} \quad (2)$$

Where $\varepsilon \equiv \begin{pmatrix} \varepsilon_t^Y \\ \varepsilon_t^M \end{pmatrix}$ is a vector of reduced-form innovations to the non-policy and policy variables respectively. The relation between the reduced-form innovations and the structural shocks is therefore:

$$A\begin{pmatrix} \varepsilon_t^Y \\ \varepsilon_t^M \end{pmatrix} = B\begin{pmatrix} v_t^Y \\ v_t^M \end{pmatrix} \quad (3)$$

Identification of the model thus requires the imposition of restrictions on the matrices A and B. This paper makes two key identifying assumptions:

(i) Policy variables react contemporaneously to non-policy variables, while the converse does not hold.

(ii) The contemporaneous restrictions on the policy block of the model reflect the operational procedures implemented by the monetary authority.

In models estimated on monthly data, (i) is consistent with a wide spectrum of alternative theoretical structures and implies a minimum assumption on the lag of the impact of policy on non-policy variables (Bagliano & Favero, 1998). It has two general implications in our model. First, non-policy variables do not respond to policy shocks within the current period. Second, the vector of non-policy variables forms the Federal Reserves information set. The former is obviously more plausible for macroeconomic than financial variables. In particular, it is difficult to rule out simultaneous feedbacks between monetary policy and high frequency series, such as the stock market. Nevertheless, this assumption is maintained for the sake of simplicity and consistency. On the other hand, the latter implication is more plausible for high frequency series that are continuously observable. In particular, it is reasonable to assume that Fed knows current values of high frequency variables, such as BAA/T-bill spreads. However, the assumption that the Fed knows current values of economic activity and consumer prices is at best an approximation of the Fed's actual information set (Leeper, Sims & Zha, 1996).

Assumption (ii) is based on institutional analysis, and is contingent upon the indicator of monetary policy in question, as shown below. Employing alternative indicators allows for the preference of the Federal Reserve to change over time, as operating procedures or other factors change. For instance, Stongin (1995) and Bernanke and Mihov (1998) document the changing operating procedures over the period 1959 to circa 1998. They find strong evidence that the Fed's operating procedures have changed over time, and hence no single indicator of policy is optimal for the full time period[11].

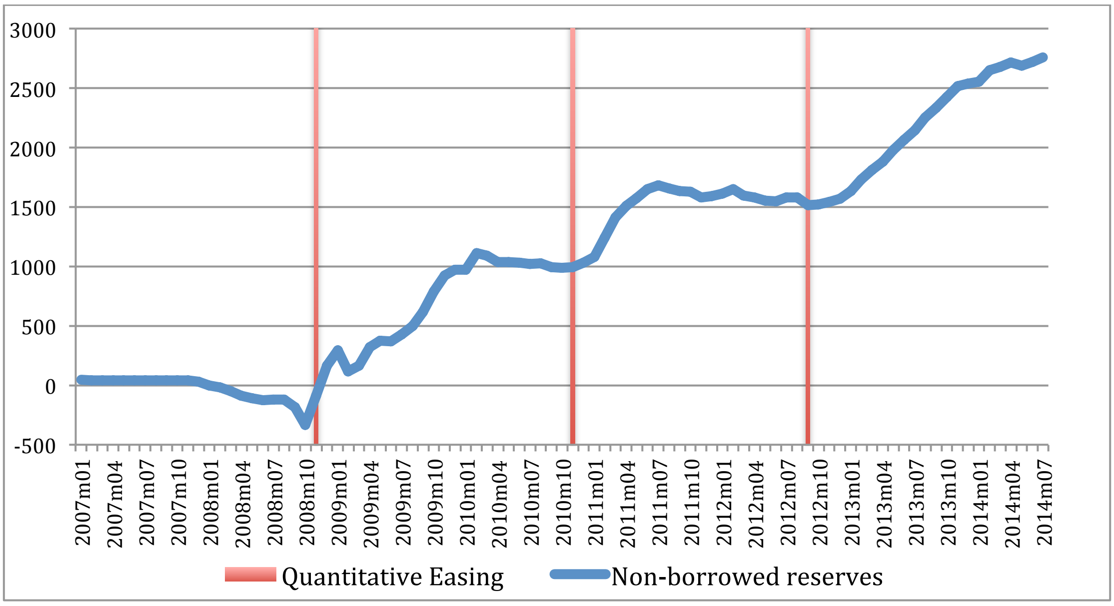
There is also considerable extraneous evidence that hitting the zero-lower-bound (ZLB) in 2008 effectively amounted to a regime change for the Fed. Specifically, the Federal Reserve resorted to unconventional policies, such as quantitative easing (QE), to conduct policy during this period as the federal funds rate had lost traction and become ineffective. Hence, while constrained by the ZLB, the federal funds rate is highly unlikely to capture the actual stance of monetary policy. In particular, the absence of variation in the federal funds rate during this period, suggests no loosening (or tightening) of policy. This is at odds, however, with the multiple implementations of QE during the period. As QE is essentially an expansionary monetary policy, its deployment suggests a

[11] These periods and their related operating procedures are as follows:
1959-1966: Free reserves targeting before the modern Federal funds market.
1966-1972: Free reserves targeting and the bank credit proviso
1972-1979: Money growth/federal funds targeting
1979-1982: Non-borrowed reserves targeting
1982-c.1998: Borrowed reserves/Federal funds targeting.

significant loosening of policy. Consequently, the federal funds rate is most likely a poor indicator of monetary policy post 2008.

Anecdotal evidence suggests that non-borrowed reserves are a superior indicator of monetary policy post 2008 than the federal funds rate. In particular, non-borrowed reserves appear to capture the unconventional policies that were implemented over the period. Consider figure 1. which shows non-borrowed reserves, measured in billions of dollars, over the period 2007m01 to 2014m07:

Figure 1. Non-borrowed reserves and starting dates of Quantitative Easing



Notes: measured in billions.
Source: FRED, Non-borrowed Reserves of Depository Institutions.

The vertical red lines represent starting dates of QE. Specifically, QE1 was introduced in November 2008; QE2 began in November 2012; and QE3 started in September 2012. As figure 3.1 indicates, non-borrowed reserves appear to increase following an implementation of QE. Hence, the major advantage of using alternative indicators of monetary policy is that one may capture changes in monetary policy that the others miss. Employing multiple indicators, thus, offers greater insight into the effects of monetary policy.

3.4.1 Identification

Accurate identification of monetary policy shocks is essential for observing their effects on financial stability. In addition, recovering the structural model from the reduced form VAR, and hence estimating a SVAR, requires restrictions to be imposed on the matrices describing the contemporaneous relationships, thereby surmounting the identification problem.

This paper adopts three alternative indicators of monetary policy shocks, which are derived by applying different structuralisations to the same reduced form VAR. Specifically, a 'semi-structural' VAR model is employed with two key identifying assumptions[12]. As will be shown below, these assumptions permit an orthogonalization identification strategy (essentially imposing a recursive ordering on the system by restricting various elements of the matrices to 'zero').

Despite the widespread use of the recursive assumption, it remains controversial for good reasons. In particular, orthogonalization involves strong a priori assumptions about the causal structure of the model. As Kilian asserts, "we impose a particular causal chain *rather than learning about causal relationships from the data*. In essence, we solve the problem of which structural shock causes the variation in ε_t by imposing a particular solution"[13] (Kilian, 2011 p.5). Hence, empirical results are only as credible as the underlying causal chain. This implies that orthogonalization is appropriate only if the recursive structure that it imposes is justifiable.

Orthogonalization, however, is judged to be sufficient for the needs of this paper as it allows us to estimate the model under a minimal set of economic relations. Abandoning the recursive assumption requires a much broader set of economic relations to be identified. Given that ultimately, this paper is concerned with financial stability and that the relations involved in financial stability remain controversial, the recursive assumption is judged to be a *relatively*

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[12] See section (3.4)
[13] Emphasis added.

'theory-free' way of achieving identification. Nonetheless, significant issues remain that present an avenue for future research[14].

Effective federal funds rate

The use of the federal funds rate as an indicator of monetary policy is motivated by its salience in the monetary policy discourse and arguments due to Bernanke and Blinder (1992) and Sims (1986, 1992). Under a federal funds targeting policy, shocks to total and borrowing reserve demand are offset by adjustments to non-borrowed reserves. Hence, non-borrowed reserves are assumed to respond contemporaneously to total reserves and the federal funds rate. In addition, we assume that the federal funds rate does not respond contemporaneously to non-borrowed reserves. This implies that the Federal Reserve targets the federal funds rate, with respect to prevailing macroeconomic conditions, and adjusts non-borrowed reserves to fully offset shocks total and borrowed reserves demand. We refer to this measure of a monetary policy shock as an EFF policy shock. As a result, estimation is implemented via Cholesky decomposition of the reduced-form residuals with the ordering shown below[15]:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ d_{21} & 1 & 0 & 0 & 0 & 0 \\ d_{31} & d_{32} & 1 & 0 & 0 & 0 \\ d_{41} & d_{42} & d_{43} & 1 & 0 & 0 \\ d_{51} & d_{51} & d_{53} & d_{54} & 1 & 0 \\ d_{61} & d_{62} & d_{63} & d_{64} & d_{65} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_t^{CFNAI} \\ \varepsilon_t^{INF} \\ \varepsilon_t^{NFPI} \\ \varepsilon_t^{EFF} \\ \varepsilon_t^{TR} \\ \varepsilon_t^{NBR} \end{pmatrix} = \begin{pmatrix} v_{1t}^{NP} \\ v_{2t}^{NP} \\ v_{3t}^{NP} \\ v_t^{S} \\ v_t^{D} \\ v_t^{B} \end{pmatrix}$$

Non-borrowed reserves (NBR)

The decision to use non-borrowed reserves as a measure of monetary policy is inspired by the work of Christiano, Eichenbaum and Evans (1996, 1998). In particular, they argue "innovations to non-borrowed reserves primarily reflect

[14] Issues concerning the orthogonalization assumption are returned to in section 4.3.

[15] See Strongin (1995), Christiano, Eichenbaum and Evans (1996), and Bagliano and Favero (1998).

exogenous shocks to monetary policy, while innovations to broader monetary aggregates primarily reflect shocks to money demand" (Christiano, Eichenbaum & Evans, 1996). Hence, under a non-borrowed reserve operating procedure, it is assumed that non-borrowed reserves respond only to policy shocks. We refer to this indicator of a policy shock as an NBR policy shock.

Hence, under a non-borrowed reserves identification of monetary policy shocks, the structural model can be recovered from the reduced-form VAR, via a Cholesky factorization of the reduced-form residuals, with the below causal order[16]:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ d_{21} & 1 & 0 & 0 & 0 & 0 \\ d_{31} & d_{32} & 1 & 0 & 0 & 0 \\ d_{41} & d_{42} & d_{43} & 1 & 0 & 0 \\ d_{51} & d_{51} & d_{53} & d_{54} & 1 & 0 \\ d_{61} & d_{62} & d_{63} & d_{64} & d_{65} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_t^{CFNAI} \\ \varepsilon_t^{INF} \\ \varepsilon_t^{NFPI} \\ \varepsilon_t^{NBR} \\ \varepsilon_t^{EFF} \\ \varepsilon_t^{TR} \end{pmatrix} = \begin{pmatrix} v_{1t}^{NP} \\ v_{2t}^{NP} \\ v_{3t}^{NP} \\ v_t^{S} \\ v_t^{B} \\ v_t^{D} \end{pmatrix}$$

'Orthogonalized' non-borrowed reserves (NBRX)

The choice of using 'orthogonalized' non-borrowed reserves as an indicator of monetary policy is primary due to arguments made by Strongin (1995). Strongin's central assumption is that "innovations in the level of total reserve are largely the result of the Federal Reserves accommodation of innovations in the demand for total reserves" (Strongin, 1995 p.467). In particular, shocks to total reserves are purely demand shocks, which the Fed must accommodate in the short-term. In addition, Strongin posits that the Federal Reserve tends not to respond to borrowing shocks (Bernanke & Mihov, 1998). We refer to this measure of a monetary policy shock as an NBRX policy shock.

Strongin asserts that this specification of the monetary policy can be identified, "simply by having total reserves immediately precede non-borrowed reserves in a standard Cholesky decomposition" (Strongin, 1995). Essentially,

[16] See Christiano, Eichenbaum and Evans (1996).

this structure extracts policy shocks from the Federal Reserve's accommodation of reserve demand shocks by projecting non-borrowed reserves on total reserves. Thus, the structural innovation capturing the monetary policy shock may be identified as the orthogonalized residual in the non-borrowed reserve equation with the below recursive structure[17]:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ d_{21} & 1 & 0 & 0 & 0 & 0 \\ d_{31} & d_{32} & 1 & 0 & 0 & 0 \\ d_{41} & d_{42} & d_{43} & 1 & 0 & 0 \\ d_{51} & d_{51} & d_{53} & d_{54} & 1 & 0 \\ d_{61} & d_{62} & d_{63} & d_{64} & d_{65} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_t^{CFNAI} \\ \varepsilon_t^{INF} \\ \varepsilon_t^{NFPI} \\ \varepsilon_t^{TR} \\ \varepsilon_t^{NBR} \\ \varepsilon_t^{EFF} \end{pmatrix} = \begin{pmatrix} v_{1t}^{NP} \\ v_{2t}^{NP} \\ v_{3t}^{NP} \\ v_t^{D} \\ v_t^{S} \\ v_t^{B} \end{pmatrix}$$

Where K is the number of variables; at least $K(K-1)/2$ restrictions (on the A matrix) are required to satisfy the order condition for identification (Moneta, 2008). Hence, it can be verified that the Cholesky decomposition approach to identification, used by this paper, is a statistically valid solution. Orthogonalization by Cholesky decomposition is mechanically accomplished by defining a lower-triangular $K{\times}K$ matrix P with positive main diagonal such that $PP' = \Sigma_\varepsilon$. Since covariance matrix's are symmetrical around the diagonal, Σ_ε has $K(K+1)/2$ free parameters. Thus, by construction $K(K+1)/2$ is the maximum number of parameters in A that can be uniquely identified. It follows that because P is lower triangular, it has $K(K+1)/2$ free parameters. As a result, P is exactly identified and the order condition is satisfied.

It is important to note the economic interpretation of estimated VAR policy shocks. While the alternative indicators of monetary policy outlined above capture different operating procedures of the Federal Reserve, they do not explain which aspect of central bank behavior that shocks pertain to. Modern monetary policy is complex and contains multiple components. Hoover and Jorda (2001) offer a succinct summary of these components and their interactions as shown in table 2.

[17] See Strongin (1995).

Table 2. Monetary Policy Shocks

		Policy maker	
Public		***Systematic***	***Unsystematic***
	Anticipated	Known policy reaction function	Credible announcement of a transitory, atypical setting of a policy instrument
	Unanticipated	Surprise shift to a new known policy function	Random shock to policy reaction function

Source: Hoover and Jorda (2001). Emphasis added.

Thus, in the context of the VAR framework, the monetary policy shock captures the unanticipated and unsystematic (exogenous) component of monetary policy. As a result, the results derived from VAR studies relate to unanticipated unsystematic monetary policy shocks.

3.4.2 Stability and Stationarity

Unit root tests suggest that most variables included in the model are non-stationary I(1) processes[18]. In contrast, unit root tests on inflation (INF) suggest that it is a stationary I(0) process. However, visual inspection of the autocorrelation function reveals high persistence indicating that it is a long memory process. In addition, using standard cointegration tests there is evidence of at least three cointegrating relationships[19]. These results raise the issue of the appropriate estimation methodology.

This paper follows the majority of the literature which typically estimates VARs in levels, even when the variables are I(1). While the vector error correction model (VECM) approach would improve the efficiency of the estimates, it is avoided for four reasons. Firstly, according to Sims (1980) estimation in levels still provides consistent estimates and avoids discarding relevant information concerning potential long-run relationships between the

[18] Unit root tests are available on request. Not reported for the sake of brevity.
[19] Cointegration tests are available on request. Not reported for the sake of brevity.

variables. Secondly, estimation in VEC form requires the imposition of possibly incorrect restrictions (Hamilton, 1994). Thirdly, in line with Gospodinov et al. (2013), the unrestricted VAR in levels is the most robust specification when there is uncertainty about the magnitude of the roots and the co-movement between the variables. Nevertheless, the possibility of spurious relationships between the integrated variables remains. However, we follow Berkelmans (2005) and ensure against this, as best we can, by confirming that the relationships in the model are plausible on economic grounds[20].

Lastly, the stability of the VAR process is assessed to ascertain the reliability of the impulse response functions. A VAR (p) process is considered stable if its characteristic polynomial has no roots outside the complex unit circle (Lutkepohl, 2004). As no root is found to lie outside the unit circle, the model satisfies the stability condition[21].

3.4.3 Specification

A constant term is included to account for the mean of the series in the VAR[22]. Lag length tests suggest an order of nine, three or two lags[23]. After concurrently considering lag length criterion, autocorrelation tests, stability of the model, the need to maintain reasonable degrees of freedom, and the possibility of a long memory process (inflation; see above), a lag order of four is selected. The LM autocorrelation test was conducted on the reduced-form VAR of four lags, and found evidence of serial autocorrelation[24].

[20] See Chapter 2.

[21] Stability test are available on request. Not reported for the sake of brevity.

[22] See Hamilton (1994)

[23] Akaike's Information Criteria (AIC) suggests nine lags, while Schwarz (or Bayesian) Information Criterion (SC) suggests two lags, and the Hannan-Quin Criterion (HQ) suggests three when estimated with a maximum of ten lags.

[24] Increasing the lag order of the VAR to a magnitude that reduces autocorrelation is not feasible given the number of observations and parameters. Autocorrelation tests are available on request and are not reported for the sake of brevity.

Examination of the residuals from the benchmark model suggests mis-specification[25]. Residuals from all equations repeatedly exceed the ± 2 standard error bands, displaying serious departures from normality and homoscedasticity. Post 2008, these departures increase in both magnitude and frequency. Some large residuals are most likely due to exceptional events, such as the September 11 attacks in 2001 and bankruptcy of Lehman Brothers in September 2008. Nevertheless, the residuals yield substantial evidence of mis-specification, likely due to parameter instability.

Indeed, stability diagnostics detect large structural breaks for all variables at several dates in the sample[26]. In particular, there are large structural breaks for most variables around the last quarter of 2008, as expected. We take two alternative approaches to dealing with these possible regime shifts. Firstly, we include dummy variables to account for outliers in the series. In particular, crisis dummies are included for 2001m09 and 2008m09. Secondly, and more effectively, we estimate a subsample: 1990m02-2007m11. The dates for the sub-sample are based on the evidence for large structural breaks and a possible regime shift in 2008, and the need to maintain system stationarity.

Overall, the results from the specification tests cast serious doubts on the adequacy of the benchmark VAR as a statistical model over the full sample. Nevertheless, we have dealt with these issues as we have seen fit, and have made no attempt to hide them. Rather, we have presented them in full view so that the reader may make up his/her own mind as to the reliability of our results. Moreover, the pre GFC sub-sample displays remarkably better characteristics than the full sample.

[25] Residual plots available on request. Not reported for the sake of brevity.
[26] Structural breaks detected on the basis of the multiple breakpoint test (global information criteria). Stability diagnostics are available on request. Not reported for sake of brevity.

Chapter 4

Results and Discussion

4.1 Full sample (1990m02-2014m07)

We will start by examining the policy shocks that emerge from the benchmark model, in order to determine the most appropriate indicator of monetary policy for the full sample. It is important to note that stimulate structural shocks are of one-standard-deviation magnitude; and that the positive shock to EFF represents contractionary monetary policy, while the positive shocks to NBR and NBRX represent expansionary monetary policy.

Overall, the NBR measure produces impulse responses that are most in accordance with the literature and thus is our preferred measure for the full sample[27]. However, the NBRX also performs remarkable well. The effects of a NBR monetary policy shock on the benchmark variables are reported in figure 2.

Broadly speaking, the impulse responses of the benchmark variables for an EFF policy shock are consistent with the literature on monetary contractions. For instance, the effective funds rate shows a positive unanticipated unsystematic shock of approximately 17 basis points. Furthermore, a sustained decrease is

[27] The dynamic responses to an EFF and NBRX policy shocks are reported in the Appendix in figures A.1, A.2, A.3 and A.4.

observed for commodity price. Moreover, consistent with the assumptions underlying an EFF policy shock, total reserves appear to be insulated from the policy shock. In particular, the total reserves point estimate barely deviates from the baseline. There is also evidence of a liquidity effect, as non-borrowed reserves start above the baseline (suggesting an immediate increase following a interest rate shock). There are, however, two exceptions.

The first exception is inflation. In particular, there is weak 'price puzzle' effect – a consistent rise in prices following a monetary policy contraction. After a statistically insignificant down-up zigzag, the point estimate settles just above the baseline. Although very small, this increase is statistically significant. Thus, the inclusion of commodity prices has failed to completely resolved the price puzzle. This suggests that the monetary policy shock has been insufficiently identified.

The second, and more damning, exception is economic activity. In particular, the impulse response of economic activity is anomalous. Following a monetary contraction, economic activity initially increases before turning negative after roughly eleven months. While an initial delay of economic activity is expected, this lag is particularly large. Furthermore, the magnitude of the initial increase is inconsistent with the literature on the effects of monetary contractions. Although other studies have documented an initial increase in economic activity following a monetary contraction, they are not as large or as prolonged as this (see Leeper, Sims & Zha, 1996). Specifically, the magnitude of this increase corresponds to an increasing likelihood of a period of increasing inflation, a result that is at odds with theory. Consequently, this result seriously undermines the credibility of the EFF identification.

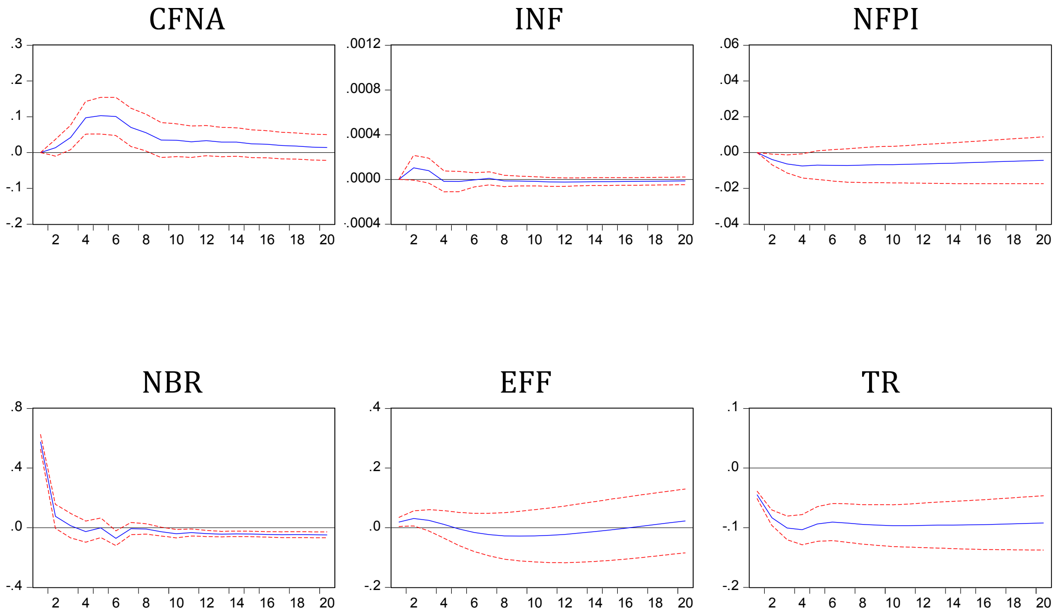
In contrast, both the NBR and NBRX policy shocks produce results that are in accordance with conventional views on the effects of a monetary expansion. However, the NBR policy shock performs marginally better. Specifically, the NBRX response of economic activity is not significantly different from zero, although the point estimate does increase. The only exception to the favorable results of both is commodity price. Specifically, commodity price has a persistently decline following a NBR and a NBRX policy shock. Although not statistically significant, the fall is heavily weighted by the error bands. Further work is required to explain and understand this response pattern.

Overall, the NBR responses for the baseline variables are the most consistent with the literature. Several observations are worth emphasizing. First, economic activity goes up with a brief lag, reaching its full effect around 5 months. Second, inflation has a minor increase that is statistically insignificant. But more importantly, there is no evidence of the price puzzle. Third, there is also little evidence of the liquidity puzzle. The federal funds rate has a persistent, albeit not statistically significant, fall in response to a positive non-borrowed reserve shock (monetary policy expansion). Lastly, the dynamic response of non-borrowed and total reserves is loosely consistent with findings by Christiano, Eichenbaum and Evans (1996) that roughly one-third of a NBR policy shock is contemporaneous transmitted to total reserves. We find that approximately one-fourth is transmitted. These results suggest that the NBR policy shock has been reasonably well specified, and that a monetary expansion has been sufficiently identified.

In summary, the NBR is the best preforming indicator, while the results from the benchmark model do not condone the use of the EFF specification. This is not unsurprising given the specification issues of the time period[28], and the problems associated with a federal funds rate measure of monetary policy post 2008[29]. Consequently, we do not proceed with a detailed discussion of the effects of an EFF or an NBRX policy shock on the financial stability variables. These results are, however, reported in the Appendix, and some comments and comparisons are made concerning them.

[28] See section 3.4.3.
[29] See section 3.4.1.

Figure 2. Effects of an NBR Policy Shock on Benchmark Variables
(Full sample)



Notes: the vertical axis shows deviations from the baseline level prior to the EFF policy shock in percentages, while the horizontal axis shows the number of quarters after the disturbance. The solid blue lines represent point estimates, while the dashed red lines are ± two-standard-errors bands (approximately 95% confidence intervals). Data are measured in log units, except for EFF, TR and NBR, which are measured as annual rates (not per cent).

We now turn our attention to the effects of an NBR shock on the financial stability variables. The dynamic responses are reported in figure 3.

The responses patterns of the financial conditions indices generally do not support the hypothesis that a monetary expansion can contribute to a buildup of financial vulnerabilities. Given the nature of these indices, one would expect a financial instability engendering effect of monetary policy to show up as a 'j-curve' type response dynamic. Specifically, following a monetary expansion financial stress should initially decrease, before trending upwards overtime and becoming positive as financial vulnerabilities buildup because of the previous loose conditions[30]. Such a pattern is weakly exhibited by the NFCI's non-financial leverage sub-index, although the index does not turn positive.

The financial conditions indices tend to demonstrate a decrease in financial stress following a positive NBR policy shock. The exception is the KCFSI, which

[30] In order to capture the intertemporal nature of this response pattern, we have increased the time period of the impulse response figures for the financial conditions indices to 40 months.

displays a small, albeit not statistically significant, increase. Nevertheless, the NFCI and the ANFCI both display a persistent decrease, with no sign of a subsequent increase. Interestingly, the NFCI exhibits a larger decrease than the ANFCI. This suggests that, in the short-term at least, monetary expansions largely strengthen financial stability by improving economic conditions. In particular, by increasing aggregate demand, a monetary expansion increases household earnings and firms' profitability. The sub-indices of the NFCI generally follow the same pattern as their parent.

The impulse responses of the asset market variables provide little evidence that monetary policy can engender financial instability. Broadly speaking, in the asset market, financial vulnerabilities arise from compressed risk premiums and frothy asset price bubbles. However, the impulse responses do not reveal strong evidence of either. In particular, the responses of the term premium, equity risk premium and credit spread are not significantly different from zero. Furthermore, even though an NBR policy shock does have a positive effect on the growth of house and equity prices, the magnitudes are very small. Specifically, the point estimate of equity price growth zigzags over the first six months, and reaches a maximum effect of 0.5%; while the impact of a monetary expansion on house price growth is more persistent, but even smaller.

The dynamic responses of the banking sector do not rule out the possibility that monetary expansions can contribute to financial instability. Firstly, there is no evidence of an effect on delinquency rates, a major source of monetary policies direct effect on financial conditions. This is surprising as the literature often shows delinquency rates substantially decreasing following a monetary expansion. However, this effect arises because debt-servicing costs fall with lower interest rates. Hence, to the extent that we are analyzing the dynamic responses of a non-borrowed reserve policy shock instead of federal funds rate shock, this channel will be weakened. Indeed, delinquency rates exhibit a sustained increase in response to a positive EFF policy shock. Therefore, under an NBR policy shock (which can be loosely affiliated with unconventional monetary policies, such as QE), monetary expansions appear to have less beneficial impact on financial conditions.

Secondly, bank credit growth appears to increase to a new baseline following a NBR policy shock. Although very small, this increase would have substantial accumulative effects. This implies that monetary expansions induce banks to loosen their lending standards, and grant more loans to risky firms.

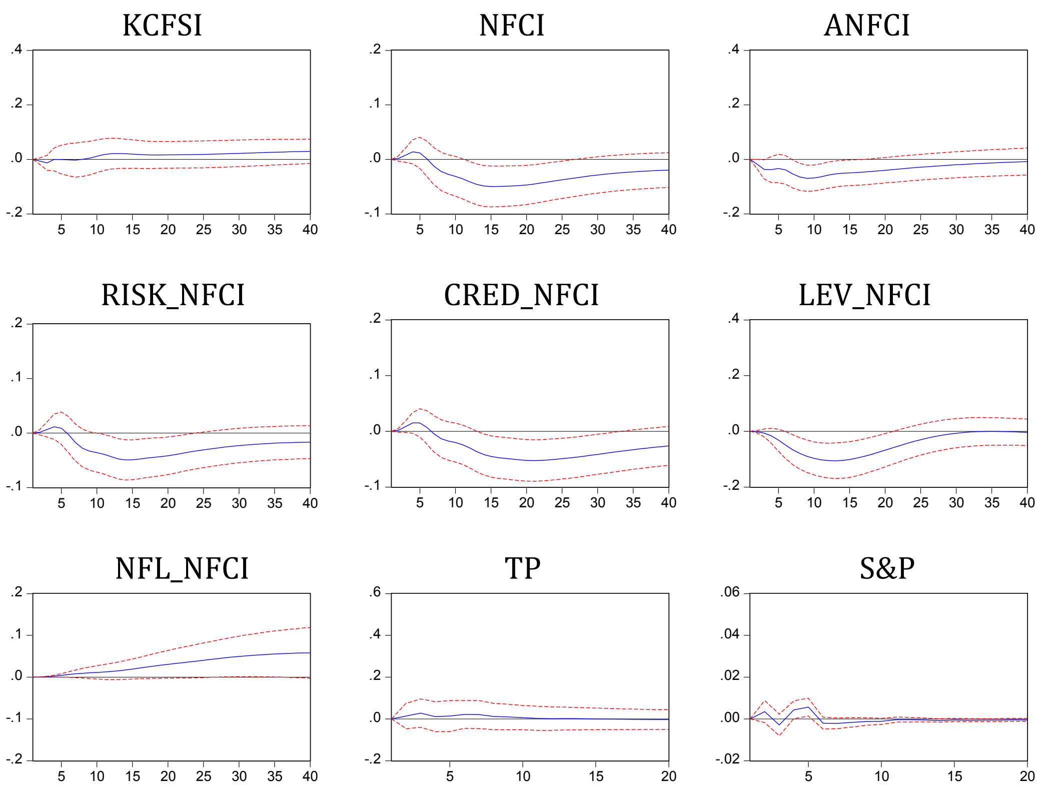
The shadow banking sector displays the most significant evidence of a financial instability channel. Specifically, both net shadow banking liabilities and broker-dealer net leverage increase persistently following an NBR policy shock. The full effect is reached after six months for net shadow-bank liabilities and is approximately 5%. For broker-dealer net leverage, the maximum effect of roughly 7% is reached after 3 months. Hence, expansionary monetary policy tends to increase both the size of the shadow-banking sector, and the fragility of financial intermediaries closely tied to securitization. Given the regulatory arbitrage and the pro-cyclical leverage of the shadow-banking sector, these results suggest a strong possibility for monetary policy to engender financial instability.

The impulse responses of the non-financial sector also document the possibility for monetary policy to create financial vulnerabilities. In particular, private credit growth responds sluggishly but appears to settle to a higher baseline after seven months or so. This increase is statistically significant and would have substantial accumulative effects on financial vulnerabilities. The sluggish response can be explained by the effect of economic activity. Specifically, private credit growth is expressed relative to GDP. Thus, to the extent that monetary expansions also affect GDP, the nominal increase in private credit may be hidden by a corresponding increase in nominal GDP. Indeed, the dynamic response of private credit growth appears to support this hypothesis. For instance, private credit does not statistically deviate from zero around the time that economic activity increases. As economic activity reverts back to trend, however, private credit growth shifts upwards. This explanation is consistent with financial frictions that delay the response of financial institutions to an unexpected unanticipated policy shock. Nevertheless, the impulse response of private credit growth displays a possibility for monetary policy to contribute to financial instability.

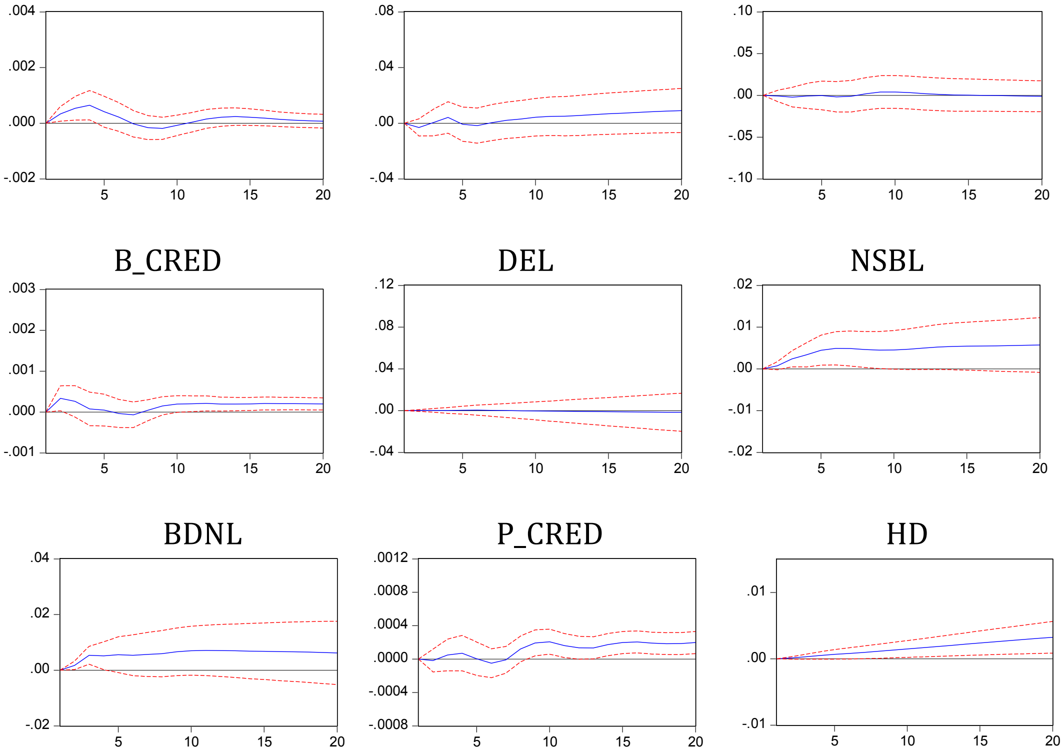
In addition, household debt has a sustained, statistically significant increase. Given the potential for household debt to act as an amplifying mechanism and produce externalities at the aggregate level, this suggests a significant increase in financial vulnerabilities.

In general, the effects of an EFF and NBRX policy shock on the financial stability variables support the above analysis. In particular, the shadow-banking sector appears to be the most susceptible channel to a buildup of financial vulnerabilities for both the alternative indicators.

Figure 3. Effects of an NBR Policy Shock on Financial Stability Variables
(Full sample)



HP ERP CRED_S



Notes: the vertical axis shows deviations from the baseline level prior to the EFF policy shock in percentages, while the horizontal axis shows the number of quarters after the disturbance. The solid blue lines represent point estimates, while the dashed red lines are ± two-standard-errors bands (approximately 95% confidence intervals). Data are measured in log units.

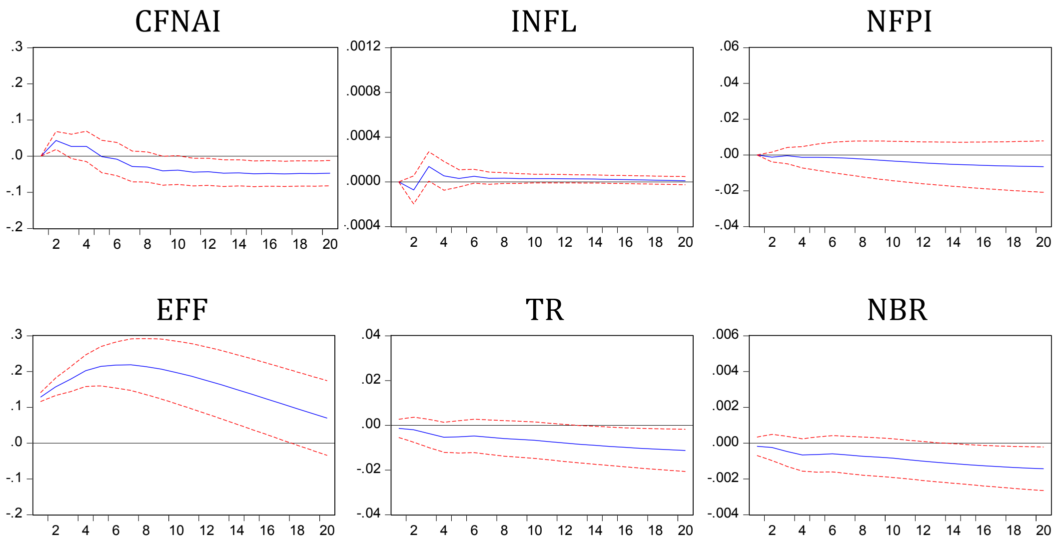
4.2 Sub-sample (1990m02-2007m11)

Contrary to the dynamic responses of the full sample, the EFF policy shock is the superior measure for the sub-sample, in the sense that its benchmark responses are most congruent with conventional views on the effects of a monetary policy contraction. Hence, only the EFF policy shocks are reported here, while the NBR and NBRX responses can be located in the Appendix. Figure 4. displays the impulse responses to an unanticipated unsystematic monetary policy shock of 13 basis points.

Overall, the impulse responses of NBR and NBRX policy shocks perform quite well. Inflation does not display evidence of the price puzzle; commodity price, as opposed to the full sample, has a sustained increase; and, total, non-borrowed and the federal funds rate reserves exhibit the same pattern of behavior as their counterparts in the full sample. The major exception for both, however, is economic activity. In particular, the impulse response of economic activity for both an NBR and NBRX policy shock is anomalous. For NBR the response is not significantly different from zero, but for NBRX it is actually significantly negative. Consequently, both of these dynamic reactions are incongruent with conventional views on the effects of a monetary policy expansion. These anomalous results therefore imply serious problems with the specification of both NBR and NBRX for the sub-sample.

In contrast, the EFF policy shock lacks such a damning exception. While the impulse response of economic activity is sluggish and does initially increase, it lacks both the magnitude and duration of its counterpart in the full sample. In particular, economic activity only has a maximum positive effect of 5% and turns negative after 5 months. The subsequent contraction is also sustained and does not return to trend within the timeframe of the impulse response function. Moreover, there is no evidence of the price puzzle or the liquidity puzzle, and commodity price trends downward, albeit not statistically significantly. These results suggest that an EFF policy shock is an appropriate specification for monetary policy.

Figure 4. Effects of an EFF Policy Shock on Benchmark Variables
(Sub-sample)



Notes: see notes figure 2.

The impulse responses of the financial condition indices tend not to provide evidence that monetary policy can engender financial instability, with one exception. In particular, the characteristic 'j-curve' (an increase followed by a decrease in this instance, because we are dealing with a monetary policy contraction) is absent except for the leverage sub-index. Thus, the evidence suggests that monetary policy may contribute to financial vulnerabilities through a leverage effect. Specifically, an interest rate cut may loosen financial conditions inducing a leverage boom, which triggers a tightening of financial conditions in the future. Such a pattern would have a devastating impact on financial stability, effectively creating an inherent boom-bust process. As a result, while overall the financial conditions indices do not suggest a large role for monetary policy in contributing to financial instability, there is strong evidence of a leverage effect.

Similar to the full sample, the impulse responses of the asset market variables provide little evidence that monetary policy can engender financial instability. In particular, there is little evidence of compressed risk premiums or frothy asset price bubbles. An exception to this is the credit spread, which does suggest a potential for compressed risk premiums. Specifically, the credit spread rises following a monetary contraction, which is symptomatic of lower risk-taking behavior. Consequently, this result suggests that a monetary expansion would have the opposite effect, thereby increasing risk-taking. Overall, however, the evidence for a significant asset channel effect of monetary policy on financial stability is minimal.

The results for the banking sector provide evidence on the costs of using monetary policy to target financial instability. In particular, an EFF policy shock results in a sustained, statistically significant, increase in delinquencies. As outlined above, such an effect arises through higher debt servicing costs. Nevertheless, such an effect is more likely to increase financial instability than decrease it. In addition, the monetary contraction almost has no effect on the growth of bank credit, implying that bank credit growth is relatively inelastic to interest rates. Therefore, large policy shock would be required to rein in excess bank credit growth. Taken together these results highlight the costs of targeting financial stability with monetary policy. Specifically, the benefits from doing so appear smaller than the costs involved. {counterproductive}

Consistent with the full sample, the shadow-banking sector exhibits the greatest potential for a buildup of financial vulnerabilities. In particular, both net shadow-bank liabilities and broker-dealer net leverage decrease following a monetary policy contraction. Although neither of these impulse responses are statistically significant, their error bands are both heavily weighted towards negative. Hence, shadow-banks appear to rein in their activities and take on less risk when faced with a positive federal funds rate shock.

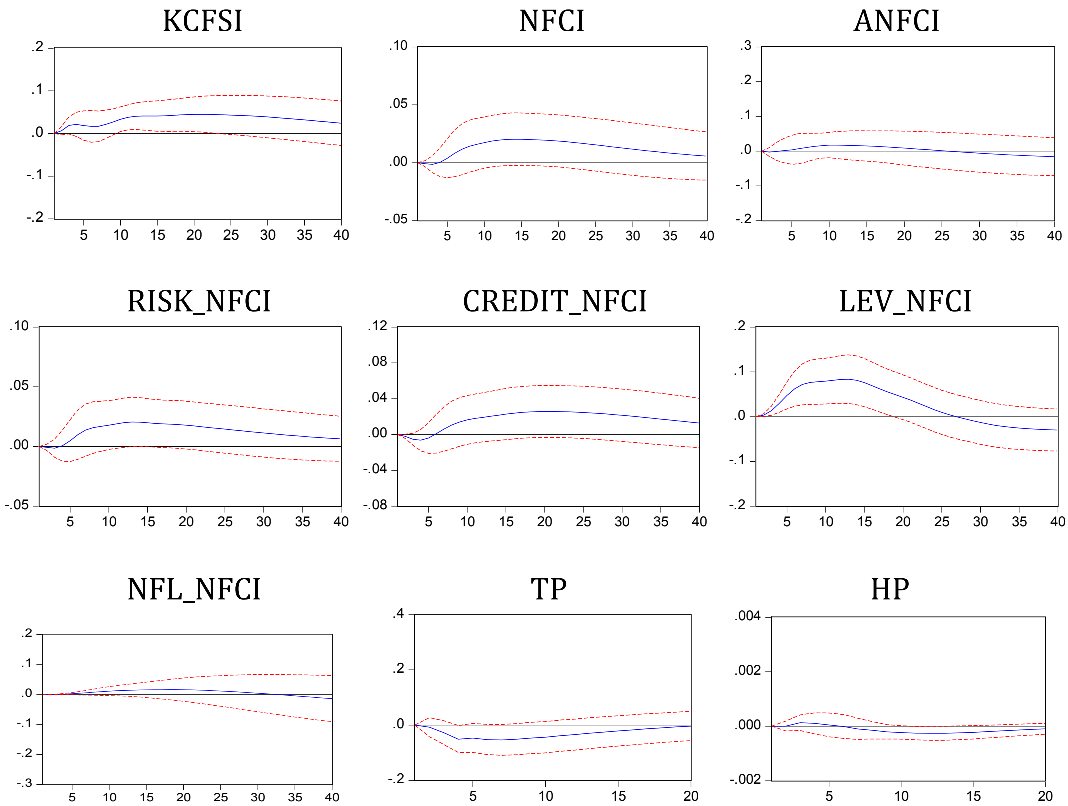
Finally, the non-financial sector also displays little evidence of a significant relationship between monetary policy and financial vulnerabilities. In particular, the impulse response of neither private credit growth nor household debt is not statistically different from zero. While the point estimate for private credit growth does trend upwards slightly, this can be explained by the effect of economic activity as outlined in the full sample. Specifically, as nominal GDP is more sensitive to policy shocks than nominal credit, private credit growth appears to increases following a positive EFF policy shock.

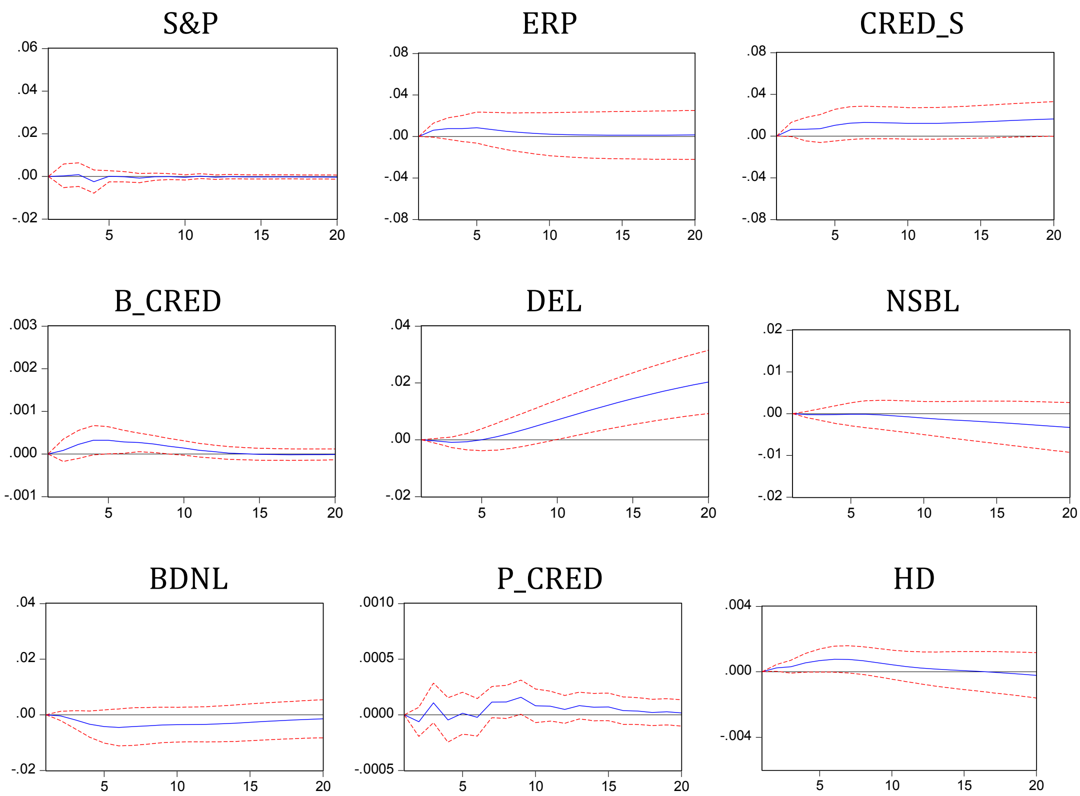
The point estimate of household debt also increases initially. After 6 months, however, it appears to settle into a downward, albeit not statistically significant trend. Financial frictions that restrict household's ability to adjust their balance sheets can explain this delay.

Broadly speaking, the effects of an NBR and NBRX policy shock on the financial stability variables support the above analysis. Yet again, the shadow-banking sector appears to be the most susceptible channel to a buildup of financial vulnerabilities for both the alternative indicators. Compared to the full sample, however, the general effect of monetary policy on financial stability appears smaller in the sub-sample regardless of identification

The differences between the two samples suggest an important caveat: estimates of the effect of monetary policy on financial stability may be biased downwards. In particular, the sub-sample produces a weaker effect of monetary policy on financial stability than the full sample. But given that the sub-sample was estimated over a period of relative stability, this is to be expected. Hence, it makes sense to estimate models of financial instability over periods that include financial crisis. However, this creates a new set of problems, as such tail-events are notoriously difficult to model. Indeed, this paper encountered such issues in the specification pre-tests of the full sample. Consequently, while the sub-sample has better statistical properties, it may underestimate the magnitude of the relationship between monetary policy and financial stability.

Figure 5. Effects of an EFF Policy Shock on Financial Stability Variables (Sub-sample)





Notes: see notes figure 3.

4.3 Criticisms

The methodology employed by this paper is subject to many criticisms. Not least among them, are criticisms lodged against the VAR methodology itself. In particular, three main challenges have been leveled against the VAR approach. First, critics have questioned the role of shocks. Specifically, they have queried whether estimated monetary policy shocks actually measure a relevant aspect of central bank behavior, and if so, what is the economic interpretation of these shocks. Second, there is concern regarding the use of informal restrictions. Skeptics worry that this widespread practice may engender undisciplined data mining. Lastly, the orthogonalization assumption generates major concern.

The VAR approach to analyzing the monetary transmission mechanism is often criticized on the basis that the monetary policy shocks do not have an economically meaningful interpretation. Critics argue that the VAR approach suggests that central banks operate as 'random number generators' (See the discussion in Bernanke and Mihov (1996)); raising the question of how estimated VAR policy shocks pertain to actual central bank behavior. As outlined in section (3.4.1), monetary policy shocks only measure the unanticipated and unsystematic (exogenous) component of monetary policy. Bernanke and Mihov (1996) argue, however, that economic interpretation of these shock can be "generated from two realistic sources: (a) imperfect information on the part of the central bank about the current economy, and (b) changes in the relative weights put by the central bank on moderating fluctuations in output and inflation" (Bernanke & Mihov, 1996 p.34).

The first source of monetary policy shocks refers to measurement errors that result from lags in the collection of data and frequent data revisions. As there is a lag between when the central bank makes decisions and the release of final data that reveals the true state of the economy, central banks often act on the basis of imperfect information. Consequently, deviations may arise between the policy rule, representing final data and the true state of the economy, and the decision of the central bank, which is potentially based on misperceptions of the true state of the economy. Such deviations can be interpreted as monetary policy shocks in the context of a VAR model.

The second source of shocks refers to the decision making process of the central bank itself. As this process is essentially a political process, it is subject to shifts in power and influence between members of the committee. Furthermore, members of the committee are likely to have different perspectives concerning the optimal stance of monetary policy, and different preferences regarding the relative weights to be put on output and inflation. As a result, central bank decisions may follow a random process as power ebbs and flows within the committee. "In this case the random part of the reaction function corresponds to the random fluctuations in central bank preferences" (Gottschalk, 2001), which can be interpreted as monetary policy shocks within the framework of a VAR model.

The second main challenge to the VAR approach concerns the use of informal restrictions. Critics posit that the use of informal restrictions ensure that VAR models unavoidable reflect, at least to some degree, the a priori views of the researcher. For instance, certain dynamics are widely held to result from a contractionary monetary policy shock: short-term interest rates rise, aggregate output and employment fall. Consequently, having imposed identifying restrictions, modelers often check whether the impulse response functions are congruent with their preconceived expectations. If they are not, researchers will often alter the restrictions of their model in order to generate more plausible responses. Thus, critics assert that the VAR methodology is susceptible to undisciplined data mining.

This paper is exceptionally vulnerable to this challenge, as we adopt informal restrictions to determine the preferred indicator of monetary policy for both samples. However, Leeper, Sims and Zha (1996) rebut this challenge by arguing that the use of informal restrictions in economics is consistent with other empirical fields, and that the process is, in fact, scientifically sound.

> "Economists adjust their models until they both fit the data and give 'reasonable' results. There is nothing unscientific or dishonest about this. It would be unscientific and dishonest to hide results for models that fit much better than the one presented (even if the hidden model seems unreasonable), or for models that fit about as well as the one reported and support other interpretations of the data that some readers might regard as reasonable" (Leeper, Sims & Zha, 1996 p.5)

Furthermore, the process of choosing between competing identifying restrictions on the basis of their different results is in the spirit of the Lucas program. Lucas (1980) argues that economists:

> "[N]eed to test them [models] as useful imitations of reality by subjecting them to shocks for which we are fairly certain how actual economies or parts of economies would react. The more dimensions on which the

model mimics the answers actual economies give to simple questions, the more we trust its answers to harder questions" (Lucas, 1980; as cited by Christiano, Eichenbaum & Evans, 1998 p.3))

Therefore, researches should be careful if a set of restrictions produce impulse response functions that are anomalous with the wider literature. This is not to say that such results ought to be dismissed automatically. Black swan results are possible and appeals to the majority can be misleading. Rather, extra care is required to ascertain the validity of results that are incongruent.

Nevertheless, the criticism concerning informal restrictions is valid to the extent that such restrictions are not made explicit. This paper, however, presents these restrictions in full view. Furthermore, we use them to guide the methodology, rather than to make the results more appealing.

The last major challenge to the VAR approach concerns the orthogonalization assumption. Generally, orthogonalization is criticized because it imposes an arbitrary recursive order on the system. Effectively, "Cholesky decomposition imposes a Wold causal order on the variables so that the shock y_1 feeds contemporaneously into $y_2, y_3, \dots, y_n$, while the shock to y_2 feeds contemporaneously into $y_3, y_4, \dots, y_n$, but into y_1 only with a lag, and so on" (Demiralp & Hoover, 2003 p.746). The issue is that while different orderings are statistically valid and observationally equivalent, they are not economically equivalent. Thus, the central problem for identification by Cholesky decomposition involves choosing and justifying the recursive ordering of the structural model.

This paper addresses this issue in a number of ways. First, we employ a semi-structural (partially identified) approach that is common in studies of monetary policy shocks. Specifically, only the policy instrument is identified, as it is the only structural shock of interest in our model. No attempt is made to identify the other variables. Thus, we are satisfied if we can successfully identify and interpret the monetary policy shock within the model. Consequently, this paper goes to great lengths to accurately identify the policy shock: alternative measure of monetary policy are used, all of which have a large presence in the literature and are theoretically justified; and, the impulse responses from a set of benchmark variables are compared with the conventional views of policy shocks in order to determine best performing specification.

Secondly, we argue that the orthogonalization assumption is preferable to the alternative in our particular area; that is, financial stability. In particular, a non-recursive identification would require a broader set of economic relations to be imposed. However, within the field of financial stability, a consensus has yet to emerge concerning the interrelationships between the elements of financial stability themselves or the wider economy. Thus, any non-recursive identification will have to be based on multiple highly contentious a priori assumptions. In contrast, this papers recursive approach allows us to achieve identification with a relatively simple assumption. Namely, that policy variables react contemporaneous to non-policy variables, while the converse does not hold. While this assumption is by no means full proof[31], its transparency and simplicity are advantages.

4.4 Limitations and Further Research

Various limitations apply to our methodology. In particular, the VAR model is linear and, as a result, does not allow for asymmetrical effects of monetary policy shocks. At its most basic level, this limitation supposes that monetary expansions and contractions have mirror opposite effects. Given the existence of a lower bound on the interest rates, this assumption seems highly dubious. Furthermore, evidence suggests that financial stability is state contingent. Hence, the behavior of leading indicators and financial stability proxies are highly likely to display nonlinearities. Therefore, extending the VAR study of financial stability to a nonlinear framework, such as the work by Karame and Olmedo (2002), is an avenue for further research that offers rich rewards.

[31] See section 3.4.1.

Another major limitation of this paper is its inability to estimate the financial stability variables in one model. As was stated in section 3.2, ideally, given the interconnected nature of the financial system, we would prefer to include all of the variables in our analysis in one large unrestricted VAR and report the resulting system of impulse response functions. However, this strategy is not feasible as the amount of variables would invite overfitting and undermine the credibility of the VAR estimates. As a result, we abstract from interconnections between financial variables. One possible solution to this problem is a factor-augmented approach. In particular, employing a factor-augmented VAR (FAVAR) methodology, such as Bernanke, Boivin and Eliasz (2003), would allow the analysis of a large data set. However, such an approach requires a broad set of restrictions to be imposed on the variables in order to achieve identification. And at present, the theoretical literature is not unanimous enough to provide such a set[32].

An exciting avenue for further research is the combination of the two limitations outlined above. Specifically, extending the FAVAR methodology to a nonlinear framework would allow an unparalleled analysis of the effects of monetary policy on financial stability. Unfortunately, such a study is beyond the scope of this paper.

[32] One possibility is Graphical Modeling (GM).

Chapter 5

Conclusion

The main purpose of this paper was to characterize the effects of monetary policy on financial stability. Of particular interest were the financial stability transmission channels of monetary policy. Three alternative indicators of monetary policy were estimated across two overlapping samples – the full sample and a pre GFC subsample. Twelve financial stability variables, disaggregated into four sectors or transmission channels, were analyzed, along with seven financial conditions indices.

The main conclusion is that the net effect of monetary policy on financial stability is rather small. Weak evidence is found for the hypothesis that monetary expansions contribute to financial vulnerabilities; or conversely, that monetary contractions reduce vulnerabilities. However, evidence was unearthed that suggested monetary contractions deteriorate financial conditions as well. In addition, the effects of monetary policy on financial stability were found to be heterogeneous across transmission channels. In particular, little evidence was found for a financial instability channel in asset markets, while the shadow banking sector displayed the most significant evidence. These findings proved generally robust across indicators of monetary policy and subsamples.

As a result, this paper offers two contributions to the literature. Firstly, while we abstracted from interconnections between financial variables, by investigating a broad set of financial variables in a unified framework, this paper provides a relatively whole picture of the net effect of monetary policy on financial stability. As such, this thesis represents a tentative first step at quantifying the net effect of monetary policy on financial stability.

Secondly, by building upon a disaggregation made in the literature, individual financial stability transmission channels of monetary policy were analyzed. As suspected, the effects of monetary policy were found to not to be uniform across transmission channels. Thus, this paper contributes to building our knowledge on the ways and means through which monetary policy affects financial stability.

Both of these contributions have practical policy dimensions. With respect to the 'lean versus clean' debate, the results generally suggest that monetary policy should not be altered to take into account financial stability objectives. Given the rather small, asymmetrical effect of monetary policy, risks to financial stability are better addressed by macroprudential policy.

Appendix

Data sources:

Variable: Chicago Fed National Activity Index
Units: Index
Source: Federal Reserve Bank of Chicago
Data conversion: At source
Notes: Three-month moving average, zero mean.

Variable: Inflation
Units: Percent
Source: Federal Reserve Bank of St. Louis
Data conversion: First difference
Notes: Authors calculations using Consumer Price Index for All Urban Consumers: All Items Less Food & Energy (CPILFESL); seasonally adjusted

Variable: Commodity price index
Units: Percent
Source: IMF
Notes: Non-fuel price index, 2005=100 (PNFUEL); seasonally adjusted

Variable: Effective federal funds rate
Units: Percent
Source: Federal Reserve Bank of St. Louis
Notes: Not seasonally adjusted

Variable: Non-Borrowed Reserves
Units: trillions of dollars
Source: Federal Reserve Bank of St. Louis
Data conversion: Scaled (min=1)
Notes: Adjusted for reserve requirements; not seasonally adjusted

Variable: Total Reserves
Units: Trillions of dollars
Source: Federal Reserve Bank of St. Louis
Notes: Adjusted for reserve requirements; not seasonally adjusted

Variable: Term premium
Units: Percent
Source: Federal Reserve Bank of New York
Data conversion: Raw data is monthly, converted to quarterly using EOP values
Notes: Based on the Adrian, Crump and Moench (2013) term structure model and calculated by the NY Fed

Variable: S&P 500
Units: Last price
Source: Bloomberg
Notes: Growth rate used in models (log first difference)

Variable: S&P/Case-Shiller U.S. National Home Price Index
Units: Index
Source: McGraw Hill Financial

Variable: Equity risk premium
Units: Percent
Source: Courtesy of Robert Shiller from his book, Irrational Exuberance http://www.multpl.com/shiller-pe/table?f=m; Federal Reserve Bank of St. Louis
Notes: ERP=1/(Shiller PE Ratio – 10 year treasury yield)

Variable: Credit spread
Units: Percent
Source: Federal Reserve Bank of St. Louis
Notes: Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant

Variable: Delinquency rate
Units: Percent
Source: Federal Financial Institutions Examination Council (FFIEC) Consolidated Reports of Condition and Income (1985-2000: FFIEC 031 through 034; 2001-: FFIEC 031 & 041)
Notes: Includes real estate loans, consumer loans, leases, C&I loans and agriculture loans

Variable: Net shadow bank liabilities
Units: Trillions of dollars
Source: Flow of funds (Z.1 Release)
Data conversion: Raw data is monthly, converted to quarterly using linear transformation
Notes: Based on Pozsar et al. (2012) definition of net shadow banking liabilities. Net shadow banking = shadow liabilities – money market funding:

Variable: Broker-dealer net leverage
Units: Ratio
Source: Flow of funds (Z.1 Release)
Data conversion: Raw data is monthly, converted to quarterly using linear transformation

Notes: Security brokers and dealers, ratio of total financial assets to equity capital

Variable: Private credit
Units: Billions of dollars
Source: Federal Reserve Bank of St. Louis
Notes: Not seasonally adjusted (CRDQUSAPABIS)

Variable: Household debt
Units: Billions of dollars
Source: Flow of funds (Z.1 Release)
Data conversion: Raw data is monthly, converted to quarterly using linear transformation
Notes: Sum of household mortgages and consumer credit

Variable: Kansas City Financial Stress Index
Units: Index
Source: Federal Reserve Bank of St. Louis
Notes: Not seasonally adjusted; zero mean

Variable: National Financial Conditions Indices
Units: Index
Source: Federal Reserve Bank of Chicago
Notes: Three-month moving averages, authors calculations

Table A.1 – Financial Conditions and Vulnerabilities

	Financial conditions	**Financial vulnerabilities**
(1) Asset markets	Risk free term structure Higher asset prices Lower risk premiums	Compressed risk premiums • Reach for yield because of nominal targets • Supported by leverage from an external finance premium, asymmetric information • Asset managers that prefer yield income or are evaluated based on relative performance Low volatility and low risk premiums • Procyclical risk management practices • Mismeasurement of risk
(2) Banking sector	Credit channel	Procyclical leverage of banks and dealers • Procyclical risk management practices and inflated collateral values Risk-shifting channel reduces the quality of credit • Low bank capital
(3) Shadow banking	Securitization	Procyclical dealer intermediated

	Liquidity creation Maturity transformation by nonbank intermediaries	leverage • Procyclical risk management practices and inflated collateral value Excessive maturity transformation • Short-term funding fragilities Regulatory arbitrage
(4) Nonfinancial sector	Borrowing conditions Balance sheet channel Cred growth (credit/GDP)	Deterioration in underwriting standards Excess leverage • Fire sale externalities • Negative demand externalities

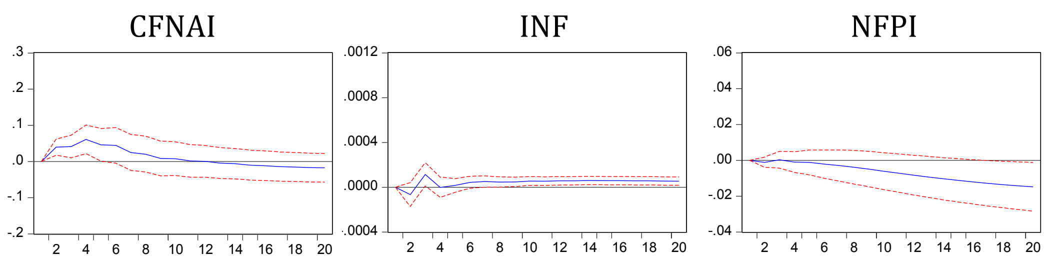
Source: Adrain and Liang (2014)

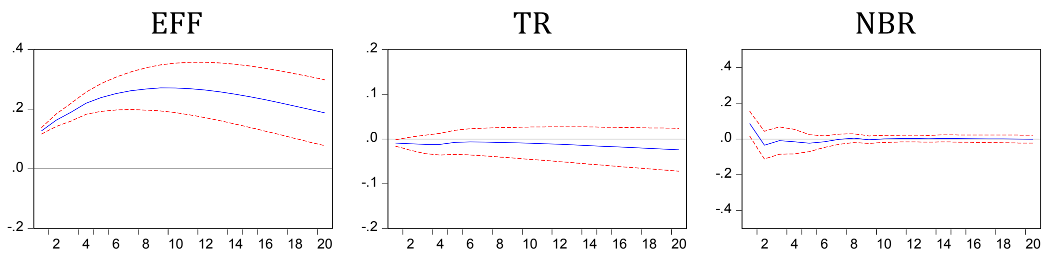
Table A.2 – Interpreting the Chicago Fed National Activity Index three-month moving average (CFNAI-MA3)

If CFNAI-MA3<-0.7 following a period of economic expansion	Increasing likelihood that a recession has begun
If CFNAI-MA3>-0.7 following a period of economic contraction	Increasing likelihood that a recession has ended
If CFNAI-MA3>+0.2 following a period of economic contraction	Significant likelihood that a recession has ended
If CFNAI-MA3>+0.7 more than two years into an economic expansion	Increasing likelihood that a period of sustained increasing inflation has begun
If CFNAI-MA3>+1.0 more than two years into an economic expansion	Substantial likelihood that a period of sustained increasing inflation has begun

Source: Federal Reserve Bank of Chicago https://www.chicagofed.org/publications/cfnai/index

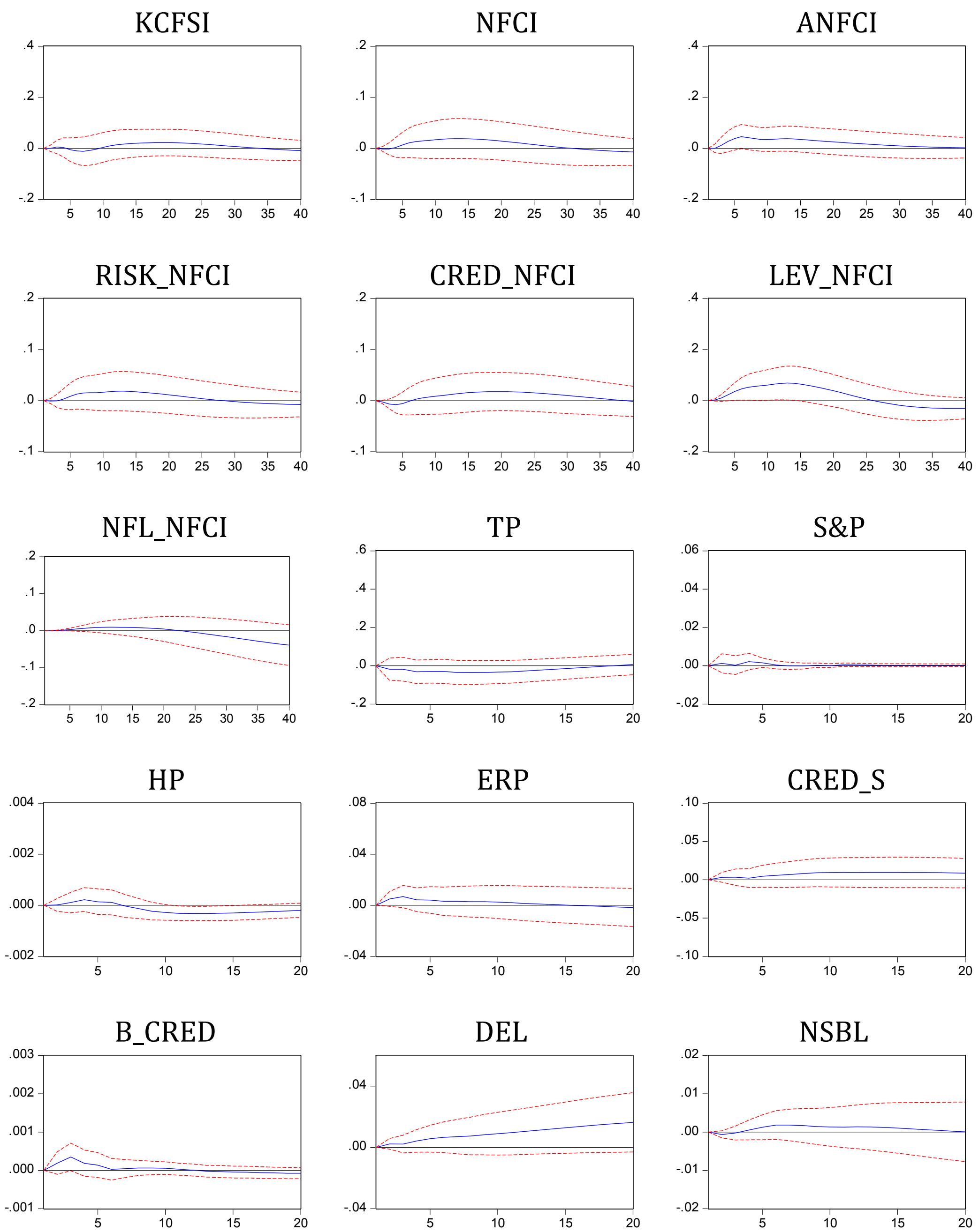
Figure A.1 – Effects of an EFF Policy Shock on Benchmark Variables (Full sample)

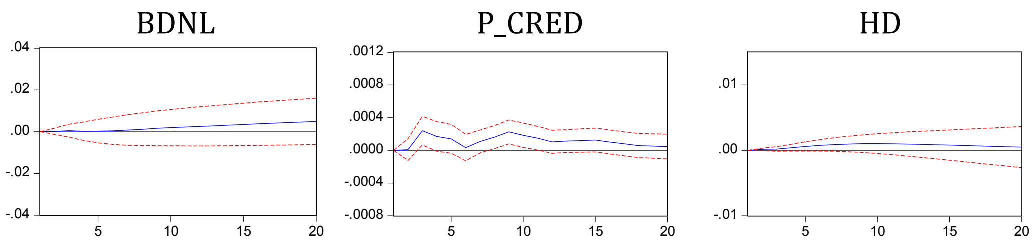




Notes: see notes figure 2.

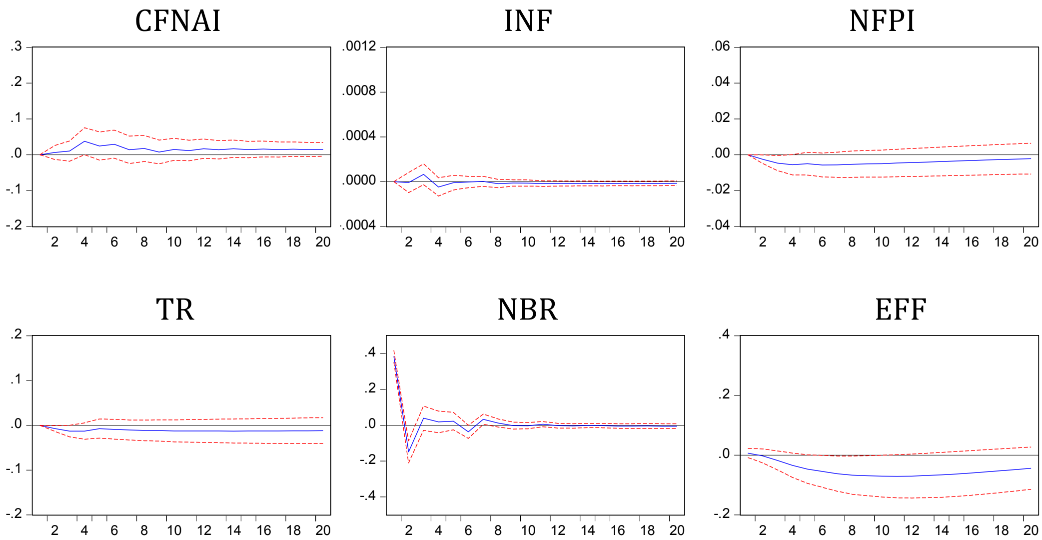
Figure A.2 – Effects of an EFF Policy Shock on Financial Stability Variables (Full sample)





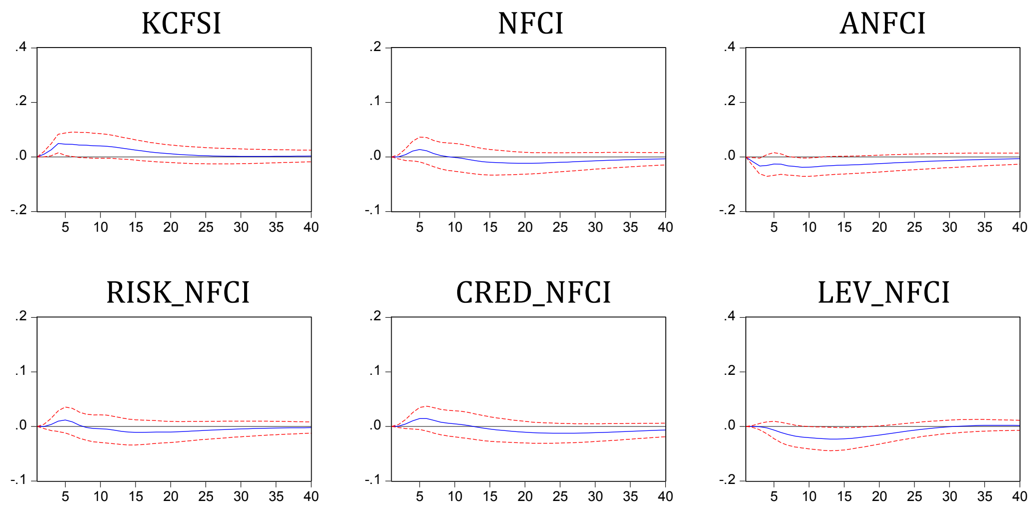
Notes: see notes figure 3.

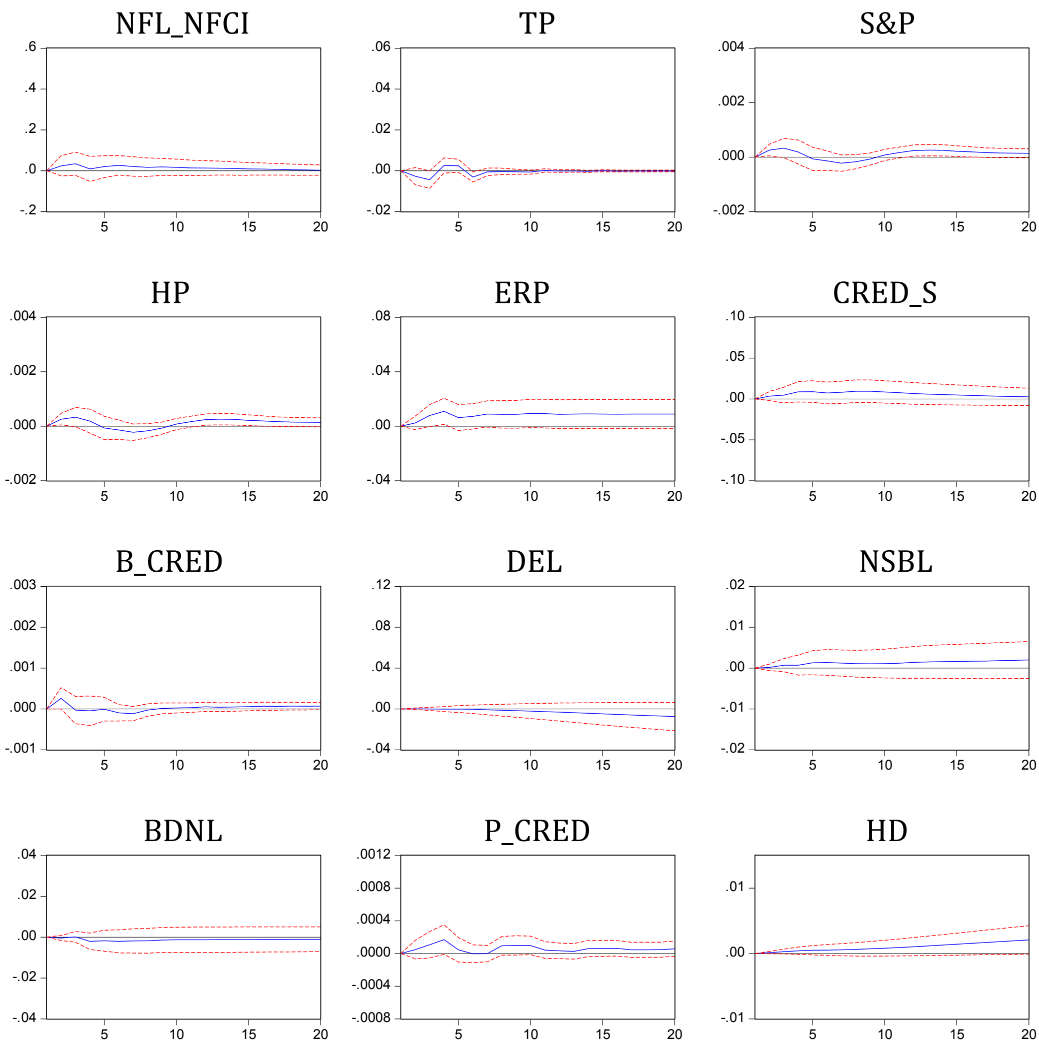
Figure A.3 – Effects of an NBRX Policy Shock on Benchmark Variables (Full sample)



Notes: see notes figure 2.

Figure A.4 – Effects of an NBRX Policy Shock on Financial Stability Variables (Full sample)





Notes: see notes figure 2.

Figure A.5 – Effects of an NBR Policy Shock on Benchmark Variables (Sub-sample)

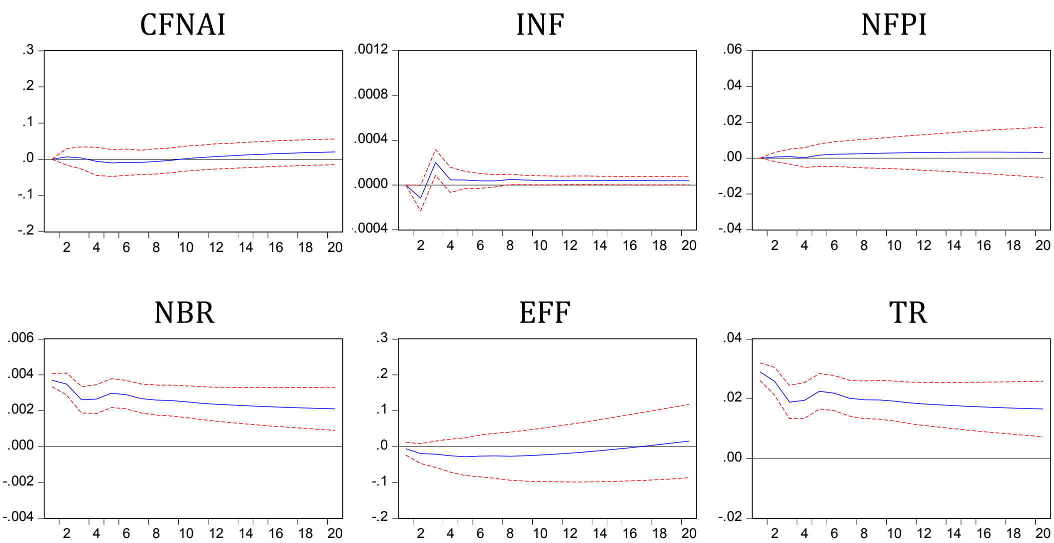
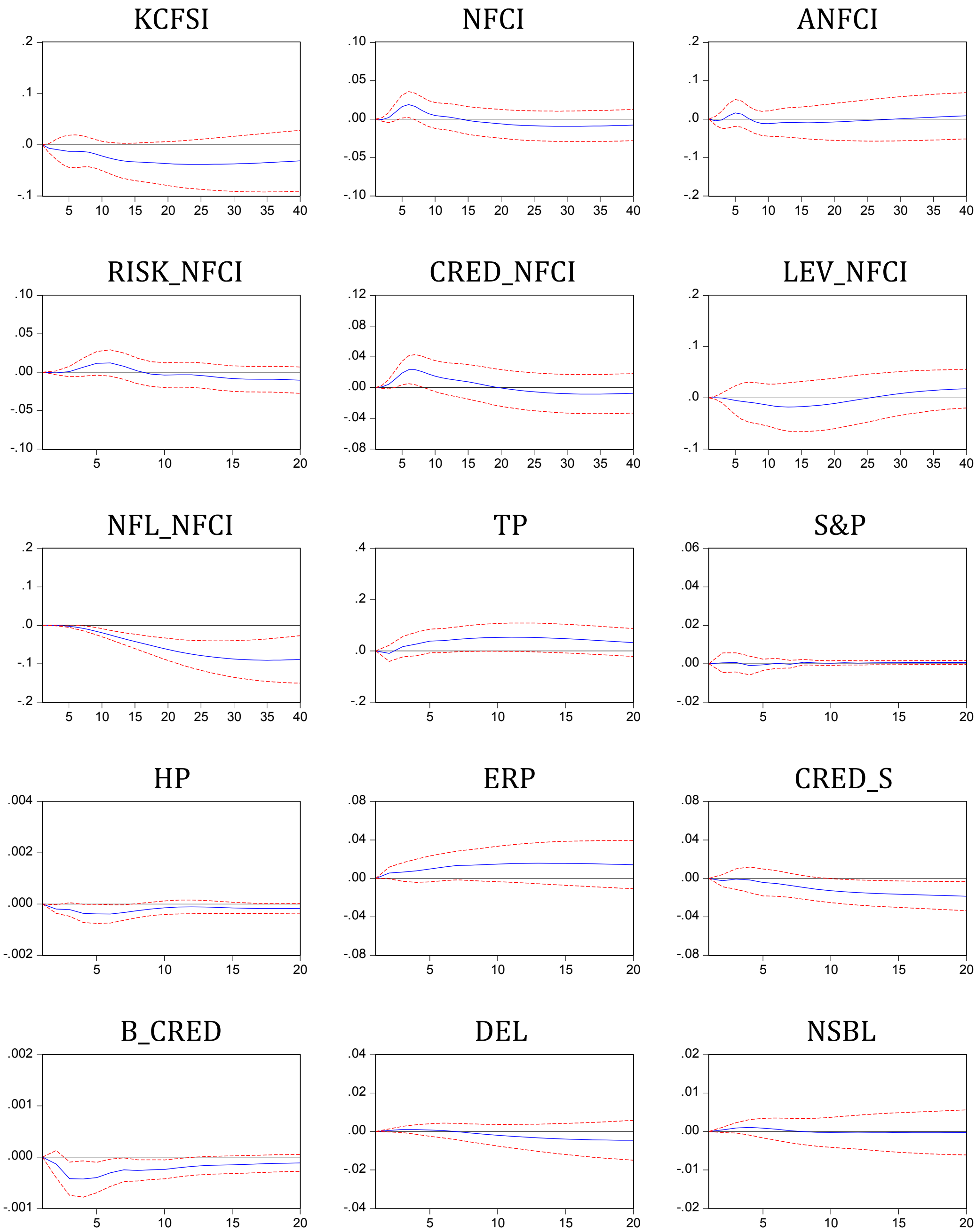
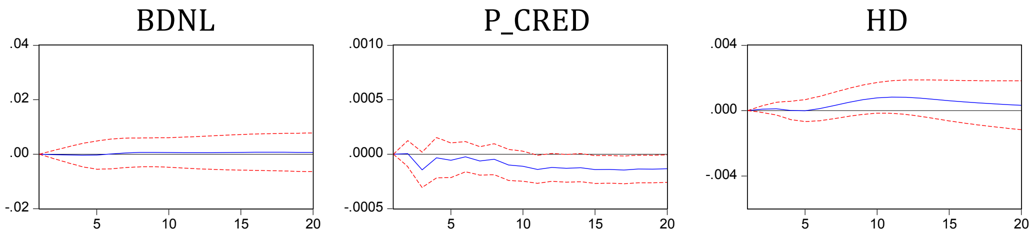


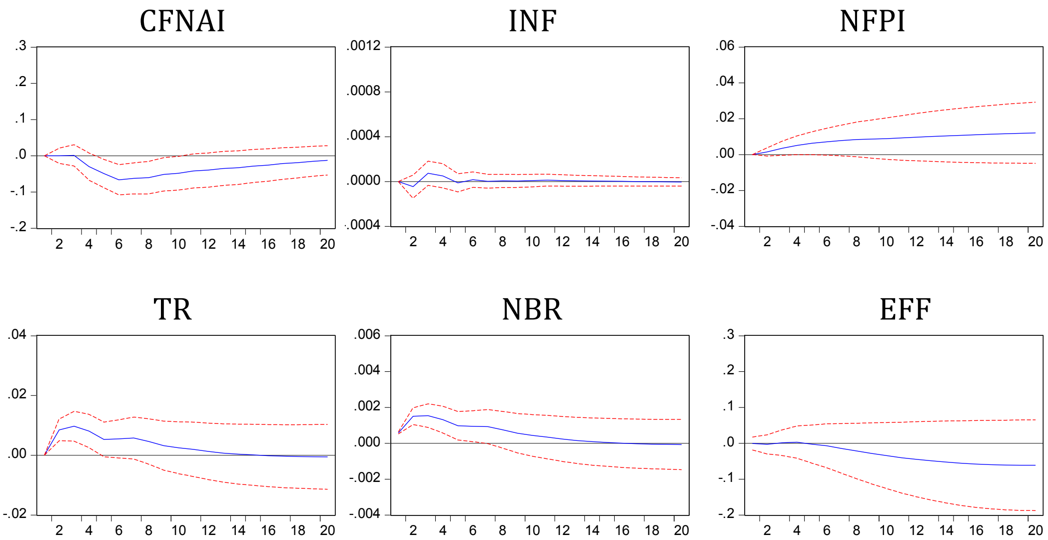
Figure A.6 – Effects of an NBR Policy Shock on Financial Stability Variables (Sub-sample)





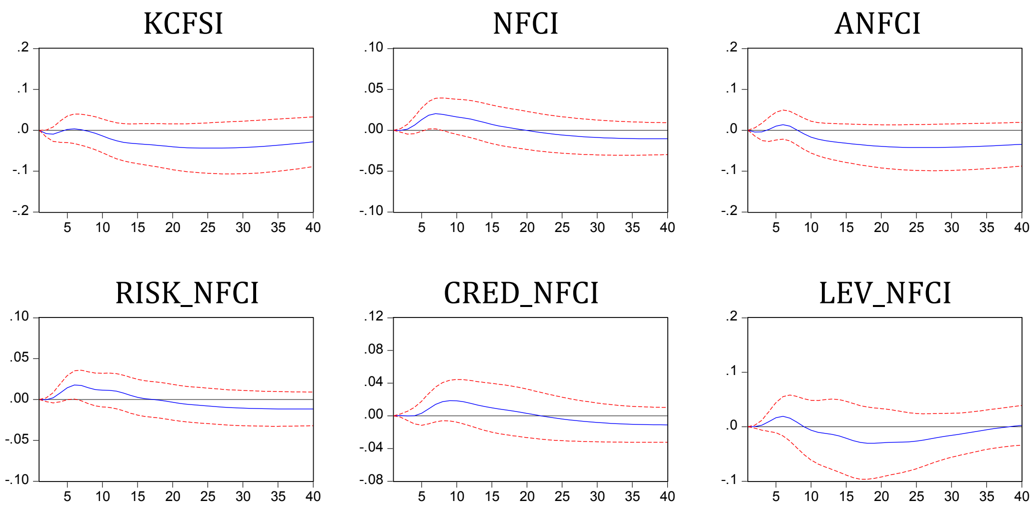
Notes: see notes figure 3.

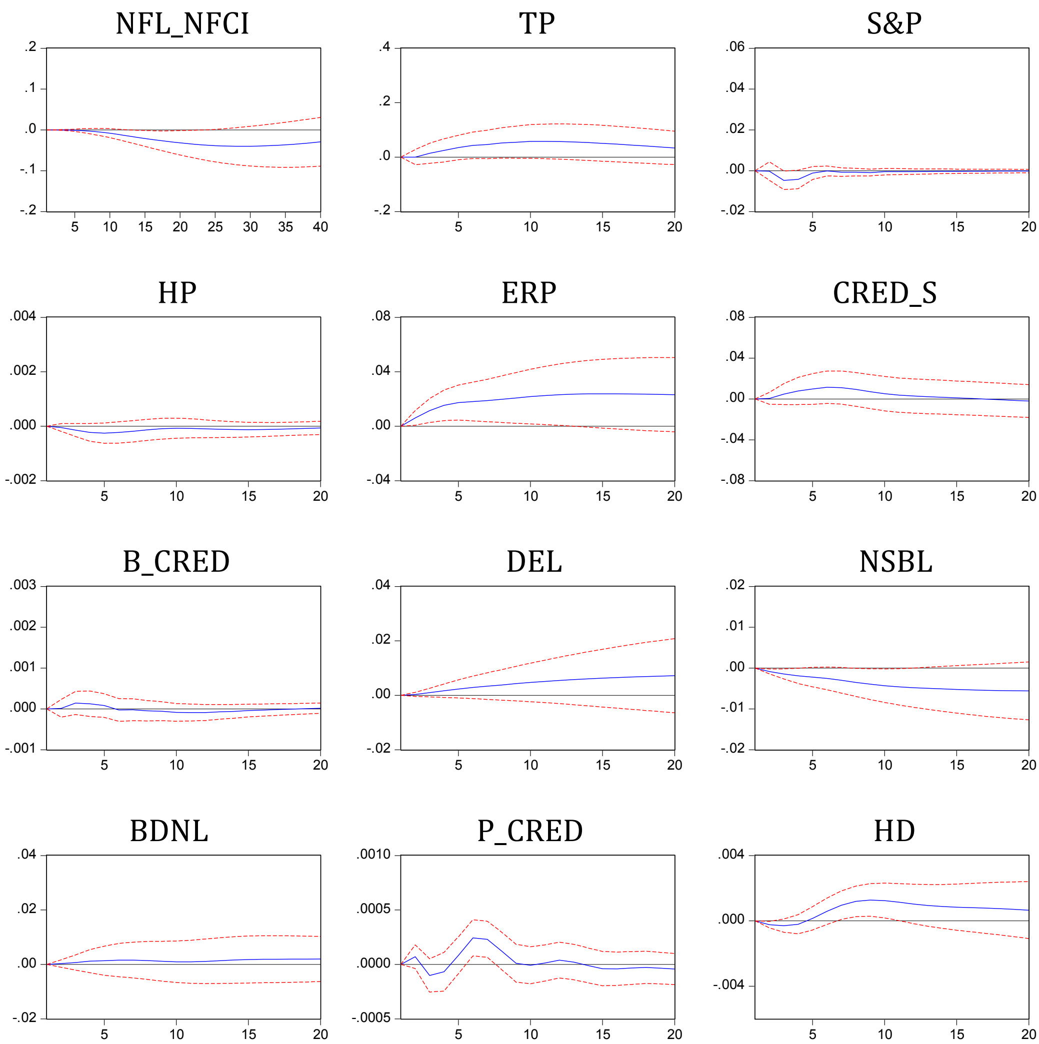
Figure A.7 – Effects of an NBRX Policy Shock on Benchmark Variables (Sub-sample)



Notes: see notes figure 2.

Figure A.8 – Effects of an NBRX Policy Shock on Financial Stability Variables (Sub-sample)





Notes: see notes figure 3.

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