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THE INTERACTION BETWEEN PRICE STABILITY AND FINANCIAL STABILITY:

CONSEQUENCES FOR THE CENTRAL BANK

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ABSTRACT

As a response to the financial crisis, central banks have been granted an increasingly important role in the maintenance of financial stability. This thesis investigates how the central bank's initial objective of price stability interacts with the objective of financial stability. Subsequently, this research analyses the potential consequences of this interaction for the role the central bank, and monetary policy, should play in maintaining financial stability.

Keywords: Price Stability, Monetary Policy, Financial Stability, Macroprudential Policy, Central Bank, Financial Crisis.

TABLE OF CONTENT

ABSTRACT i
TABLE OF CONTENT ii
LIST OF ABBREVIATIONS iv
1. Introduction 5
2. Monetary and macroprudential policy 7
2.1 Monetary and macroprudential policy objectives 8
2.2 Monetary and macroprudential policy instruments 8
3. The interaction between monetary and macroprudential policy 12
3.1 The theoretical relationship between price stability and financial stability 12
3.2 Empirical analysis of the relationship between price stability and financial stability 15
3.2.1 Data description 15
3.2.2 Variables selection 16
3.2.3 Descriptive statistics 18
3.3 Methodology 20
3.3.1 The VAR model 20
3.3.2 Number of lags 21
3.3.3 Stationarity 21
3.3.4 Cointegration 22
3.4 Empirical results 23
3.4.1 Correlation between price stability, financial stability and GDP 23
3.4.2 VAR Model: Lag length selection 23
3.4.3 VAR Model: Stationarity 24
3.4.4 VAR Model: Cointegration 26
3.4.5 Vector Error Correction Model 27
4. The role of the Central Bank in maintaining financial stability 30
4.1 Three perspectives on the combination of monetary and macroprudential policy 31
4.1.1 The separated perspective 31
4.1.2 The extended perspective 31
4.1.3 Integrated perspective 32
4.2 Research on the effectiveness and institutional set-up of monetary and macroprudential policy 33
4.3 Time Inconsistency Model 36

4.3.1 Setting 1: Social planner under commitment 39
4.3.2 Setting 2: Social planner with discretion 40
4.3.3 Setting 3: Two authorities with discretion, separate mandates 42
5. Discussion 44
6. Conclusion 45
Bibliography 47
Appendix 53
1. VAR analysis 53
1.1 Graphical visualisation variables 53
1.2 Phillips-Perron stationarity test 54
1.3 Vector Error Correction model estimations 55
1.4 Robustness test 58
1.4.1 VAR estimates in levels 59
1.4.2 Impulse response functions in levels 61
2. Dynamic Inconsistency Model 63
2.1 Setting 1 63
2.2 Setting 2 64
2.3 Setting 3 67

LIST OF ABBREVIATIONS

ADF-test	Augmented Dickey Fuller Test
BoE	Bank of England
EBU	European Banking Union
ECB	European Central Bank
ESRB	European Systemic Risk Board
EU	European Union
Fed	Federal Reserve System United States of America
IMF	International Monetary Fund
LCR	Liquidity Coverage Ratio
SSM	Single Supervisory Mechanism
TFEU	Treaty on the Functioning of the European Union
UK	United Kingdom
VAR model	Vector Autoregressive model
VEC model	Vector Error Correction model

1. Introduction

The recent financial crisis and its enduring aftermath has demonstrated the importance of financial stability in maintaining economic prosperity and macroeconomic stability. The crisis led to a revaluation of the possibilities policymakers needed to prevent for such periods of major economic unrest.

The financial crisis showed that monetary policy alone was ineffective to keep the financial system safe and sound. This insight resulted in a search for new policy instruments that could better monitor and ensure financial stability. Together with the development of financial stability policy, the question rose how the institutional framework covering these responsibilities should be designed, especially in light of the potential interaction between monetary policy and macroprudential policy. Although in the ideal situation monetary policy should primarily be focused on price stability while macroprudential policy handles threats to financial stability, it is inevitable that both policy fields affect each other's outcome (IMF, 2013). Financial stability, and the accompanying financial regulations, and monetary policy and the resulting monetary conditions can be interlinked and interdependent in various ways. So not only the question which tools and frameworks were necessary to insure financial stability became highly debated, also the conjunction of financial stability tools with monetary policy and *vice versa* has been subject to fierce debate among academics and policymakers.

These questions are especially important for the role of the central bank. For long, price stability was seen by many as the main and sufficient solution a central bank could offer to maintain financial stability (Criste and Lupu, 2013). At the beginning of this century most central banks in advanced economies focussed on inflation targeting based on this view. Price stability was in turn deemed to foster macroeconomic stability (Committee on International Economic Policy and Reform, 2011). In this light, it is interesting to see that before the crisis, most central banks had not even adopted an official definition of financial stability nor defined their responsibilities in this field in legal terms. Most central banks referred to these responsibilities in merely general terms as 'contributing' or 'supporting' to financial stability (Oosterloo and de Haan, 2003). As the financial crisis made it evident that a focus on solely price stability was insufficient to maintain financial and economic stability, central banks needed to operate in a new landscape. (Bean et al., 2010; IMF, 2013).

The search for better financial control resulted in multiple countries in a substantially expended mandate for the central bank. In the European Union (EU), the European Central Bank (ECB) has become engaged in macroprudential and microprudential supervision. The ECB is since 2011 involved in oversight of the financial system by its large role in the European Systemic Risk Board (ESRB). Despite the fact that the ESRB is still endowed with relatively limited powers, this is a first step towards European macroprudential oversight (Committee on International Economic Policy and Reform, 2011). Furthermore, the ECB has since 2014 become responsible for banking regulation and supervision with the establishment of the European Banking Union (EBU) and its Single Supervisory Mechanism (SSM), which made the ECB responsible for supervision of the largest Euro area banks. Although the combination of monetary and macro- and microprudential supervision is not exceptional for central banks, these responsibilities are new for the ECB.[1] Not only the ECB has gained new macroprudential tasks as reaction to the financial crisis, a comparable extension of responsibilities took place in the United Kingdom (UK), where in 2012 the Financial Services Act 2012 granted the Bank of England (BoE) a formal financial stability objective.

As central banks became involved in regulating the functioning of the financial markets, the question rose which role monetary policy should play in maintaining financial stability, and whether both policy goals should in practice be assigned to the same institution (see, for example Criste and Lupu, 2013; Boexck et al., 2015 or Smets, 2014.) As the policies instruments for price stability and financial stability can interact, coordination between these fields could improve the outcome, making a good argument for the combination of both objectives within the central bank. Some scholars therefore have argued that combing both functions within the central banks results in a more effective conduct of monetary and macroprudential policy, especially in times of crisis. Wadhwani (2010) argued that combining both fields within the central bank is the best way to prevent for coordination problems. Beck and Gros (2013) use the same argument to favour the combination of monetary policy and banking supervision within the central bank, again especially during crisis (Beck and Gros, 2013). Peek et al. (1999) showed in a study on the US economy that confidential data on the banking sector, resulting from financial stability tasks, helped the Federal Reserve (Fed) to significantly improve its forecasts of inflation and unemployment, thereby allowing for more effective monetary policy. Others even advocated to abandon the 'Tinbergen Rule'. The Tinbergen Rule entails that a policymaker should have (at least) as many separate and dedicated instruments as objectives and that the instruments must be addressed to the objectives that they can most effectively achieve.[2] The Committee on International Economic and

[1] For an overview of the legal developments in the European Monetary Union as a result of the crisis, see Smits, 2015.
[2] Definition derived from Smets (2013) and Bean et al. (2010).

Policy Reform (2011) argued that instead of having one instrument devoted entirely to one objective, monetary and macroprudential objectives must be treated as a joint-optimization problem, where monetary and macroprudential tools are used synchronously to achieve both objectives.

The main arguments presented in the literature against the combination of tasks within one institution are the potential conflict of interest resulting from the interaction between monetary and macroprudential policy (e.g. Gerba and Macchiarelli, 2015, or Dabrowski, 2016) The combination of these, potentially conflicting objectives, could lead to confusion on the central bank's mandate, threats to its credibility and independence and conflicts of interest (IMF, 2013). Furthermore, it is feared that the combination of multiple objectives, policy instruments and analytical approaches could lead to inconsistent policy, which could harm the central bank's credibility and its initial mandate of price stability (Bundesbank, 2015).

Due to the fact that financial stability is a relatively new responsibility for many central banks and experience and knowledge on the effectiveness of macroprudential policy is still limited (IMF, 2013), this thesis focusses on the interaction between monetary and macroprudential policy. To contribute to the recent debate, we study how the interaction between monetary and macroprudential policy affects the optimal institutional framework for monetary and macroprudential policy. The main question this thesis aims to answer is: How do price and financial stability – and monetary and macroprudential policy- interact, and what are the consequences of this interaction for the role the central bank should play in financial stability? The main question is answered by three sub-questions:

1. *How do price and financial stability interact?*
2. *Which role should monetary policy play in preserving financial stability?*
3. *What are the advantages and disadvantages of combining monetary and macroprudential policy within the central bank?*

The thesis can roughly be divided in two parts. After the introduction, monetary and macroprudential policy and their respective objectives and transmission channels, are closely studied in chapter 2. Chapter 3 firstly describes the theoretical interaction between these two fields, where after a Vector Autoregressive (VAR) model is developed to analyse the interaction between price and financial stability in the Eurozone. The second main part of the theses is developed in chapter 4, which focusses on the role the central bank and monetary policy should play in preserving financial stability.

2. Monetary and macroprudential policy

To study the potential consequences of combining the objectives of price stability and financial stability within one institution, it is first necessary to determine the potential ways in which both fields can influence each other. To do so, we first focus on monetary and financial stability policy as such, and briefly discuss their objectives and instruments.

2.1 Monetary and macroprudential policy objectives

A discussion on the interaction between monetary and macroprudential policy needs to start with a clear definition of their objectives. The objective of monetary policy is the easiest to define: the key target of monetary policy is price stability. Not all central banks have defined price stability similarly, although most central banks pursue comparable inflation targets. The ECB has defined price stability as inflation below, but close to 2%.[3] The Fed has described the goal of monetary policy as inflation at the rate of 2 percent over the longer run.[4] The objective of macroprudential policy is more difficult to define. In general, macroprudential policy is aimed at financial stability. But unlike price stability, there is no established definition for financial stability, nor an aggregate indicator to measure its development (Gersl and Hermanek, 2007; Criste and Lupu, 2014). Gadanecz and Jayaram (2009) put forward the following definition for financial stability: 'a financial system … in the absence of excessive volatility, stress or crisis' (Gadanecz and Jayaram, 2009, p. 366). However, they immediately indicate that this simple definition fails to capture the added value of financial stability to the real economy. The ECB uses a broader, more encompassing definition and describes financial stability as: 'a condition in which the financial system – intermediaries, markets and market infrastructures – can withstand shocks without major disruption in financial intermediation and in the effective allocation of savings to productive investment' (ECB, 2015, p.4).

2.2 Monetary and macroprudential policy instruments

To study the potential interaction between these fields and their instruments, we discuss the basic tools available for the relevant policymaker. To realize the described objectives, monetary and macroprudential policy make use of a range of instruments. Monetary policy is founded on the robust positive relationship between long-term money growth and inflation, a relationship that holds across

[3] The objective of the ECB is defined in Article 127 of the Treaty on the Functioning of the European Union (TFEU).
[4] The Board of Governors of the Federal Reserve System has described this goal in a Press Release on January 25, 2012. Accessible at: https://www.federalreserve.gov/newsevents/press/monetary/20120125c.htm (last accessed: 04-07-2016).

countries and policy regimes (ECB, 2011). To see how monetary policy tools can be used to reach price stability, we briefly discuss the money market.

We distinguish between a narrow and a broad definition of money. For simplicity, we only look at the monetary base, or base money (B), consisting of the currency in circulation and reserves that commercial banks hold at the central bank and broad money, which includes base money and other financial assets as non-bank overnight deposits, saving and time deposits and other short-term liabilities of the banking system (M1-M3) (Van Marrewijk, 2007; Romer, 2012). A traditional, textbook theory on the supply of money is the money multiplier approach. In this theory, money supply is essentially driven by the central bank, which conducts monetary policy by adjusting the level of base money (ECB, 2011; Van Marrewijk, 2007). The theory derives from a fractional-reserve banking system, in which, in times of confidence and under normal conditions, banks only have to hold a fraction of the deposits they have accepted in liquid form. The rest of the deposits will be used to acquire profits and will thus be used to provide additional loans (ECB, 2011; Mcleay et al., 2014). When a central bank increases the monetary base, and thus the volume of reserves available for banks, banks will therefore create additional money and multiply the central bank's action. The volume of broad money is the result of the monetary base and the size of the money multiplier. It follows that a higher money multiplier will increase the amount of broad money created per unit of central bank base money. Therefore, with money demand being equal, an increase of central bank base money, or an increase in the money multiplier, has an inflationary effect (Van Marrewijk, 2007; Romer, 2012).

However, in practice in modern economies, money creation by commercial banks is not restricted by the amount of monetary base set by the central bank (ECB, 2011). Basically, commercial banks create money, mostly in the form of deposits, by making new loans. When a bank grants a loan, it credits the account of the lender with a bank deposit of the size of the loan and thereby creates new money. The amount of reserves at the central bank is not a binding constraint for these loans; banks first decide how much to loan based on market conditions, which then affects how much central bank money banks want to hold in reserve (McLeay et al., 2014). Commercial banks thus determine the broad money stock by their lending behaviour. Monetary policy, macroprudential policy and market conditions all affect this lending behaviour and set limits to the commercial bank's lending activities (Bridges et al., 2011; McLeay et al., 2014).

In normal times, central banks in modern economies implement monetary policy by steering the short-term money market interest rates. In this light, we distinguish three transmission channels through which monetary policy operates, namely the interest-rate channel, the credit channel and the risk-taking channel.

The interest-rate channel is the most traditional and direct, and briefly works as follows. The central bank set the key interest rates which determines the costs of credit for commercial banks, which directly influences the rate at which they are willing to lend to others.[5] Expansionary monetary policy, thus a decrease in the key interest rates, leads to a fall in the real interest rate. The lower real interest rates lowers the cost of capital, increases money demand, which results in an increase in investment, which leads to an increase in aggregate demand and a rise in output (Mishkin, 1996). Furthermore, the lower interest rates alter the trade of between current consumption and savings, making current consumption more attractive (Boeckx et al., 2015). Finally, the fall in real interest rates also effects the economy by other asset price channels as the exchange rate channel. As domestic real interest rates fall, deposits in the domestic currency become less attractive compared to deposits in foreign currency, leading to a fall of the value of the domestic currency. The depreciation of domestic currency causes a rise in net exports and thus in aggregate output (Mishkin, 1996).

Monetary policy can also work through the credit channel, which can be subdivided in the bank lending channel and the balance sheet channel (Boeckx et al., 2015). These channels of monetary transmission arise because of information problems in the credit market. The bank lending channel is based on the fact that many, especially household and SME, are dependent on banks to access the credit market. Expansionary monetary policy increases the bank reserves and bank deposits and thus the loanable funds banks possess, which increases the availability of bank loans for the borrowers. The increased availability of loans allows for more investment and consumer spending, which increases output (Mishkin, 1996). The balance sheet channel is based on the view that monetary policy can be amplified by changes in the external funding premium of agents. The external funding premium relates to the net worth of agents, and captures the difference in cost of internal capital and external capital, which is the result of information asymmetries in the market. Low net worth agents have less collateral for their loans, which increase the external funding premium. Simplified, a decrease in an agent's net worth makes it riskier to lend money to that agent, which increases the cost of external capital, resulting in a

[5] The ECB distinguishes between 'the interest rate on the main refinancing operations, which provide the bulk of liquidity to the banking system, the rate on the deposit facility, which banks may use to make overnight deposits with the Eurosystem, and the rate on the marginal lending facility, which offers overnight credit to banks from the Eurosystem'. For an overview of the key interest rates of the ECB, see: https://www.ecb.europa.eu/stats/monetary/rates/html/index.en.html (last accessed: 04-07-2016).

decrease in lending and thus in investments. Monetary policy can affect the balance sheet of these agents in multiple ways. Expansionary monetary policy makes investment more attractive compared to saving. Low interest rates can make the stock market more attractive, which increases demand for equities, and consequently raising their prices. This increases the agents net worth, lowers the external finance premium and increases lending, investment and output. Furthermore, expansionary monetary policy can affect the general price and could lead to an unexpected rise in inflation. This lowers the firm's liabilities in real terms, but should not affect the value of the firm's assets. An unexpected rise in inflation could therefore improve the firm's net worth, with the same effects as described above (Mishkin, 1996, Boeckx et al., 2015). In short, the influence of monetary policy on the lending conditions of banks and the balance sheet position of borrowers boosts the initial monetary effect.

Finally, monetary policy can also work through the risk-taking channel. (ECB, 2007; Gambacorta, 2009). This channel works by the assumption that a long period of expansive monetary policy can encourage agents, in particular banks and financial institutions, to become more (or over) confident and take more risk and build up debt. Banks may decide to lend more if they perceive the risks to have fallen (Mcleay et al., 2014). Gambacorta (2009) finds in a study on a bank dataset, that loose monetary policy can influence risk taking in two ways: firstly through a search for (higher) yields, and secondly by the impact of loose monetary policy on interest rates, which in turn impacts the valuations, incomes and cash flows, which alters how banks measure risk. (Gambacorta, 2009). Both mechanisms have an impact on output and ultimately inflation.

Macroprudential policy instruments are targeted at the financial system as a whole, which differentiate them from policy instruments aimed at individual institutions (Committee on International Economic Policy and Reform, 2011). Macroprudential policy tools can be subdivided in three main categories. Firstly the capital rules, which include leverage-ratios, systemic-risk buffers and other (counter-cyclical) capital buffers (Boeckx et al., 2015). The second category are the liquidity ratios as the Liquidity Coverage Ratio (LCR).[6] In short, the LCR is 'a short-term ratio which requires financial institutions to hold high quality liquid assets to meet short-term obligations which are caused by sudden liquidity disruptions. Banks are required to hold an amount of highly liquid assets at least equal to their net cash outflows over a 30-day stress period' (Bonner and Eijffinger, 2012, p. 2). In times of crisis, this

[6] As described in BASEL III: BCBS (2010a). International framework for liquidity risk management, standards and monitoring. Basel Committee on Banking Supervision and BCBS (2010b). Strengthening the resilience of the banking sector. Basel Committee on Banking Supervision.

requirement could force banks who are close to the minimum liquidity ratio to decrease lending volumes. The third category are the lending ratios, which include for example loan-to-value caps or loan-to-income caps (Boeckx et al., 2015).[7] These policy tools are used to reduce systemic risk and can directly affect the balance sheet of financial institutions, to make them more resilient against negative economic shocks.

3. The interaction between monetary and macroprudential policy

As can be derived from the policy tools and transmission mechanisms discussed above, monetary and macroprudential policy work on very overlapping fields. Nonetheless, there is only limited academic literature on the question how these fields interact (Blot et al., 2015). To answer this question, we identify how the objectives of both policy areas, namely price and financial stability, interact, and take a closer look at the complementarity or potential conflicting effects of monetary and macroprudential policy instruments.

3.1 The theoretical relationship between price stability and financial stability

One of the most influential articles on the relationship between price and financial stability is written by Anna Schwartz. In the article 'Why Financial Stability Depends on Price Stability', she developed the following hypothesis: 'a regime of monetary and price stability is the route to financial stability' (Schwartz, 1995, p. 25).[8] Borio and Lowe (2002) described the presumed mechanism as follows: 'a monetary regime that produces aggregate price stability will, as a by-product, tend to promote stability of the financial system' (Borio and Lowe, 2002, p. 27).[9] The underlying argumentation is that price instability will on the one hand cause inflation distortions, and thereby growing uncertainty and shorter investment horizons. On the other hand, price instability would stimulate speculative investments and could negatively affect the value of collateral (Blot et al., 2015). Both effects would lead to financial instability.

However, the recent financial crisis has cast doubt on the hypothesis postulated by Schwarz (1995). Relatively low and stable inflation in the years before the crisis did not prevent the crisis from

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[7] For an overview of macroprudential measures taken in the EU, see, among others: ESRB, 2016. A review of Macroprudential Policy in the EU in 2015, May 2016: 1-57 and EBA, 2015. EBA Report on the range of practices regarding macroprudential policy measures, Communicated to the EBA, July 2015: 1-44.

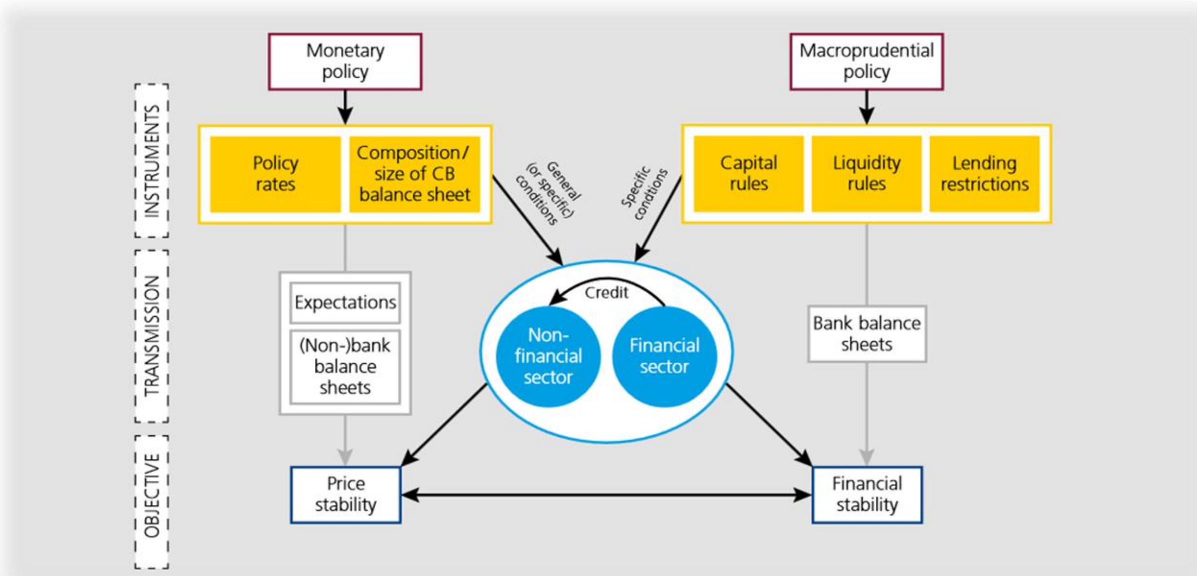
[8] The hypothesis is sometimes also called the Conventional Wisdom (Blot et al. 2015).

[9] This approach is also mostly followed by central banks before the crisis. Most central banks were assigned the primary mandate of price stability and would only consider financial stability concerns in case it would threaten the price stability objective (Bernanke and Gertler, 2001). The consequences of the interaction between price and financial stability will be discussed in chapter 4.

happening. In the literature, the positive relationship between price stability and financial stability has been question already before the crisis. Bori and Lowe (2002) argued that a stable low inflation could lead to financial instability as loose monetary policy makes high-risk projects more attractive, as discussed above. Also Gambacorta finds that, due to the search for yields, low interest rates can lead to an increase in risk-taking (Gambacorta, 2009).

But not only do price stability and financial stability influence each other, also the instruments for monetary and macroprudential policy can interact. Boeckx et al. (2015) visualized the interaction between the policy fields of monetary and macroprudential policy in the following figure:[10]

Figure 1: Interaction monetary and macroprudential policy **Source: Boeckx et al., 2015**



To make the interaction between both fields more concrete, we take a closer look at the various interactions. As discussed above, banks are highly relevant for the transmission channels from monetary policy to the real economy. As exemplified by the recent financial crisis, financial instability can have dramatic consequences for the financial intermediate market. Due to a lack of trust, financial institutions cease to extend credit, which makes money supply and the monetary transmission channels collapse (Dabrowski, 2016). When in the aftermath of the crisis the supply of bank credit was drying up, unlocking bank lending to the real economy became a main goal of monetary policy. Both the ECB and the Fed have specifically named unblocking the channelling of credit through banks to the real economy as an objective of its asset purchase programs (Gambacorta and Shin, 2016).

[10] Source: Boeckx et al., (2015).

Bank recapitalization to insure the solvency of banks has also been an objective of the financial supervisors. In this light, monetary and macroprudential policy can be complementary, as healthy financial institutions foster financial stability and ensures smooth monetary transaction channels. Macroprudential measures which prevent systemic unrest lower the chances that the monetary policy authority must intervene because of major disruptions in the economy (think for example of the current zero lower bound situation), while financial stability benefits from monetary policy addressing financial imbalances which form a risk for price stability (as exemplified by the non-conventional measures adopted during the crisis). Or, as Gambacorta and Shin (2016) put it: 'both the macro objective of unlocking bank lending and the supervisory objective of sound banks are better served when bank equity is high' (Gambacorta and Shin, 2016, p. 23). They conclude in a bank-level study that higher bank capital is associated with greater lending due to the lower funding cost for better capitalized banks (Gambacorta and Shin, 2016).

It follows that bank capital is of great importance for both monetary as macroprudential policy. This is best visible from the non-standard monetary policy measures central banks took in response to the crisis. These measures, like security and asset purchase programmes, had direct monetary policy effects, but also recapitalized ailing financial institutions, which directly improved financial stability. The improved financial stability, in turn, had a positive feedback loop into price stability (Brunnermeier and Sannikov, 2014). Such (non-standard) monetary measures are difficult to separate from macroprudential policy, both in their objective as in their working.

On the other hand, the objectives and corresponding policy tools of monetary and macroprudential policy can also be in conflict. Especially by the risk-taking channel, loose monetary policy and the corresponding low interest rates can lead to greater risk-taking in the financial system (Smets, 2014; Gambacorta, 2009). In this light, Ongena and Peydro (2011) find that low interest rates stimulate greater risk-taking and greater liquidity exposure by banks, especially by the lower-capitalized ones.[11] Another example can be found in the emergency liquidity assistance provided by the central bank to financial institutions in need during the crisis.[12] Although such policies may avoid a crash of the

[11] These findings are among others confirmed by Gambacorta and Marques-Ibanez (2011), Del Ariccia, Laeven and Suarez (2016).

[12] For example by the ECB during the crisis, see: ECB, Eurosystem, 'ELA Procedures; the procedures underlying the Governing Council's role pursuant to Article 14.4 of the Statute of the European System of Central Banks and the European Central Bank with regard to the Provision of ELA to individual credit institutions', accessible at: https://www.ecb.europa.eu/pub/pdf/other/201402_elaprocedures.en.pdf (last accessed: 07-07-2016).

banking system, it can also decrease the incentive for banks to restructure and recapitalize. In this manner, monetary policy directly affects financial stability.[13]

Conversely, macroprudential policy tools can also directly affect monetary policy. This can be exemplified by taking a closer look at one of the financial stability policy tools described above, the LCR. LCRs require financial institutions to hold high quality liquid assets to meet short-term obligations. This requirement could force banks that are close to the minimum liquidity ratio to decrease lending volumes and thus decrease the supply of money. Especially shortly after a crisis, when solvent banks seek to strengthen their solvency further by cutting credit exposure, the objective of the financial supervisor (ensuring the soundness of banks) and the monetary authority (encouraging bank landing) may start to become conflicting (Gambacorta and Shin, 2016).Or, as Bonner and Eijffinger (2012) conclude: 'despite its [LCR's] positive effect on financial stability… LCR is likely to dampen the effectiveness of monetary policy' (Bonner and Eijffinger, 2012, p. 19).

To test how price stability and financial stability are interrelated, and to test for the hypothesis that price stability will promote financial stability, we analyse a dataset of the Eurozone.

3.2 Empirical analysis of the relationship between price stability and financial stability

3.2.1 Data description

To analyse the interrelationship between price stability and financial stability, we take a closer look at the Eurozone. Based on the arguments presented above, our hypothesis is that price stability has a positive effect on financial stability, while *vice versa*, we expect financial stability to have a positive effect on price stability.

We focus the empirical part of this research on the Eurozone for two reasons. Firstly, the interrelation between price stability and financial stability is very topical in the Eurozone. The effectiveness of non-conventional monetary policy measures as Quantitative Easing is highly contested in the both politics and academic literature, while financial stability concerns as those on the Italian banking sector or the consequences of a Brexit fill the newspapers daily. Secondly, the *sui generis* character of the Eurozone, where one monetary authority (the ECB) decides on monetary policy for 19 different economies, each with their own (potential) financial imbalances, makes the Eurozone one of a kind. Finally, the recent

[13] For an overview of the potential risks of loose monetary policy for financial stability, see: Claeys and Darvas (2015).

changes in the financial stability responsibilities of the ECB make the discussion on the relationship between price stability and financial stability in the Eurozone especially relevant.

To capture the interaction between financial stability and price stability in the Eurozone, we have composed a dataset containing data from the ECB. The data describes a fixed composition of the 19 current Eurozone countries.[14] As the currencies of the current Euro states were fixed on the 1st of January 1999, our first observation is 1999 Q1 (ECB, 1998). The last observation of our sample is defined by data availability, which makes 2016 Q1 the latest observation.

3.2.2 Variables selection

We are particularly interested in the interaction between three main economic variables: output, price stability and financial stability. These variables are also the three main components of the model we will discuss in chapter 4.

We first need to define a variable which captures the general output of the economy. The most intuitive variable to capture output is the change in GDP. This variable is also used by most of the studied literature, as by Gelain and Ilbas (2014), Blot et al. (2015) and Boeckx et al. (2015). We use *quarterly GDP growth* rate over 1 year of a fixed composition of the current 19 Euro area countries, and our data is calendar and seasonally adjusted. This data is derived from the ECB.

Secondly, we need a variable which describes price stability in the Eurozone. To capture price stability, we look at the *Harmonised Index of Consumer Prices* (HICP) to measure inflation. This is the same index used by the ECB to evaluate its objective to maintain annual inflation below, but close to 2% over the medium term. Quint and Rabanal (2014) and Blot et al. (2015) also make use of this indicator to capture changes in prices. HICP incorporates basically all goods and services purchased by consumers. Again, we use quarterly obtained data of the fixed composition of the current 19 Euro area countries.

Thirdly, we want to include variables to describe the monetary conditions in the Eurozone. Therefore, we look at two variables, namely the key interest rate set by the ECB and the supply of money. For the interest rate set by the ECB, we use the interest rate on the *Main Refinancing Operations*. This rate is calculated by taking the average rate during the quarter. These operations provide the bulk of liquidity to the banking system and the refinancing rate is one of the ECB's monetary policy tools. Secondly, to

[14] Except, due to their character, for the CISS indicator and the main refinancing rate.

take the amount of money in the economy into account, we use the level of *M3 money*. Again, we use quarterly data on annual growth rates. Both statistics are derived from the ECB.

Furthermore, we need an indicator to capture financial stability. As described in the papers of Galati and Moessner (2010) and Gadanecz and Jauaram (2009), academic research has not yet reached consensus on an encompassing indicator for financial stability. This is also reflected by the amount of different indicators used in the literature. Gelain and Ilbas (2014) make use of the Gilchrist-Zakrajsek (2012)-spread, which is used as a proxy for financial intermediary health and thus a predictor for financial distress. Research as that of Quint and Rabanal (2014) used housing prices and the level of private sector debt as indicators for financial stability. This analysis makes use of an aggregate indicator for financial stability composed by the ECB: the *Composite Indicator of Systemic Stress* (CISS). The *CISS* is a composite indicator composed by the ECB, which aims to monitor key sectors of the economy by combining individual indicators to capture developments in, and interactions between, these sectors (Gadanecz and Jayaram, 2009). The CISS indicator measures 15 indicators of systemic stress in five important sectors of the financial system, namely: financial intermediaries sector, money markets, equity markets, bond markets and foreign exchange markets. The current level of stress in these markets is measured by several indicators, which are combined in the CISS indicator. The indicator takes a value larger than zero but smaller or equal to one (Holló, Kremer and Lo Duca, 2012). We use this indicator because of its inclusive character and because it is one of the main indicators used by the ECB itself. Also Blot et al. (2015) follows this approach.

Finally, we include the annual growth rate of *Loans vis-à-vis euro area non-financial corporations*. We have a specific interest in this variable because multiple (theoretical) papers focus on the amount of leverage in the economy as an indicator for financial stability (e.g. Ueda and Valancia, 2012 or Smets, 2014). Leverage indicates the level of borrowed funds used to increase returns relative to the amount of own capital.[15] Unfortunately, raw data on the amount of leverage in the Eurozone is difficult to obtain. Although Loans to NFC does not provide information on the level of leverage, nor measure the indebtedness of firms, it does provide an interesting insight in the availability of loans (the bank lending channel) and the general level of trust in the economy. An overview of the data selection is given in table 1.

[15] For a more inclusive research of leverage, see Gambacorta and Shin (2016).

Table 1: Data selection

Variable	Source	Description	Observations
Inflation	ECB	HICP Overal Index- Euro Area 19 (fixed composition) – Annual rate of change	69
GDP growth	ECB	GDP volume growth- Euro Area 19 (fixed composition)- growth rate of 1 year	69
Main refinancing rate	ECB	Main refinancing operations interest rate	69
M3 growth	ECB	Monetary Aggregate M3 vis-à-vis euro area non- Monetary and Financial Institutions (MFIs)- Annual growth rate	69
CISS	ECB	Composite Indicator of Systemic Stress – Euro Area	69
Loans to NFC growth	ECB	Loans vis-à-vis euro area Non-Financial Corporations (NFC) by MFIs- total maturity- Annual growth rate	69

3.2.3 Descriptive statistics

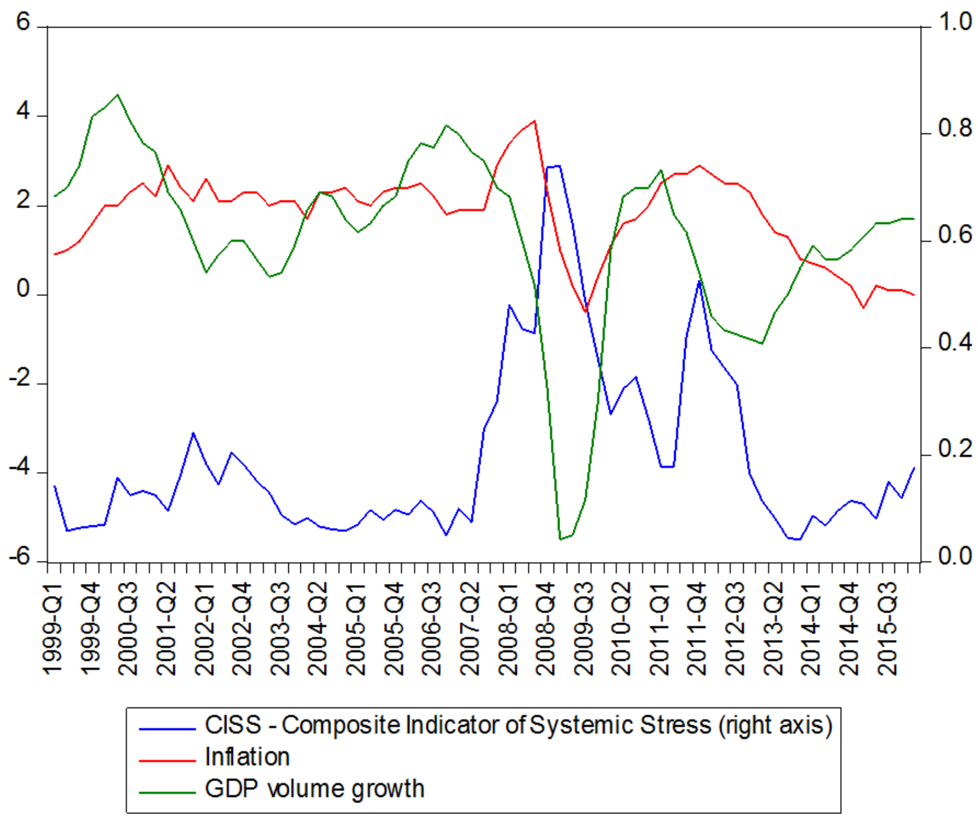
The data selection results in a dataset containing 6 variables in 69 observations. A visualisation of each variable over time can be found in Appendix 1.1. A visual inspection of the data reveals that the variables tend to follow a similar pattern, whereby especially the large impact of the start of the crisis in 2007 is distinct. Interestingly, the CISS indicator seems to have little predictive value, as it indicated very little systemic stress until the very start of the crisis. The variables do not seem to have a constant mean and variance over time, which could be an indication of non-stationarity. This will further be analysed in paragraph 3.3.2. Table 2 provides further insight in the descriptive statistics of the dataset.

Table 2: Descriptive statistics

	CISS	GDP GROWTH	LOANS TO NFC GROWTH	MAIN REFINANCING RATE	INFLATION	M3 GROWTH
Mean	0.20	1.29	4.55	2.10	1.81	5.33
Median	0.13	1.60	3.60	2.00	2.10	5.57
Maximum	0.74	4.50	14.90	4.75	3.90	12.17
Minimum	0.04	-5.50	-3.60	0.00	-0.40	-0.10
Std. Dev.	0.17	2.00	5.43	1.40	0.95	3.09
Obs.	69	69	69	69	69	69

In figure 2, our three main variables are plotted. This graph further illustrates a similar pattern between these variables.

Figure 2: Inflation, GDP growth and financial stability



3.3 Methodology

We analyse the interaction between price stability and financial stability in two manners. Firstly, we simply look at the correlation between our three main variables: price stability, GDP growth and financial stability. Secondly we use a Vector Autoregressive model (VAR-models) to study the interaction between price stability and financial stability, by also including a set of other macroeconomic variables as described in subsection 3.2.1. Although looking at the correlation between price and financial stability is a relatively simple and limited approach, it does provide us with some insight on the question whether price stability positively relates to financial stability, as proposed by Schwartz (1995). The latter approach provides us more insight in how our variables relate as the VAR analysis incorporates the dynamics between variables over multiple periods. As the VAR analysis is more complicated, it requires a sound methodological approach.

3.3.1 The VAR model

Many academic papers make use of VAR-models to test for interaction between a set of variables, because VAR models can be used to study multivariate time-series data and take their dynamic properties and interactions into account. (Carter Hill et al. 2008). The VAR model describes the dynamic progress of multiple variables by their common history, as it explains one variable by its own lags and the lags of the other included variables. A standard VAR(p) model can be described by:

$$Y_t = \delta + \Theta_1 Y_{t-1} + \cdots + \Theta_p Y_{t-p} + \varepsilon_t \quad (1)$$

whereby Y_t is the $k \times 1$ vector containing the variables of our model, δ is the $k \times 1$ constant vector, Θ_j a $k \times k$ matrix of the coefficients of the variables, Y_{t-1} the vector of the lag of all variables in the system and ε_t the $k \times 1$ vector of the error terms (Verbeek, 2013). Each variable is hereby thus explained by its own lags and the lags of the other variables in the system. An important advantage of this model is that the relationship between the variables does not have to be established on forehand. *Prima facie*, all variables are treated equally with no difference between endogenous and exogenous variables (Verbeek, 2013). We use the VAR model to incorporate the past dynamics of price and financial stability.

The VAR model is a general framework which can be used to describe the interrelationship between stationary variables. Thus, to be able to use the VAR model correctly, we must first establish whether all our variables are stationary *I(0)* variables, in which case we could run the regression in levels. If our variables are nonstationary, we must examine whether our variables are cointegrated and thus follow a common trend. If the variables are nonstationary and not cointegrated, we will run the regression by taking first differences. However, if the variables are nonstationary and cointegrated, we adjust our approach to allow for the cointegration between the nonstationary variables by using a Vector Error Correction (VEC) model (Verbeek, 2013).

The VEC model is a restricted VAR model which is developed to work with nonstationary series that are cointegrated. The advantages of using a VEC model for a cointegrated relationship within our model, is firstly that we do not need to give up valuable information about the cointegration in our series, and secondly that we can run the adjusted regression without the risk of running a spurious regression (Carter Hill et al., 2008). The VEC model adds an error correction term to the model, which describe how the time-series adjust to disequilibrium and corrects to the long-term equilibrium. To perform the following tests, we will use the statistical software package *Eviews 9*.

3.3.2 Number of lags

Regardless whether the best approach is to use a VAR or a VEC model, we need to define the appropriate amount of lags to use in our model. The amount of lags determines the number of previous periods which are included in the model. *Eviews 9* allows for an easy way of testing the appropriate amount of lags to be included, as it can perform five lag length selection tests. We therefore look at the Sequential modified LR test statistic, the Final Prediction Error test, the Akaike Information Criterion, the Schwarz Information Criterion and the Hannan-Quinn Information Criterion to select the appropriate amount of lags (Verbeek, 2013). Based on the literature and economic reasoning, we expect to include approximately 3 lags (Blot et al. 2015).

3.3.3 Stationarity

To test if our variables are stationary, we follow a double approach. Firstly, we will visually analyse our time-series, to see if there are any appearing trends or drifts over time. Secondly, we will use the Augmented Dickey-Fuller test (ADF-test) to test the stationarity of our variables and make sure we do not run a spurious regression. Although there are also other tests for stationarity, the ADF-test is the most common test for this purpose. The null-hypothesis of the ADF-test is that the series contains a unit root. There are three variances of the ADF-test, to test for the series containing an intercept and a time trend, only an intercept and no time trend, or no intercept and no time trend. We will start with testing for both a constant and a time trend, when necessary test for only a constant or no constant and no time trend. We will test our results by comparing the t-statistics with the critical values for the

Dickey-Fuller test given by Davidson and Mackinnon (1993).[16] We make use of automatic lag length selection, for which we use the Akaike Info Criterion. If we can reject our null hypothesis of a unit root, we conclude our series are stationary and are integrated of an order of zero, *I(0)*. Alternatively, if we cannot reject the null-hypothesis of a unit root, we will use the test to determine the order of integration of our variables. The order of integration determines the number of times we must take first differences to make the series stationary (Carter Hill et al., 2008).

If this test turns out to be inconclusive, we apply another testing method for stationarity provided by *Eviews*, namely the Phillips-Perron test. This test works slightly different that the ADF-test, and can offer us more certainty about the results.

3.3.4 Cointegration

When our tests suggest the variables are nonstationary, we will subsequently test for cointegration. When the variables turn out to be cointegrated, this forms an exception on the rule that nonstationary variables should not be used in regressions to avoid the problem of a spurious regression. In this case, we make use of the VEC-model. To test for cointegration, we look at the residuals of our model. If our variables are nonstationary *I(1)* variables, we expect their differences also to be nonstationary *I(1)*. However, when the differences are a stationary *I(0)* process, then our variables are likely to be cointegrated. Cointegration thus implies that the difference e_t is stationary, so that the variables share a similar stochastic trend. This implies that the variables never diverge too far from each other (Verbeek, 2013; Carter Hill et al., 2008).

Several methods exist to test for cointegration. In this research, the Johansen Cointegration Test is applied. This test has, for example compared with the popular Engle-Granger approach, as main advantages that it can identify multiple cointegration relationships in multivariate series. This methodology is developed by Johansen in two papers and a book (Johansen, 1988, 1991 and 1995). This method uses a maximum likelihood estimation which allows testing for multiple cointegration relationships. The test uses a double approach, by the so-called trace test and the maximum eigenvalue test. We choose to use the Johansen Cointegration Test mainly for its major advantage of being able to detect multiple cointegration relationships between the multivariate series.

[16] Presented in Verbeek (2013).

3.4 Empirical results

3.4.1 Correlation between price stability, financial stability and GDP

Our first approach to answer the question how price stability and financial stability interact is to calculate the correlation coefficients of the three main variables: price stability, financial stability and GDP growth. Based on the research of Schwartz (1995), we expect price stability to positively correlate with financial stability, indicating that a rise in inflation would lead to financial instability. The results presented in table 3 indicate such a positive but insignificant relationship between price and financial stability in the Eurozone. Our other main variable, GDP growth, does show a significant correlation with both price and financial stability. Our results indicated that a rise in GDP growth results in an increase in financial stability (or a decrease in the CISS indicator) and a rise in inflation.

Table 3: Correlation between price stability, financial stability and GDP*

Ordinary Covariance Analysis Included observations: 69	**CISS**	**GDP growth**	**Inflation**
CISS	1.000		
GDP growth	-0.635 (0.00)	1.000	
Inflation	0.124 (0.31)	0.285 (0.02)	1.000

**Significance level of each correlation is given in parenthesis.*

3.4.2 VAR Model: Lag length selection

For our second approach, we make use of a VAR model estimate on the interaction between the variables described in chapter 3.2: quarterly inflation, quarterly GDP growth, the CISS indicator, quarterly M3 growth, the main refinancing rate, and Loans to non-financial sector. To select the optimal amount of lags to be included in the model, we use the five lag selection tests offered by *Eviews*. The results are presented in table 4 below.

The results presented in table 4 indicate that, according to the majority of the tests, the most appropriate amount of lags to be included in the model is 2. This is also comparable with the research of Blot et al. (2015), who included 3 lags in their VAR model in a comparable research. To include two lags in our model would mean that the consequences of our variables are included until six months later, which seems a reasonable assumption.

Table 4: Lag length selection

Lag	LogL	LR	FPE	AIC	SC	HQ
1	-199.7970	NA	7.20e-05	7.485618	8.710266*	7.967278
2	-138.4320	99.35286*	3.30e-05*	6.680380	9.129677	7.643700*
3	-102.9256	50.72342	3.60e-05	6.696050	10.37000	8.141030
4	-69.51057	41.37095	4.51e-05	6.778113	11.67671	8.704754
5	-24.74492	46.89734	4.43e-05	6.499839	12.62308	8.908140
6	21.43861	39.58589	4.96e-05	6.176552*	13.52444	9.066513

*Lag order selected by the criterion marked by *. LR: sequential modified LR test statistic (each test at 5% level), FPE: Final Prediction Error, AIC: Akaike information criterion; SC: Schwarz information criterion.*

3.4.3 VAR Model: Stationarity

To be able to decide upon the right approach in our model, we need to establish if our variables are stationary. To do so, we first visually analyse our dataset. A graphical visualisation of each variable can be found in Appendix 1.1.

Visually, we can conclude that our variables do not appear to be fluctuating around a linear trend, except perhaps for the main refinancing rate. This is also a logical consequence of the fact that all other variables (except for CISS-indicator) are growth rates compared to the previous years. The CISS indicator can only have a value between [0,1] and is therefore expected to be stationary. To have a more definitive answer, we test for stationarity by the ADF-test. The results can be found in table 5 below.

The null-hypothesis of the ADF test is that the series have a unit root and are therefore nonstationary. If we can reject this null-hypothesis, this indicates that the series does not contain a unit root and is likely to be stationary. The results shown in table 5 indicate that CISS, GDP growth, Loans to NFC, Inflation and M3 growth are nonstationary at the 5% significance level, as we cannot reject the null-hypothesis of a unit root. The exception is the main refinancing rate, for which the null-hypothesis of a unit root can be rejected at a 5% level, indicating that this variable is stationary. At a 10 % significance level, we can also reject the null-hypothesis of a unit root for the variables Loans to NFC and GDP growth.

Table 5: Augmented Dickey-Fuller Test

Variable	Trend, intercept or no trend no intercept	T-statistic (p-value)
CISS	Intercept	-2.492 (0.12)
GDP growth	None	-1.754 (0.08)
Loans to NFC growth	None	-1.769 (0.07)
Main refinancing rate	Trend and intercept	-3.801 (0.02)
Inflation	Trend and intercept	-1.943 (0.62)
M3 growth	None	-0.635 (0.44)
ΔCISS	None	-6.877 (0.00)
Δ GDP growth	None	-3.576 (0.00)
Δ Loans to NFC growth	None	-2.533 (0.01)
Δ Main refinancing rate	None	-3.945 (0.00)
Δ Inflation	None	-6.000 (0.00)
Δ M3 growth	None	-3.780 (0.00)

**Significance level is given in parenthesis. Lag length selection by Akaike Info Criterion.*

To make these results more robust, we also apply the Phillips-Perron stationarity test. The results of this test can be found in Appendix 1.2. Using this approach, only GDP growth indicates to be stationary at the 5% significance level, while for all other variables the null-hypothesis of a unit root cannot be rejected.[17]

Intuitively, we had expected that our variables would face less stationarity problems. The variables GDP, Loans to NFC, Inflation and M3 are all growth rates, which suggest that the distribution of these variables would not change much in time. As similar argument can be made for the CISS indicator, which has a value between [0,1]. To make our results more robust, we also run the model in levels. The results, and a comparison with the results derived from the analysis below, are presented in Appendix 1.4.

We can conclude from both stationarity tests presented above that all variables are stationary in their first differences, indicating that all other variables are integrated in an order of one, *I(1)*. As we need

[17] At a 5% nor at a 10% significance level.

all variables to be *I(0)* to be able to run the regression in levels, we will continue with the next step to check whether our variables are cointegrated.

3.4.4 VAR Model: Cointegration

To test whether our variables are cointegrated, and thus if we should use a VAR or a VEC model, we use the Johansen Cointegration test. The Johansen Cointegration test uses the Trace test and the Maximum Eigenvalue test to indicate the amount of cointegration relationships in our model. We included two lags, based on the results presented above. The results of this test are presented in table 6 and 7.

Table 6: Johansen Cointegration Test: Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Probability
None *	0.500549	114.1897	95.75366	0.0015
At most 1	0.393895	68.36944	69.81889	0.0649
At most 2	0.201840	35.32311	47.85613	0.4311
At most 3	0.162609	20.44368	29.79707	0.3932
At most 4	0.115735	8.731044	15.49471	0.3909
At most 5	0.009247	0.613132	3.841466	0.4336

*Trace test indicates 1 cointegrating equation at the 0.05 level. * denotes rejection of the hypothesis at the 0.05 level*

Table 7:Johansen Cointegration Test: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Probability
None *	0.500549	45.82025	40.07757	0.0101
At most 1	0.393895	33.04633	33.87687	0.0626
At most 2	0.201840	14.87943	27.58434	0.7577
At most 3	0.162609	11.71264	21.13162	0.5762
At most 4	0.115735	8.117912	14.26460	0.3669
At most 5	0.009247	0.613132	3.841466	0.4336

*Max-eigenvalue test indicates 1 cointegrating equation at the 0.05 level. * denotes rejection of the hypothesis at the 0.05 level.*

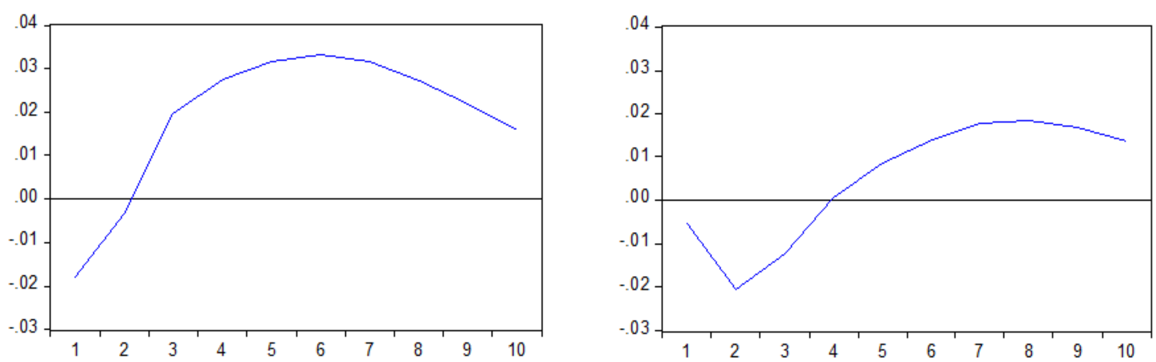
Both the Trace as the Maximum Eigenvalue reject that there are none cointegration equations at the 5% significance level. Both methods also come to the same conclusion for at most 1 equation, which cannot be rejected at the 5% significance level. Therefore, we can conclude that our model contains one cointegrating equation and that we therefore can use the VEC model for our estimations.

3.4.5 Vector Error Correction Model

As the analysis presented above indicates that our variables are nonstationary and have one cointegrated equation, we continue our analysis with the VEC model. The estimations of our VEC model are presented in Appendix 1.3.[18] To be able to better analyse the interaction and the potential causality between price and financial stability, we derive the impulse response functions of our model. We use the impulse response functions to measure the response of one variable to an impulse in another variable in our model, while keeping all other variables constant (Verbeek, 2013). We therefore apply an impulse, or a shock, of one standard deviation and analyse the response of the other variable to this shock. As this research focusses on the interaction between price stability and financial stability, we present the impulse response functions of these variables and GDP growth in figure 3, 4 and 5. We include ten periods in our impulse response function, corresponding to ten quarters, which is equivalent to 2.5 year. We measure the response to Cholesky one Standard deviation.[19]

Figure 3 displays the response of financial stability indicator CISS to inflation and GDP growth. In line with the research of Schwarz (1995), we find that an increase in inflation would lead to a higher value for CISS in the long run, indicating a decrease of financial stability. This indicates that price stability and low inflation indeed foster financial stability. This relationship is also confirmed by our

Figure 3: Response of CISS to Inflation (left) and to GDP growth (right)



VEC estimates presented in Appendix 1.3, which shows a significant positive effect of inflation on CISS at the 10% significance level. The negative effect of an increase in inflation on financial stability

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[18] To test for robustness, we have also run the model in levels. The results of the VAR estimates are presented in Appendix 1.4. These results, and the corresponding impulse response functions, show very comparable results.
[19] Unfortunately, confidence bands cannot be included in the impulse response functions of a VEC model in *Eviews 9*. These confidence bands are included in the impulse response functions from the VAR model run in levels. These impulse response functions, and their interpretation, can be found in Appendix 1.4.

establishes from the second period. The reversed pattern in the first period could potentially be explain by the by Gambacorta (2009) studied effect of low inflation on financial stability. As discussed, he argues that low inflation (and corresponding low interest rates) could encourage investors to search for higher yields by engaging in riskier activities. A negative shock of inflation could in that manner positively affect CISS and decrease financial stability. In the longer run, the negative effect of inflation on financial stability, by increased uncertainty and shorter investment horizons – as proposed by Schwartz (1995) - becomes visible.

When we analyse the impulse response function of CISS to GDP growth, we find that GDP growth positively affects financial stability in the short run. The VEC estimates indicate that this is a significant negative relationship between GDP growth and CISS at the 10% level, indicating that GDP growth would foster financial stability.[20] In the long run however, the impulse response function indicates that GDP growth can negatively affect financial stability, which could potentially be explained by the assumption that periods of prolonged economic growth could lead to an increase in risk-taking.

Figure 4 provides the corresponding impulse response functions for the relation between inflation and financial stability and GDP growth.

Figure 4: Response of Inflation to GDP growth (left) and to CISS (right)

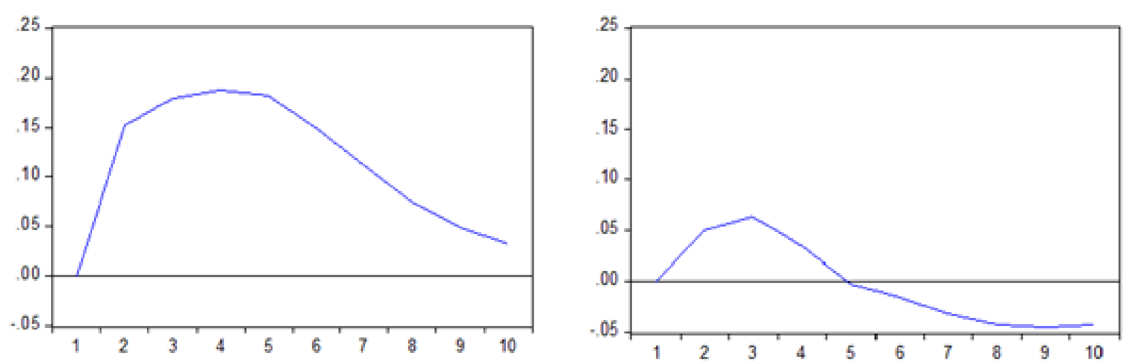


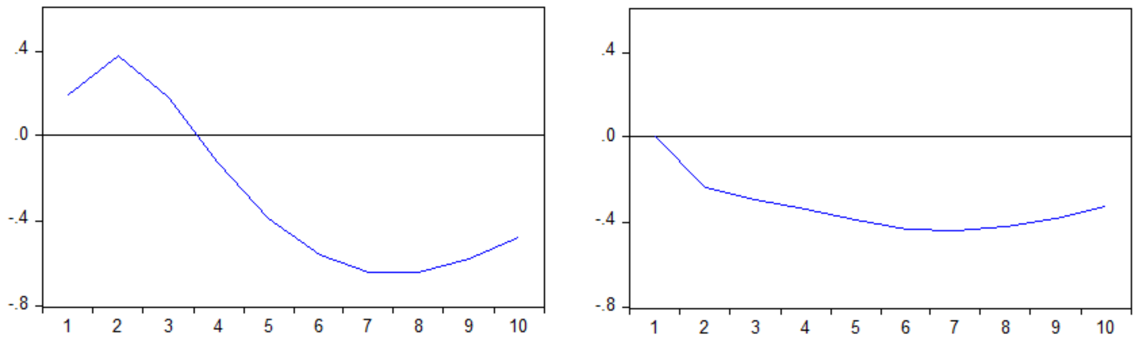
Figure 4 indicates that an increase in GDP growth would lead to an increase in inflation, which is a significant effect at the 5% significance level according to our VEC estimations. The relationship between financial stability and inflation is less explicit. An increase in CISS, and thus a decrease in financial stability, would lead to an increase in inflation in the first 5 periods, where after inflation

[20] The confidence bands of the VAR model in levels, presented in Appendix 1.4, also indicated that this is a significant effect.

would decrease. However, we find the effect of financial stability on inflation to be insignificant in our VEC estimations.

Finally, figure 5 presents the impulse response functions of GDP growth to Inflation and CISS.

Figure 5: Response of GDP growth to Inflation (left) and to CISS (right)



The impulse response function of GDP growth to Inflation indicates that an increase in inflation would lead to an increase in GDP growth in the short run, and a decrease in GDP growth in the long run. However, our VEC estimations indicate that the effect of inflation on GDP growth is insignificant.[21] The effect of financial stability is more clearly; an increase in CISS, and thus a decrease of financial stability, will negatively affect GDP growth. This effect is significant at the 10% significance level. Our VEC estimations furthermore identify a significantly positive relationship between Loans to the NFC and GDP growth and a positive significant effect of M3 growth on GDP growth.

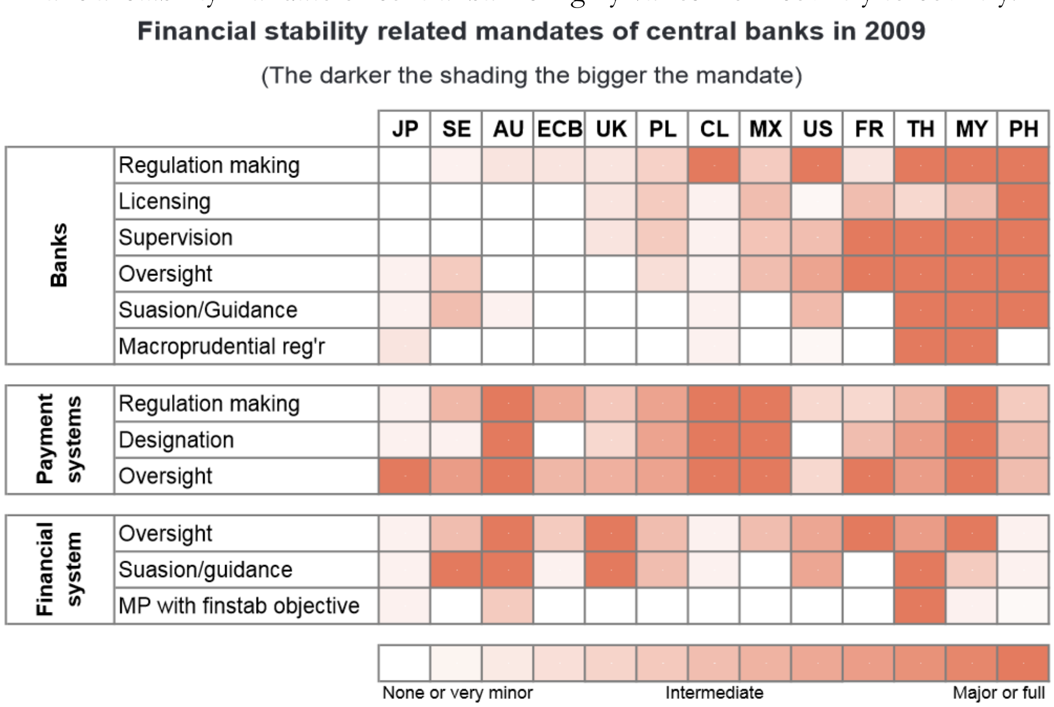
From the analysis above can be concluded that price stability, financial stability and GDP growth are highly interacting. We find evidence that, in line with our hypothesis, price stability significantly improves financial stability, while also GDP growth significantly affects both fields. We do not find a similar significant effect of financial stability on inflation. Despite the conclusion that price stability fosters financial stability, we cannot conclude that price stability is a sufficient condition for financial stability. As can be seen in the graphical visualisation of inflation and CISS,[22] a relatively stable (and close to the target of 2.0%) inflation before 2007 did not prevent the severe financial instability to develop that caused the recent financial crisis. Furthermore, as discussed in our theoretical discussion in chapter 3.1, also the policy instruments for price and financial stability are working on all three fields, and are potentially interacting, complementary or even conflicting. Monetary policy and inflation have

[21] The VAR estimates in levels, presented in Appendix 1.4. show a significant negative relation between inflation and GDP growth, indicating that a rise in inflation would lead to a decrease in GDP growth.
[22] See Appendix 1.1.

an impact on financial stability and the real economy, while macroprudential tools can equally affect credit growth and potential imbalances, and thus economic prosperity and price stability. The finding that these three fields are mutually depended, and the indication that price stability might add to, but cannot guarantee financial stability, raises the question what role monetary policy should play in preserving financial stability and how the responsibility for the policymakers in these fields should be divided.

4. The role of the Central Bank in maintaining financial stability

The level of interaction between price and financial stability shown above and the potential interaction between the monetary and macroprudential policy instruments have direct consequences for the effectiveness monetary and macroprudential policy. This legitimizes the question how the institutional design for both fields should look like and what the role of the central bank should be in the conjunction of these fields. In 2011, the Bank for International Settlement published an influential report on central bank governance and financial stability (BIS, 2011). In this report, the BIS elaborated on the different institutional frameworks in which central banks were involved in financial stability. The study showed a large variety of mandates between different central banks. As is shown by figure 6, the financial stability mandate of central banks highly varies from country to country.[23]



[23] As a result of the crisis, multiple central banks have since 2009 received more responsibilities for financial stability. This resulted for example in a large share of votes for the ECB and the European national central banks in the ESRB, while also in the UK the central bank has been given an explicit mandate for both macro and microprudential policy. The

4.1 Three perspectives on the combination of monetary and macroprudential policy

The discussion on the involvement of the central bank in financial stability, and under which conditions, received more attention after the crisis. Although the literature on this field is in its infancy, and consensus on the interaction between monetary and macroprudential policy is far from reached (Bundesbank, 2015), three main views can be distinguished on how much both policy fields should be aligned to achieve the set objectives.[24]

4.1.1 *The separated perspective*

Supporters of the separated perspective argue that monetary policy and macroprudential policy should be executed separately. Monetary policy must focus on its narrow mandate of price stability and macroprudential policy should focus on financial stability, each with their own instruments (Bundesbank, 2015; Smets, 2014; Gerba and Macchiarelli, 2015).[25] Monetary policy should in this perspective only take financial stability considerations into account if they directly affect price stability. The main development with the pre-crisis situation is the acknowledgment of the need for effective and credible macroprudential policy to maintain financial stability (Bundesbank, 2015). The main underlying assumption of this perspective is that both policy fields are sufficiently capable to achieve the goal of price stability and financial stability on its own, with its own instruments. This perspective lies closest the earlier discussed hypothesis of Schwartz (1995) who argued that price stability 'is the route to financial stability'. In the literature, the separated perspective is also often called the 'conventional approach' (Blot et al., 2015; Committee on International Economic Policy and Reform, 2011), referring to the convention practice at central banks that monetary policy pursues the narrow goal of price stability, while regulatory macroprudential policy targets financial stability. This vision is also reflected in the institutional setup of the Bundesbank and the ECB, where much attention is paid to independence and clear mandates.[26]

4.1.2 *The extended perspective*

Fed has been charged with the regulation of systemic banks, and has a voting right in the Financial Stability Oversight Council. For more information on current developments, see Smets (2014).

[24] These perspectives are, among others discussed by Bundesbank (2015), Smets (2014) and Gerba and Macchiarelli (2015).

[25] The Bundesbank (2015) describes this perspective as 'the idealised perspective', while Smets (2014) uses the term 'a modified Jackson Hole Consensus'.

[26] Amtenbrink (2005).

The extended perspective[27] is based on the view that monetary policy should primarily be aimed at price stability, but that a too narrow focus on short term price stability, as was custom before the crisis, prevents monetary policy from tackling longer term financial imbalances (Bundesbank, 2015; Smets, 2014; Gerba and Macchiarelli, 2015). This broader focus would also be in line with the aim of price stability on the longer term. The view stresses that macroprudential policy cannot fully preserve financial stability with macroprudential policy tools alone, but should operate in conjunction with monetary policy (Bundesbank, 2015). Financial stability considerations should therefore be part of monetary policy, as secondary objectives (Smets, 2014). The view thereby takes the effect of monetary policy on financial stability into consideration and argues that monetary policy should lean more aggressively against the wind in case of rising financial imbalances. The institutional setup of the Fed is grounded on this view, which is also largely supported by the Bank of International Settlements. Also, some of the late policy measures in the field of financial stability by the ECB can be seen to be based on this view (Gerba and Macchiarelli, 2015).

4.1.3 Integrated perspective

Supporters of the final view, the integrated perspective, still see an excessively and ineffectively strict separation between price and financial stability in the extended perspective (Bundesbank 2015; Gerba and Macchiarelli, 2015).[28] Based on the above discussed interaction between both fields, they argue that price and financial stability are so deeply intertwined, and that the instruments and transmission channels for both fields are likewise highly interacting, that it is both ineffective as impossible to clearly separate both objectives. Financial market conditions should therefore always be part of monetary decision-making. Monetary and macroprudential policy should be used simultaneously and in conjunction to ensure price and financial stability at the same time (Bundesbank 2015). It is in this light that the Committee on International Economic and Policy Reform (2011) argued to abandon the Tinbergen Rule and advocated to see monetary and macroprudential objectives as a joint-optimization problem. The main underlying argument is that, as a result of the impact of monetary policy on the build-up of risk, for example by the risk-taking channel, a too narrow focus on price stability will result in financial imbalances. If monetary policy does not preventively take financial stability considerations into account, both financial and price stability will be endangered (Bundesbank, 2015).

[27] Smets (2014) calls this 'Leaning against the Wind Vindicated'.
[28] Smets (2014) calls this 'Financial Stability is Price Stability'.

4.2 Research on the effectiveness and institutional set-up of monetary and macroprudential policy

All three perspectives have in common that they acknowledge some interaction between price stability and financial stability, and that they endorse the need for an effective field of macroprudential policy with its own instruments to preserve financial stability. The main question is whether monetary policy and the central bank should play an important role in financial stability. The empirical evidence on the high level of interaction presented in subsection 3.4 makes an argument to adopt an perspective which incorporates financial stability in monetary decision-making. Due to these interactions, central banks will need to consider the trade-offs between these fields, which would lead to the incorporation of financial stability considerations in the monetary field. The academic literature on the discussion on the best institutional setup for the conduct of financial stability policy is however still limited. Most of the literature does find the benefits of the complementary nature of both fields, while others stress the potential trade-offs and potential conflict of interest. We discuss a selection.

In a dynamic general equilibrium model with a banking sector, Angelini et al. (2014) analyse the interaction between capital requirements and monetary policy. They find only modest benefits of capital requirements in normal times, compared to a situation where only monetary policy is used for stabilization policies. They identify a need for cooperation between both authorities to obtain these gains. However, in case of financial shocks affecting the supply of credit, the benefits of a capital requirements policy tool yields a significant asset for macroeconomic stabilization, especially when both authorities cooperate.

De Paoli and Paustian (2013) analyse in which way monetary and macroprudential policy should be conducted to most effectively handle macroeconomic fluctuations. In a New Keynesian model with normal rigidities and credit constraints, which also includes credit frictions, they shed light on the effects of introducing macroprudential policies and the potential coordination issues. They conclude that the introduction of a macroprudential policy tool aimed at credit market distortions can substantially improve welfare after a cost-shock. Furthermore, they find that choosing a macroprudential policy tool which is too similar to that of monetary policy can lead to costly coordination problems between the policymakers. If there is no coordination between the monetary and macroprudential authority and the authorities act under discretion, they argue that a conservative mandate for both authorities would be welfare improving.

Quint and Rabanal (2014) developed an estimated two-country model of the euro area with real, nominal and financial friction, on which monetary and macroprudential policy have effect. They find that macroprudential policy improves general welfare by helping to reduce macroeconomic instability. Furthermore, they conclude that macroprudential policy is complementary to monetary policy, as it helps to reduce accelerator effects and thus requires a less strong reaction of the interest rates as response to financial instability. However, in certain circumstances, the introduction of macroprudential policy can have winners and losers. Especially when macroprudential regulations react to credit-to-GDP ratios, such policy can negatively affect the welfare of borrowers, while increasing general welfare.

In an analysis on US data, Gelain and Ilbas (2014) address the question how monetary and macroprudential policy should interact to preserve financial stability. They focus on the best degree of coordination between the monetary and macroprudential policymaker. They conclude that there are substantial gains from coordination when the macroprudential authority has been assigned a sufficiently important interest in the output gap, in line with the objective of the monetary policy authority. In case the macroprudential authority solely (or primarily) focusses on credit growth, better outcomes can be realized in the absence of coordination, even if in this scenario the central bank performs worse. Therefore, they conclude that the added value of macroprudential policy for monetary policy depends on the relative weight assigned to output fluctuation in the mandate of the macroprudential policy authority.

The majority of the research presented above finds considerable benefits from macroprudential policy as such and emphasize the need for coordination between the monetary and macroprudential field. The involvement of monetary policy in financial stability would improve such coordination and cooperation. Another benefit of placing the responsibility for both fields within one institution, in practice the central bank, would be that financial stability would in that case be executed by an (in the vast majority of countries) independent institution, while the experience and expertise on the financial markets present at central banks could be utilized (Bundesbank, 2015).

But also certain risk of coordination between, or even the combination of these fields can be distinguished. While research on the interaction between price and financial stability is far from reaching consensus, involvement of the monetary policy authority in achieving financial stability could cause severe credibility risks. Credibility is of vital importance for a central bank, as it steers expectations and ultimately the effectiveness of monetary policy (Borio, 2014; Bundesbank, 2015).[29] This risk entails that a central bank may not be able to deliver what they are expected to deliver. The risk may arise through several ways.

Firstly, credibility could be endangered by the multiplication of objectives and goals within the central bank. It could be unrealistic to expect a central bank to provide price stability, financial stability and simultaneously fine-tune the economy (Borio, 2014). Failure in one of these tasks could harm the credibility of the central bank as a whole. This is especially a threat for the central bank's reputation as these objectives can, as discussed above, also become conflicting. Trade-offs between these objectives can cause a severe risk to the central bank's credibility (Bundesbank, 2015). In this light, also the IMF warns that although 'policy coordination can improve outcomes, making it advantageous to assign both policies to the central bank, concentrating multiple (and sometimes conflicting) mandates in one institution can muddy its mandate, complicate accountability and reduce credibility' (IMF, 2013, p.21).

Secondly, a too strong focus on financial stability by the monetary authority could jeopardize the central banks independence. In the nineties, consensus emerged on the beneficial effect of central bank independence on price stability. Research as that of Eijffinger, Schaling and Hoeberichts (1998) or Alesina and Summers (1993) found an inverse relationship between the degree of central bank independence and inflation. Based on these findings, central bank independence is one of the main pillars of the institutional framework of central banks as the Bundesbank and the ECB (Amtenbrink, 2005). The high degree of independence is granted to central banks based on the beneficial effect of independence on the clearly defined goal of price stability. However, when monetary policy, and the central bank, is also geared towards financial stability this independence is also used to obtain a far less clearly defined objective. But financial stability is not only far less clearly to define, and thus to measure, but also more politically sensitive. Financial stability measures, either monetary or macroprudential, lie closer to the (quasi) fiscal and economic field and can effect banks or even individuals very directly (Bundesbank, 2015). This does not only raise questions of the democratic legitimacy of the central bank, but also make the central bank operate in politically contested fields, which could make the central bank more sensitive for criticism and political pressure. Ultimately, both could negatively affect the central bank's credibility and degree of independence.[30]

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[29] For an extensive analysis for the importance and development of credibility of the central bank, see Bordo and Siklos (2014).

[30] For an in-depth analysis of the importance of central bank independence and accountability and the potential consequences of the recent developments in the role of the ECB, see: Van de Laar (2015).

Finally, a time-inconsistency problem for monetary policy could arise if the central bank is also made responsible for financial stability. A time inconsistency problem arises when an optimal policy is announced to be adopted, and expectations are set as a result of that announcement. When these expectations are then given, this policy becomes suboptimal at a later point, which results in another policy to be adopted than the one announced earlier (Kydland and Prescott, 1997).

4.3 Time Inconsistency Model

To study the potential consequences of assigning the responsibility for financial stability and monetary policy both to the central bank instead of to two separate authorities, we develop a model in line with the famous paper of Kydland and Prescott (1997). In this paper, Kydland and Prescott study the output-inflation trade off. This trade-off describes how policymakers can be tempted to increase inflation to push output above its normal level, although this effect only holds in the short run (Romer, 2012). Kydland and Prescott used a quadratic loss function to show how, when expectations are rational, the inability of policymakers to commit to low-inflation policy could lead to higher inflation without the long-run trade-off due to what they call 'dynamic inconsistency' (Kydland and Prescott, 1977; Romer, 2012). Their paper has become very influential in the determination of the objectives of central banks.

To use this approach to study the effects on assigning the responsibility for financial stability to the central bank, we extend the model developed in Kydland and Prescott (1997) with a term which captures financial stability (the third term of equation (1) below). We use a simple quadratic loss function in line with earlier work as that of Ueda and Valencia (2012), Carlstrom, Fuerst and Paustian (2010), Smets (2014) and De Paoli and Paustian (2013). In our model, we use a simplified version of the loss function analysed in Ueda and Valancia (2012). This loss function is derived from the model developed in Carlstrom, Fuerst and Paustian (2010), who have integrated agency costs in the credit market into a standard Dynamic New Keynesian model with normal rigidities. The objective of the policymaker is to minimise the following loss function:

$$L = \frac{1}{2}(\pi - \pi^*)^2 + \frac{a}{2}(y - y^*)^2 + \frac{b}{2}(\theta - \theta^*)^2 \tag{1}$$

where y is output, π is inflation and θ is leverage. Starred variables identify the corresponding social optimal targets and $a > 0$ and $b > 0$. A similar loss function is used by Ueda and Valencia (2012) to analyse the effect of central bank independence, and by Smets (2014) to analyse the interlinkage of financial stability and monetary policy. De Paoli and Paustian (2013) derive a comparable loss function based on a New Keynesian Model with normal rigidities and endogenous monetary policy which incorporates credit frictions.

The quadratic loss function is a useful tool to identify how economic distortions result in welfare losses in the economy. The first term of the loss function captures price stability and explains how distortions in inflation influence welfare. The second term describes the effect of the output gap on welfare. The third term is less standard in quadratic loss functions and relates to the objective of the macroprudential authority.

It is difficult to set a clear variable that sufficiently describes the intended goal of macroprudential policy. Also in the literature, there is no common definition of a financial stability indicator that should be used in loss-functions as the one described here (Galati and Moessner, 2010). We therefore follow the approach of Smets (2014) and Ueda and Valencia (2012) and include the level of leverage in the economy. The third term thus describes the costs of deviations in leverage in the economy, and relates to debt overhang and potential financial crisis.

Leverage indicates the level of borrowed funds used to increase returns relative to the amount of own capital. We define leverage as the ratio of total assets to equity, which is in line with Gambacorta and Shin (2016). There are valid reasons to include the level of leverage in the loss function. An excessive build-up of leverage can expose severe threats to financial stability, especially when, during down turns, the financial markets force the financial sector into a destabilizing deleverage process (Basel Committee on Banking Supervision, 2014). Such an excessive build-up of leverage in the banking system is seen as an underlying cause of the Great Recession (Gambacorta and Shin, 2016). Before the crisis, loose monetary policy and relax or even absent macroprudential regulations encouraged risk-taking, leading to excessive leverage, excessive growth and a housing boom in many countries. When the economy slowed down, this trigged the financial downturn (Carmassi, Gros and Micossi, 2009; Crotty, 2009)

In our model, leverage in the economy is given by:

$$\theta = \bar{\theta} - (\pi - \pi^e) + \delta_0 \tag{2}$$

such that leverage is reduced by unexpected inflation and positively affected by the macroprudential policy tool δ_0, given the level of leverage in the steady state. We think of variable δ_0 as a macroprudential policy tool that effects credit growth in the economy, like the capital requirements, loan-to-value ratios or leverage ratio requirements discussed in subsection 2.2. Gelain and Ilbas (2014) describe this tool as a bank levy or subsidy. We assume that loosen macroprudential policy, shown by a higher value of δ_0, increases the availability of credit, which positively affects output by increased investment and consumption. This policy tool can be set by the authority responsible for financial stability. Leverage is furthermore negatively related to unexpected inflation. An unexpected rise in inflation reduces the current real value of debt.[31] In this manner, unexpected inflation can have a stabilizing effect on existing debt, which could improve financial stability (Bundesbank, 2015). Finally, we assume hereby that $\bar{\theta} > \theta^*$, meaning that there is a tendency to over-accumulate debt, leading to excessive leverage.

In line with the work of Kydland and Prescott, output in our model is given by a Lucas supply curve, augmented with a term that captures the effects of a change in the supply of credit.

$$y = \bar{y} + \alpha(\pi - \pi^e) + \beta\delta_0 \tag{4}$$

where $\bar{y}$ denotes the level of output in the steady state and π^e is expected inflation. Furthermore, we include the effect of the macroprudential policy tool on output by including δ_0. We assume that *a* and β are positive. In our model, output is thus positively affected by unexpected inflation and by easing of macroprudential policy, given $\bar{y}$. Finally, and in line with Kydland and Prescott we assume that $\bar{y} < y^*$, describing that steady state output is lower than the optimal level.

Inflation is determined by the monetary policy tool π_0, which can be set by the monetary authority. In practice, the monetary authority can only affect inflation by the interest rates. However, we assume that the monetary policymaker can effectively set inflation.[32] In a more complete model, also the feedback from output to inflation and the potential effect of macroprudential policy on inflation should be included. These effects are not included for simplicity.[33] Inflation is therefore given by:

$$\pi = \pi_0 \tag{5}$$

Expected inflation can likewise be described as:

[31] Potentially, also the assumed positive effect of unexpected inflation on output, as presented in equation (4), can have a tendency to reduce excessive leverage.
[32] We follow Kydland and Prescot (1977) in this approach.
[33] Ueda and Valancia (2012) do include the effect of macroprudential policy on inflation in their model and find comparable results.

$$\pi^e = \pi_0^e \tag{6}$$

Our model has two policy tools, π_0 and δ_0, which can be set by the responsible authority. In the next section, the model is used to illustrate the effect of assigning the financial stability objective to the monetary authority under commitment and under discretion. In the first setting, we study the case of a social planner who minimizes loss-function (1) by setting both policy tools under commitment. This implies that the social planner makes a binding commitment about what the level of inflation will be. Expected inflation is thereafter based on this commitment. This results in $\pi_0^e = \pi_0$. In the second setting, we analyse a social planner identical to the one in the first setting, but now assume that the policymaker sets the policy tools under discretion. This implies that the policymaker sets inflation taking expectations of inflation and output as given (Romer, 2012). In the third and final situation, we study a setup with two policymakers, one (the central bank) with the objective of price stability, and the other (the macroprudential authority) concerned with the objective of financial stability and output. Both authorities thereby minimize their own loss-function. We assume that the authorities set their policy tools simultaneously and under discretion.

4.3.1 Setting 1: Social planner under commitment

First we analyse a setting in which a social planner optimizes loss function (1), subject to (2) to (6), by setting π_0 and δ_0. This setting is similar to one policymaker who cares about the output gap, price stability and financial stability setting both policy tools ('the social planner' context of Ueda and Valencia (2012), p.7) or a full cooperation context between two policymakers (Gelain and Ilbas, 2014, p. 18). We assume that the social planner can commit, so that $\pi_0^e = \pi_0$. Finally, we set the optimal level of inflation π^* equal to zero for simplicity. The social planner optimizes loss-function (8):

$$L = \frac{1}{2}(\pi)^2 + \frac{a}{2}(y - y^*)^2 + \frac{b}{2}(\theta - \theta^*)^2 \tag{8}$$

Equation (2) to (6) are incorporated in loss function (8). When equation (8) is then minimized subject to π_0 and δ_0, the resulting optimal reaction functions for π_0 and δ_0 are:[34]

$$\pi_0^* = 0 \tag{9}$$

[34] The step-by-step calculations for these solutions can be found in Appendix 2.1: Setting 1.

$$\delta_0^* = \frac{a\beta}{a\beta^2 + b}\,(y^* - \bar{y}) - \frac{b}{(a\beta^2 + b)}(\bar{\theta} - \theta^*) \tag{10}$$

In social optimum, the monetary policy tool will simply be used to realize the optimal level of inflation, which is equal to zero. The macroprudential policy tool will be set by an optimization of the trade-off between the beneficial effects on welfare of a smaller output gap and the negative effects of an accumulation of debt (remember that we assume that $\bar{\theta} > \theta^*$ and $\bar{y} < y^*$). This implies that δ_0 will be set higher in case of an increased output gap, and be set lower by a higher amount of leverage compared to the optimal level.

4.3.2 Setting 2: Social planner with discretion

Secondly, we analyse a setting where the social planner (or the central bank) has a mandate for both financial stability and price stability and is also concerned with the output-gap. The central bank therefore minimizes the same loss-function as equation (8):

$$L = \frac{1}{2}(\pi)^2 + \frac{a}{2}(y - y^*)^2 + \frac{b}{2}(\theta - \theta^*)^2 \tag{11}$$

We assume that the social planner operates under discretion and takes expected inflation as given. When the social planner sets loss-function (11) subject to (2) to (6) under discretion, this results in the following loss-function:

$$L = \frac{1}{2}(\pi_0)^2 + \frac{a}{2}(\bar{y} + \alpha(\pi_0 - \pi^e) + \beta\delta_0 - y^*)^2 + \frac{b}{2}(\bar{\theta} - (\pi_0 - \pi^e) + \delta_0 - \theta^*)^2 \tag{12}$$

When the social planner optimizes loss-function (12) to π_0 and δ_0, this results in the following optimal reaction functions for π_0 and δ_0:[35]

$$\pi_0^* = \frac{a\alpha}{1 + a\alpha^2 + b}(y^* - \bar{y}) + \frac{b}{1 + a\alpha^2 + b}(\bar{\theta} - \theta^*) + \frac{a\alpha^2 + b}{1 + a\alpha^2 + b}\pi^e + \frac{b - a\alpha\beta}{1 + a\alpha^2 + b}\delta_0 \tag{13}$$

$$\delta_0^* = \frac{a\beta}{a\beta^2 + b}(y^* - \bar{y}) - \frac{b}{a\beta^2 + b}(\bar{\theta} - \theta^*) + \frac{b - a\alpha\beta}{a\beta^2 + b}(\pi_0 - \pi^e) \tag{14}$$

Equation (13) indicates that instead of the earlier retrieved result of an inflation of zero, the policymaker now has an incentive to allow a higher inflation to achieve a smaller output gap and lower

[35] The step-by-step calculations for these solutions can be found in the Appendix 2.2: Setting 2.

excessive leverage (as we assume that $\bar{\theta} > \theta^*$ and $\bar{y} < y^*$). As the policymaker operates under discretion, it takes the expected inflation as given. When expected inflation is equal to (or larger than) the optimal level of inflation of zero, equation (13) shows that the optimal reaction for the policymaker is to pursue expansionary monetary policy to achieve a smaller output gap and to lower the real debt burden. A larger output gap and a larger level of excessive leverage will therefore lead to higher inflation. This tendency could be constraint by the macroprudential policy tool given in the last term of equation (13) in case of a negative sign. To see how the macroprudential policy tool affects the resulting level of inflation, we take a closer look at δ_0^*.

The optimal reaction function of δ_0^* remains an optimization of the trade-off between the beneficial effects on welfare of a smaller output gap and the negative effects of excessive leverage. However, the macroprudential tool now also incorporates the beneficial effects of unexpected inflation on the output gap and the level of excessive leverage. To identify the effect of δ_0^* in (13), we take a closer look at the probable sign of δ_0^*. To solve (13) and (14) jointly for π_0 and δ_0, we simplify and rewrite the equations by: [36]

$$\delta_0^* = A + B(\pi_0 - \pi^e) \tag{15}$$

And:

$$\pi_0^* = C + D\delta_0 \tag{16}$$

When we subsequently solve equations (15) and (16) for δ_0^*, this results in:

$$\delta_0^* = \frac{A + BC - B(\pi^e)}{1 - BD} \tag{17}$$

Although we can conclude that C has a positive sign, such conclusions cannot be drawn for A, B and D. The sign of δ_0^* will therefore be determined by the effectiveness of macroprudential policy and unexpected inflation on output and leverage, and their respective weight in the loss-function of the policymaker.[37]

This leads to the conclusion that the central bank would especially allow for higher unexpected inflation, when the macroprudential policy tool proves to be insufficiently effective, or when after a

[36] Again, the step-by-step calculations can be found in Appendix 2.2: Setting 2.
[37] The interpretation of the sign of A, B, C and D can be found in Appendix 2.2: Setting 2.

shock, only monetary policy can be adjusted in the short run.[38] When, for example, the macroprudential policy δ_0^*, as lending or capital requirements, is set too low and thus not effective in limiting excessive leverage, the burden of stabilizing the economy is ultimately at the monetary policy tool. In that case, it would be optimal for the monetary authority to allow for higher inflation to stabilize the real debt burden.

The main argument of Kydland and Prescott (1977) is that over the long term, the tendency to allow higher inflation will not have beneficial effects. This also holds in our setting. As expectations are rational, expected inflation will equal actual inflation over time as the public will know that the policymaker will have an incentive to deviate from the expected inflation once the expectations are formed (Romer, 2012). The policymaker's objective of price stability, financial stability and output optimization will over time lead to higher inflation, which in the long run will not have a beneficial effect on financial stability and output. The fact that the social planner also has financial stability and minimization of the output gap as its objectives leads to an inefficiently high inflation.

4.3.3 Setting 3: Two authorities with discretion, separate mandates

In the analysis of the setting of a social planner, or a central bank with a triple (or dual) mandate, we concluded that when acting under discretion, this leads to a suboptimal outcome. In the third setting, we analyse a regime in which we have two authorities, who each set their own policy tool under discretion. We hereby assume that both authorities minimize their own loss-function, subject to their respective objective. As a result of its mandate, the central bank has price stability as its sole objective. In our model, the macroprudential authority receives a double mandate and aims to stabilize the economy by controlling for deviations of output from the optimal level and safeguards financial stability by controlling the level of leverage in the economy. This assumption is contrary to Ueda and Valencia (2012), who only assume a financial stability mandate for the macroprudential authority. However, as also the Basel Committee on Banking Supervision describes 'reducing the risk from spill overs from the financial sector to the real economy' as one of the main objectives of macroprudential policy, we include output as an objective of the macroprudential authority (Basel Committee on Banking Supervision, 2010c, p.1). This is also in line with the main conclusion from Gelain and Ilbas (2014), who conclude that there are considerable gains from coordination when the macroprudential

[38] Ueda and Valencia (2012) use the fact that monetary policy is easier and more frequently adjusted to indicate the time inconsistency of a duel mandate central bank.

authority has been assigned a sufficiently important interest in the output gap. This approach is also followed by Angelini et al. (2011).

Again, we assume that the optimal level of inflation is zero. As we assume that both authorities have their own objective, the resulting loss-function of the central bank is given by:

$$L_{CB} = \frac{1}{2}(\pi)^2 \tag{18}$$

As the macroprudential authority only has a mandate for financial stability and output, the loss-function of the macroprudential authority is given by:

$$L_{MA} = \frac{a}{2}(y - y^*)^2 + \frac{b}{2}(\theta - \theta^*)^2 \tag{19}$$

When the central bank minimizes (18) subject to (2) to (6), this results in the following optimal value for π_0: [39]

$$\pi_0^* = 0 \tag{20}$$

As the central bank only has a mandate for price stability, it will only focus on inflation. The central bank will therefore use its instrument π_0 to reach the optimal level of inflation of zero, equal to the social optimum realized before.

The macroprudential authority's loss-function is given by equation (19). When the macroprudential authority incorporates (2) to (6) in this loss-function and minimizes for policy tool δ_0, this results in the following optimal value for δ_0:

$$\delta_0^* = \frac{a\beta}{a\beta^2 + b}(y^* - \bar{y}) - \frac{b}{a\beta^2 + b}(\bar{\theta} - \theta^*) + \frac{b - a\alpha\beta}{a\beta^2 + b}(\pi_0 - \pi^e) \tag{21}$$

When the sole objective for price stability is pursued by central bank, the optimal value of inflation of zero is achieved, even if the central bank has discretion. The public knows that the central bank will only focus on price stability and will set the inflation to zero. This means that also the optimal value for the macroprudential policy tool is achieved again, and become similar to the optimal reaction function we derived under commitment.

[39] The step-by-step calculations for these solutions can be found in the Appendix 2.3: Setting 3.

Our model indicates that a time-inconsistency problem could occur when the institutional framework does not sufficiently guarantee that the monetary policy authority does not deviate from its announcements on inflation, and allows for higher inflation to lower the real value of debt, improve financial stability and lower the output gap.[40] This will over time lead to higher inflation, but will, in line with Kydland and Prescott (1997), not have a beneficial effect on financial stability and output in the long run.

Such an incentive arises when the central bank is given a multiple mandate and is made responsible for price stability, financial stability and output. This problem can be avoided by a clear separated mandate between the monetary authority and the macroprudential authority. A reliable and clear prioritization for the objective of price stability could also lead to (more) optimal outcomes.

The model presented above is based on strong assumptions which potentially do not hold in the real economy. Therefore, these conclusions cannot directly be projected on the real economy. Nonetheless, evidence that these risks are materializing in practice are not too difficult to find. High levels of (public) debt overhang are one of the potentially enduring legacies of the recent financial crisis (Committee on International Economic Policy and Reform, 2011). Monetary authorities have been carrying out unprecedented non-conventional monetary measures, while the implementation of stricter macroprudential measures as capital and liquidity ratios for banks has faced severe resistance (Borio, 2014).

5. Discussion

As a response to the recent financial crisis, multiple central banks have been given new financial stability responsibilities. Despite the importance of this development, research on the effect of these new responsibilities has been scarce. This thesis has aimed to add to the limited, but growing field of literature on the interrelation of price and financial stability, and the consequences of this interaction for the central bank.

The fact that main central bank as the ECB or the BoE have only recently been given financial stability responsibilities makes that data on the effect of this change is very scare. The effect of the new responsibilities is difficult to study directly at this stage. Over time, further (empirical) research is required to see whether multiple objectives indeed give rise to an incentive for the central bank to

[40] These conclusions are in line with Ueda and Valencia (2012), who studied the optimal institutional setup for the agencies that conduct monetary and macroprudential policy in a more extensive, two-stage model.

allow for higher inflation under specific circumstances. Also a direct comparison between multiple central banks with different institutional set-ups and objectives would form a very interesting addition to this field of literature. Such research could give a more clear answer to the question whether risks, as those presented in this thesis, in practice materialize.

6. Conclusion

The financial crisis has demonstrated the need for an effective framework of macroprudential policy to maintain financial stability. The increased attention on financial stability has in many countries resulted in the introduction of new responsibilities in this field and the development of corresponding macroprudential policy tools. The implications of this development on monetary policy and the central bank has been the main theme of this thesis.

This thesis has firstly focussed on how price and financial stability – and monetary and macroprudential policy- interact. Subsequently, we aimed to analyse the potential consequences of this interaction for the role the central bank, and monetary policy, should play in maintaining financial stability.

Our empirical analysis has shown that price stability, financial stability and GDP growth are highly interacting. In line with our hypothesis, we conclude that price stability fosters financial stability, while both price stability and financial stability are interacting with GDP growth. Furthermore, we have presented evidence that monetary policy tools are intimately interacting with main determinants of financial stability, as credit supply and risk-taking. Likewise, macroprudential policy tools can have major impact on the effectiveness of monetary policy, as exemplified by the LCRs. Although we found that price stability has a positive effect on financial stability, in line with the price stability orientated policy frameworks existing at most central banks before the crisis, this does not mean that price stability is a sufficient condition for financial stability.

The finding that these fields, and their policy tools, are highly interacting and mutually depended has major consequences for the role monetary policy and the central bank should play in preserving financial stability. We distinguished three main views on how much both policy fields should be aligned: the separated perspective, the extended perspective and the integrated perspective.

The empirical evidence on the high level of interaction presented in this thesis makes an argument to adopt a perspective which incorporates financial stability in monetary decision-making. Due to these interactions, central banks must consider the trade-offs between these fields, which inevitable leads to the incorporation of financial stability considerations in the monetary field. Denial of this tension between price stability and the other objectives, and refraining from addressing it, could harm the reputation of the central bank. The involvement of the central bank in financial stability would furthermore improve coordination and cooperation between these fields. The experience and expertise on the financial markets present at the central bank, combined with the high level of independence granted to most central banks, could be utilized to reach both objectives. These arguments make a strong case for the adoption of an explicit financial stability mandate for the central bank. However, the incorporations of financial stability considerations at the central bank, or the adoption of an explicitly defined financial stability objective with corresponding macroprudential policy tools, is not without risks.

The multiplication of objectives could harm the reputation of the central bank. The potentially conflicting character of price and financial stability could cause trade-offs which complicates the central bank's accountability and harms its credibility. Operating at the politically tensed field of financial stability could make the central bank more sensitive for criticism and political pressure, which ultimately harms its credibility and independence. Finally, the multiplication of objectives could lead to a time-inconsistency problem is the central bank operates under discretion.

To illustrate the time-inconsistency problem, we developed a model in line with that of Kydland and Prescott (1997). Under discretion, we showed that the optimal reaction for the policymaker is to pursue expansionary monetary policy to achieve a smaller output gap and a lower level of excessive leverage. This is especially the case when macroprudential policy proves to be insufficiently effective. The combination of the objectives of price stability, financial stability and output optimization will lead to higher inflation, which in the long run will not have a beneficial effect on financial stability and output. A potential solution here could be a clear separation of mandates or a clear prioritization to the objective of price stability.

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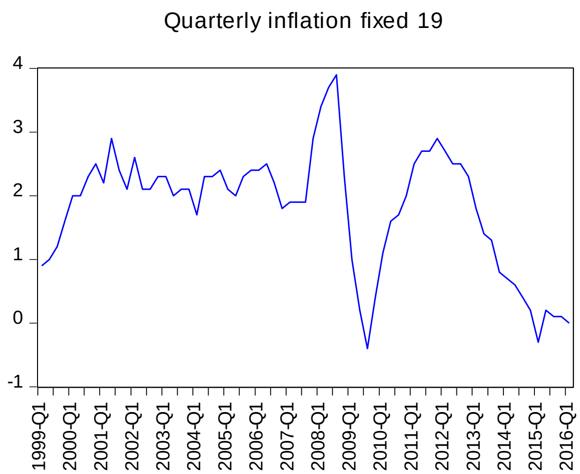
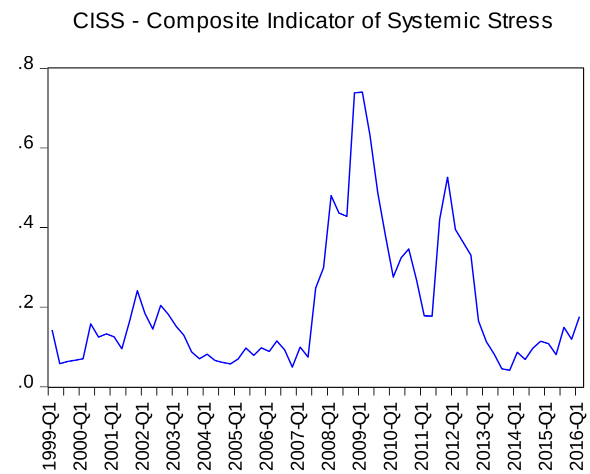
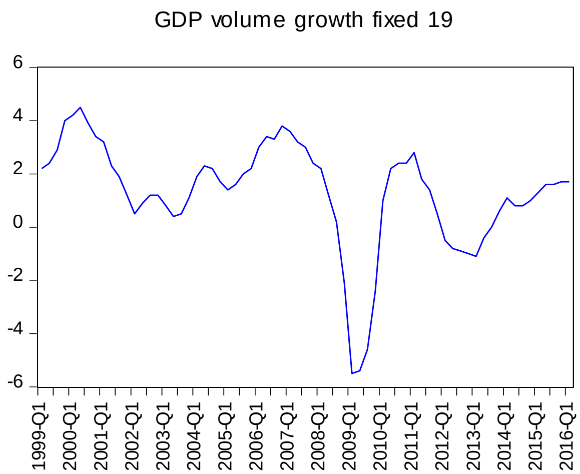
Appendix

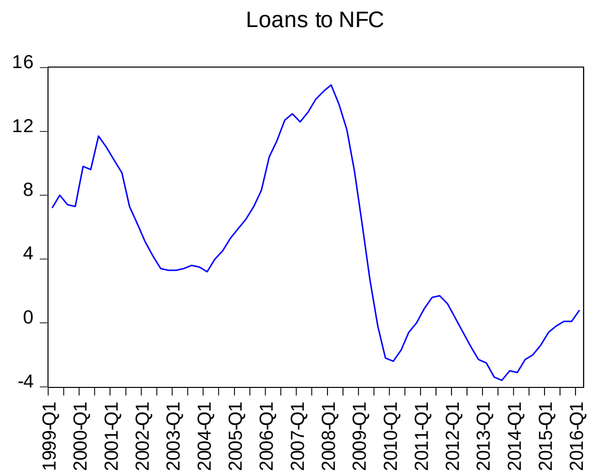
1. VAR analysis

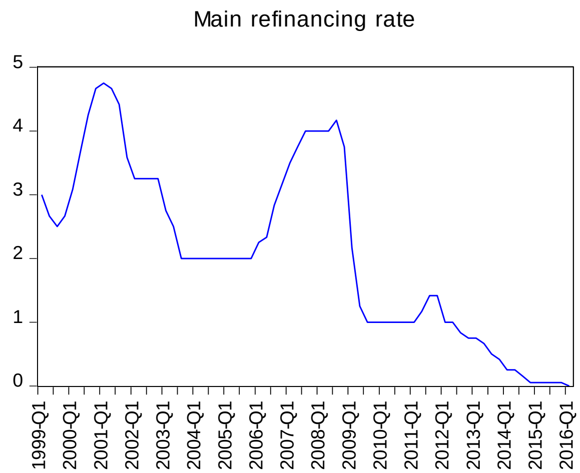
1.1 Graphical visualisation variables

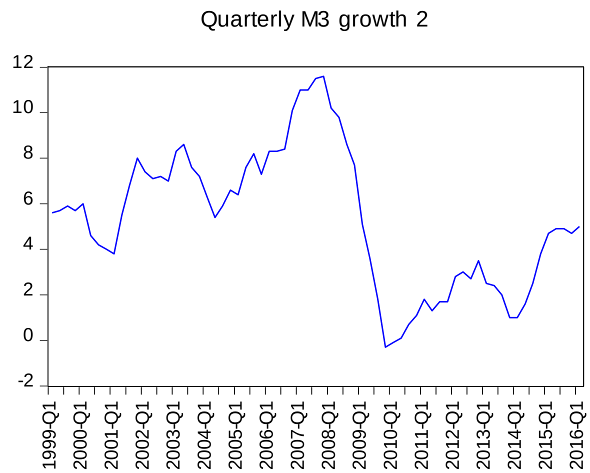












1.2 Phillips-Perron stationarity test

Variable	Trend, intercept or no trend no intercept	T-statistic (p-value)
CISS	None	-1.226 (0.20)
GDP growth	None	-2.236 (0.03)
Index loans to NFC	None	-1.429 (0.14)
Main refinancing rate	None	-1.234 (0.19)
Inflation	Trend and intercept	-2.812 (0.20)
Quarterly M3 growth	None	-0.919 (0.32)
ΔCISS	None	-6.898 (0.00)
Δ GDP growth	None	-4.088 (0.00)
Δ Index loans to NFC	None	-3.582 (0.00)
Δ Main refinancing rate	None	-3.980 (0.00)
Δ Inflation	None	-5.831 (0.00)
Δ Quarterly M3 growth	None	-5.29 (0.00)

Significance levels are given in parentheses. Bandwidth (Newey-West automatic) using Bartlett Kernel.

1.3 Vector Error Correction model estimations

Vector Error Correction Estimates
Included observations: 66 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
INFLATION(-1)	1.000000
LOANS TO NFC(-1)	-0.179961 (0.14643) [-1.22897]
M3 GROWTH(-1)	0.295185** (0.15842) [1.86329]
MAIN REFINANCING RATE(-1)	-1.225764* (0.44031) [-2.78389]
GDP GROWTH(-1)	2.635980* (0.44154) [5.97003]
CISS(-1)	9.224806* (3.07393) [3.00098]
C	-5.199716

Error Correction:	D(INFLATION)	D(LOANS TO NFC)	D(M3 GROWTH)	D(MAIN REFINANCING RATE)	D(GDP GROWTH)	D(CISS)
CointEq1	0.021564 (0.03995) [0.53972]	0.061906 (0.05879) [1.05300]	-0.031748 (0.08179) [-0.38816]	0.047394* (0.01906) [2.48632]	-0.176881* (0.04607) [-3.83938]	-0.001505 (0.00733) [-0.20517]

D(INFLATION(-1))	0.039019	-0.260890	0.033885	0.030613	0.276466	0.049118**
	(0.16166)	(0.23788)	(0.33095)	(0.07713)	(0.18641)	(0.02968)
	[0.24136]	[-1.09673]	[0.10239]	[0.39690]	[1.48308]	[1.67499]
D(INFLATION(-2))	-0.078452	-0.312008	0.147941	-0.205833*	-0.237604	0.039047
	(0.16647)	(0.24495)	(0.34078)	(0.07942)	(0.19195)	(0.03056)
	[-0.47128]	[-1.27376]	[0.43412]	[-2.59160]	[-1.23782]	[1.27769]
D(LOANS TO NFC(-1))	0.014571	0.211165**	0.055015	0.032629	0.172642**	0.016405
	(0.07964)	(0.11719)	(0.16304)	(0.03800)	(0.09184)	(0.01462)
	[0.18295]	[1.80188]	[0.33743]	[0.85868]	[1.87987]	[1.12202]
D(LOANS TO NFC(-2))	-0.045971	0.323734*	0.031701	0.045302	0.216428*	-0.013414
	(0.08047)	(0.11840)	(0.16473)	(0.03839)	(0.09279)	(0.01477)
	[-0.57131]	[2.73414]	[0.19244]	[1.18001]	[2.33252]	[-0.90805]
D(M3 GROWTH(-1))	-0.029469	-0.146283	0.224891	-0.080091*	-0.096517	0.004632
	(0.07215)	(0.10617)	(0.14771)	(0.03443)	(0.08320)	(0.01325)
	[-0.40842]	[-1.37780]	[1.52252]	[-2.32652]	[-1.16005]	[0.34970]
D(M3 GROWTH(-2))	0.058074	0.332644*	0.237802	-0.017436	0.202595*	-0.001298
	(0.07407)	(0.10899)	(0.15163)	(0.03534)	(0.08541)	(0.01360)
	[0.78408]	[3.05216]	[1.56834]	[-0.49340]	[2.37212]	[-0.09546]
D(MAIN REFINANCING RATE(-1))	-0.030841	-0.350904	-0.005181	0.344950*	0.174370	0.046637
	(0.28695)	(0.42224)	(0.58743)	(0.13691)	(0.33088)	(0.05268)
	[-0.10748]	[-0.83106]	[-0.00882]	[2.51959]	[0.52698]	[0.88530]
D(MAIN REFINANCING RATE(-2))	0.130601	-0.072357	0.881097	-0.163084	-0.402148	0.026701
	(0.26209)	(0.38566)	(0.53655)	(0.12505)	(0.30222)	(0.04812)
	[0.49830]	[-0.18762]	[1.64216]	[-1.30418]	[-1.33063]	[0.55492]

D(GDP GROWTH(-1))	0.356325*	0.746214*	0.320606	0.054674	0.644323*	-0.034602**
	(0.10476)	(0.15415)	(0.21446)	(0.04998)	(0.12080)	(0.01923)
	[3.40133]	[4.84077]	[1.49493]	[1.09387]	[5.33377]	[-1.79913]
D(GDP GROWTH(-2))	-0.050664	0.207801	-0.082652	-0.029212	0.139949	-0.012758
	(0.09679)	(0.14242)	(0.19814)	(0.04618)	(0.11161)	(0.01777)
	[-0.52345]	[1.45907]	[-0.41714]	[-0.63259]	[1.25394]	[-0.71797]
D(CISS(-1))	0.522566	-0.742286	-1.174628	-1.556932*	-1.753179**	0.069154
	(0.81550)	(1.19998)	(1.66946)	(0.38908)	(0.94036)	(0.14971)
	[0.64079]	[-0.61858]	[-0.70360]	[-4.00153]	[-1.86437]	[0.46191]
D(CISS(-2))	1.205716	1.664255	1.251492	-0.033344	1.762817	-0.272491
	(0.94283)	(1.38735)	(1.93015)	(0.44984)	(1.08719)	(0.17309)
	[1.27882]	[1.19959]	[0.64839]	[-0.07412]	[1.62144]	[-1.57427]
C	-0.014308	-0.052752	0.047330	-0.024428	0.025830	0.005950
	(0.05214)	(0.07673)	(0.10674)	(0.02488)	(0.06013)	(0.00957)
	[-0.27440]	[-0.68754]	[0.44340]	[-0.98190]	[0.42960]	[0.62153]
R-squared	0.345430	0.797423	0.326322	0.729567	0.777227	0.313284
Adj. R-squared	0.181787	0.746778	0.157902	0.661959	0.721534	0.141605
Sum sq. resids	8.403491	18.19549	35.21836	1.912944	11.17387	0.283228
S.E. equation	0.402002	0.591535	0.822968	0.191800	0.463554	0.073802
F-statistic	2.110881	15.74555	1.937553	10.79110	13.95552	1.824824
Log likelihood	-25.63669	-51.13007	-72.92307	23.20344	-35.03943	86.23829
Akaike AIC	1.201112	1.973639	2.634032	-0.278892	1.486043	-2.189039
Schwarz SC	1.665584	2.438111	3.098505	0.185580	1.950515	-1.724567
Mean dependent	-0.018182	-0.100000	-0.013636	-0.037879	-0.018182	0.001706
S.D. dependent	0.444422	1.175520	0.896813	0.329887	0.878444	0.079657

Significant at a 5% significance level marked by * (|t-stat|>2.00), significant at a 10% significance level marked by ** (|t-stat|>1.671).

1.4 Robustness test

To make our results more robust, we also run the model in levels as a VAR model. We especially do this as, intuitively, we had expected that our variables would face less stationarity problems. The variables GDP, Loans to NFC, Inflation and M3 are all growth rates, which suggest that the distribution of these variables would not change in time. As similar argument can be made for the CISS indicator, which has a value between [0,1].

The results from the VAR model show a very similar picture as the results presented above. As in the VEC model, inflation has a significant positive effect on financial stability indicator CISS at the 10% significance level, indicating that a rise in inflation would lead to increased financial instability. The significant positive effect of GDP growth on financial stability becomes insignificant in our VAR estimations.

Similar to the VEC estimates, the VAR estimates indicated that an increase in GDP growth results in an increase in inflation, which is a significant effect at the 5% significance level. Also the relationship between inflation and the financial stability indicator does not changes and remains insignificant and positive.

When we compare the results for GDP growth, it is interesting to see that the negative effect of inflation on GDP growth becomes significant in for the second lag. As in the VEC model, Loans to NFC has a positive and significant effect on GDP growth, while we again find a negative significant effect of CISS on GDP growth, indicating that a decrease in financial stability harms GDP growth.

The high R-square value presented in the VAR estimates below could indicate a flaw in this model; a flaw which is also indicated by the non-stationarity results in our stationarity tests.

1.4.1 *VAR estimates in levels*

Vector Autoregression Estimates
Included observations: 67 after adjustments
Standard errors in ( ) & t-statistics in [ ]

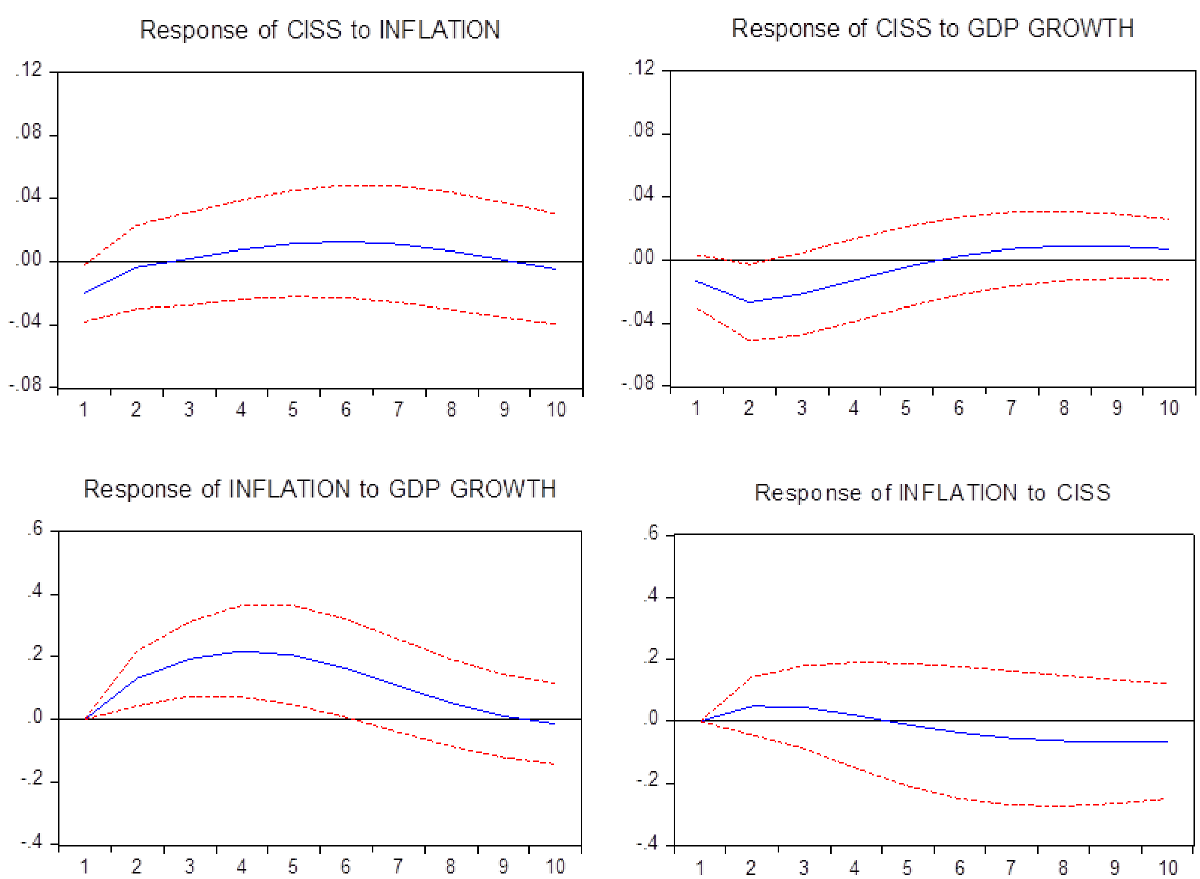
	INFLATION	LOANS TO NFC	M3 GROWTH	MAIN REFINANCING RATE	GDP GROWTH	CISS
INFLATION(-1)	0.869123*	0.115118	0.135786	0.097365	0.177687	0.051796**
	(0.15396)	(0.25163)	(0.32098)	(0.07815)	(0.20230)	(0.03079)
	[5.64506]	[0.45749]	[0.42304]	[1.24583]	[0.87835]	[1.68235]
INFLATION(-2)	-0.048815	-0.019370	-0.087426	-0.087753	-0.452037*	-0.048455
	(0.15429)	(0.25217)	(0.32166)	(0.07832)	(0.20273)	(0.03085)
	[-0.31639]	[-0.07681]	[-0.27179]	[-1.12046]	[-2.22977]	[-1.57046]
LOANS TO NFC(-1)	0.066231	0.977018*	-0.060388	0.027226	0.198338**	3.54E-05
	(0.08168)	(0.13350)	(0.17029)	(0.04146)	(0.10733)	(0.01633)
	[0.81083]	[7.31839]	[-0.35461]	[0.65663]	[1.84797]	[0.00217]
LOANS TO NFC(-2)	-0.095662	-0.015916	0.081298	0.014107	-0.124308	0.002975
	(0.08307)	(0.13577)	(0.17319)	(0.04217)	(0.10915)	(0.01661)
	[-1.15154]	[-0.11722]	[0.46941]	[0.33454]	[-1.13885]	[0.17909]
M3 GROWTH(-1)	0.000871	-0.114602	1.132215*	-0.072312*	-0.155131**	0.005573
	(0.06575)	(0.10746)	(0.13707)	(0.03337)	(0.08639)	(0.01315)
	[0.01325]	[-1.06651]	[8.26016]	[-2.16673]	[-1.79575]	[0.42385]
M3 GROWTH(-2)	0.019351	0.220973**	-0.249745**	0.059272**	0.099094	-0.005113
	(0.06801)	(0.11115)	(0.14178)	(0.03452)	(0.08936)	(0.01360)
	[0.28455]	[1.98813]	[-1.76153]	[1.71703]	[1.10900]	[-0.37600]
MAIN REFINANCING RATE(-1)	-0.039013	-0.762463*	-0.109337	1.072063*	-0.285879	0.071894
	(0.26096)	(0.42651)	(0.54405)	(0.13247)	(0.34289)	(0.05219)
	[-0.14950]	[-1.78768]	[-0.20097]	[8.09306]	[-0.83374]	[1.37768]

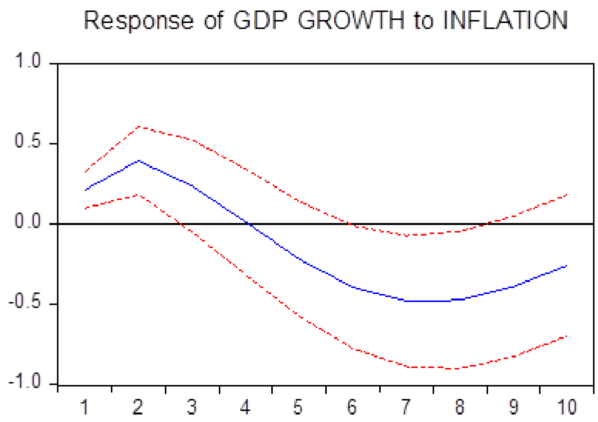
MAIN REFINANCING RATE(-2)	0.178937	0.314715	0.073418	-0.224832**	0.272293	-0.074760
	(0.23225)	(0.37958)	(0.48419)	(0.11789)	(0.30516)	(0.04644)
	[0.77045]	[0.82911]	[0.15163]	[-1.90709]	[0.89229]	[-1.60969]
GDP GROWTH(-1)	0.342634*	0.803665*	0.062641	0.107809*	1.138999*	-0.032325
	(0.10241)	(0.16738)	(0.21351)	(0.05199)	(0.13457)	(0.02048)
	[3.34559]	[4.80138]	[0.29339]	[2.07381]	[8.46429]	[-1.57838]
GDP GROWTH(-2)	-0.221216*	-0.347569*	0.058772	-0.043506	-0.440820*	0.020944
	(0.07987)	(0.13054)	(0.16652)	(0.04054)	(0.10495)	(0.01597)
	[-2.76955]	[-2.66247]	[0.35294]	[-1.07303]	[-4.20030]	[1.31122]
CISS(-1)	0.712993	-0.346111	-1.135586	-1.530489*	-3.810058*	1.016561*
	(0.68775)	(1.12403)	(1.43381)	(0.34911)	(0.90366)	(0.13753)
	[1.03671]	[-0.30792]	[-0.79201]	[-4.38402]	[-4.21627]	[7.39157]
CISS(-2)	0.586343	-0.413245	-0.563734	1.330751*	1.768606	-0.182876
	(0.85412)	(1.39594)	(1.78066)	(0.43356)	(1.12226)	(0.17080)
	[0.68649]	[-0.29603]	[-0.31659]	[3.06938]	[1.57594]	[-1.07070]
C	-0.362398	-0.166577	0.683238	0.113664	1.284800*	0.036592
	(0.26674)	(0.43595)	(0.55610)	(0.13540)	(0.35048)	(0.05334)
	[-1.35862]	[-0.38210]	[1.22863]	[0.83947]	[3.66583]	[0.68600]
R-squared	0.873593	0.989852	0.948908	0.985300	0.951889	0.836722
Adj. R-squared	0.845503	0.987596	0.937554	0.982034	0.941197	0.800438
Sum sq. resids	7.547477	20.16061	32.80408	1.944734	13.03022	0.301814
S.E. equation	0.373856	0.611019	0.779412	0.189772	0.491223	0.074761
F-statistic	31.09931	438.9203	83.57604	301.6315	89.03282	23.06031
Log likelihood	-21.92232	-54.83665	-71.14521	23.50662	-40.21527	85.91945
Akaike AIC	1.042457	2.024975	2.511797	-0.313631	1.588515	-2.176700
Schwarz SC	1.470234	2.452751	2.939573	0.114146	2.016292	-1.748924
Mean dependent	1.832836	4.458209	5.322388	2.081841	1.264179	0.200655
S.D. dependent	0.951138	5.486323	3.118995	1.415813	2.025721	0.167353

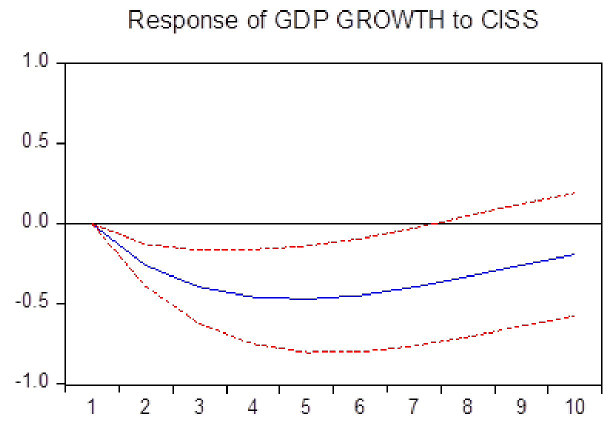
Significant at a 5% significance level marked by * (|t-stat|>2.00), significant at a 10% significance level marked by ** (|t-stat|>1.671).

1.4.2 Impulse response functions in levels

Subsequently, we also derive the impulse response functions for the VAR estimates of our model. The figures are presented below. In this case, the impulse response functions illustrate the response of inflation, GDP growth and CISS to Cholesky One S.D. Contrary to the VEC model, *Eviews 9* is able to present the corresponding 95% confidence bands for the VAR model. The impulse response functions present very comparable results as those presented in subsection 3.4. The confidence bands indicate that the responses of CISS to GDP growth, Inflation to GDP growth, GDP growth to Inflation, and GDP growth to CISS are significantly different from zero.




Response of GDP GROWTH to INFLATION
1.0
0.5
0.0
-0.5
-1.0
1
2
3
4
5
6
7
8
9
10


Response of GDP GROWTH to CISS
1.0
0.5
0.0
-0.5
-1.0
1
2
3
4
5
6
7
8
9
10

2. Dynamic Inconsistency Model

2.1 Setting 1

This paragraph describes the setting where a social planner optimizes loss function (1) under commitment.

We assume that the social planner can commit, so that $\pi_0^e = \pi_0$. Finally, we assume that the optimal level of inflation is zero. This results in loss function (8):

$$L = \frac{1}{2}(\pi)^2 + \frac{a}{2}(y - y^*)^2 + \frac{b}{2}(\theta - \theta^*)^2 \tag{8}$$

When the set assumptions and equation (2) to (7) are incorporated, this results the following loss function:

$$L = \frac{1}{2}(\pi_0)^2 + \frac{a}{2}(\bar{y} + \beta\delta_0 - y^*)^2 + \frac{b}{2}(\bar{\theta} + \delta_0 - \theta^*)^2$$

When this loss function is minimized subject to π_0 and δ_0, the resulting first order conditions for π_0 and δ_0 are:

$$\pi_0 : 0 = \pi_0$$

$$\delta_0 : 0 = a\beta(\bar{y} + \beta\delta_0 - y^*) + b(\bar{\theta} + \delta_0 - \theta^*)$$

This results in the optimal value for π_0:

$$\pi_0^* = 0 \tag{9}$$

The optimal value for δ_0 is given by:

$$a\beta(\bar{y} - y^*) + b(\bar{\theta} - \theta^*) = -a\beta^2\delta_0 - b\delta_0$$

Or:

$$a\beta(\bar{y} - y^*) + b(\bar{\theta} - \theta^*) = -(a\beta^2 + b)\delta_0$$

Which leads to:

$$\delta_0^* = \frac{a\beta}{a\beta^2 + b}(y^* - \bar{y}) - \frac{b}{(a\beta^2 + b)}(\bar{\theta} - \theta^*) \tag{10}$$

2.2 Setting 2

This paragraph describes the setting where the social planner optimizes loss-function (1) with discretion:

We analyze a setting where the social planner (or the central bank) has a dual mandate for both financial stability and price stability and is also concerned with the output-gap. Again we assume that the optimal level of inflation is zero. This results in the following loss-function.

$$L = \frac{1}{2}(\pi)^2 + \frac{a}{2}(y - y^*)^2 + \frac{b}{2}(\theta - \theta^*)^2 \quad (11)$$

We assume that the central bank operates under discretion. When the central bank minimizes loss-function (11) subject to (2) to (6), this gives the following loss-function:

$$L = \frac{1}{2}(\pi_0)^2 + \frac{a}{2}(\bar{y} + \alpha(\pi_0 - \pi^e) + \beta\delta_0 - y^*)^2 + \frac{b}{2}(\bar{\theta} - (\pi_0 - \pi^e) + \delta_0 - \theta^*)^2 \quad (12)$$

When the social planner optimizes loss-function (12) to π_0 and δ_0, this results in the following first order conditions:

$$\frac{\partial L}{\partial \pi_0}: 0 = \pi_0 + a(\bar{y} + \alpha(\pi_0 - \pi^e) + \beta\delta_0 - y^*) * \alpha + b(\bar{\theta} - (\pi_0 - \pi^e) + \delta_0 - \theta^*) * -1$$

Rewriting gives:

$$\pi_0 + (a\alpha(\bar{y} - y^*) + a\alpha^2(\pi_0 - \pi^e) + a\alpha\beta\delta_0 - b(\bar{\theta} - \theta^*) + b(\pi_0 - \pi^e) - b\delta_0 = 0$$

Or:

$$-(1 + a\alpha^2 + b)\pi_0 = a\alpha(\bar{y} - y^*) - a\alpha^2\pi^e + a\alpha\beta\delta_0 - b(\bar{\theta} - \theta^*) - b\pi^e - b\delta_0$$

Which leads to the following optimal value for π_0:

$$\pi_0^* = \frac{a\alpha}{1 + a\alpha^2 + b}(y^* - \bar{y}) + \frac{b}{1 + a\alpha^2 + b}(\bar{\theta} - \theta^*) + \frac{a\alpha^2 + b}{1 + a\alpha^2 + b}\pi^e + \frac{b - a\alpha\beta}{1 + a\alpha^2 + b}\delta_0 \quad (13)$$

Similarly, optimizing for δ_0 gives:

$$\frac{\partial L}{\partial \delta_0}: 0 = a(\bar{y} + \alpha(\pi_0 - \pi^e) + \beta\delta_0 - y^*) * \beta + b(\bar{\theta} - (\pi_0 - \pi^e) + \delta_0 - \theta^*)$$

Rewriting gives:

$$a\beta(\bar{y} - y^*) + a\alpha\beta(\pi_0 - \pi^e) + a\beta^2\delta_0 + b(\bar{\theta} - \theta^*) - b(\pi_0 - \pi^e) + b\delta_0 = 0$$

Or:

$$-(a\beta^2 + b)\delta_0 = a\beta(\bar{y} - y^*) + b(\bar{\theta} - \theta^*) + a\alpha\beta(\pi_0 - \pi^e) - b(\pi_0 - \pi^e)$$

Which leads to:

$$\delta_0^* = \frac{a\beta}{a\beta^2 + b}(y^* - \bar{y}) - \frac{b}{a\beta^2 + b}(\bar{\theta} - \theta^*) + \frac{b - a\alpha\beta}{a\beta^2 + b}(\pi_0 - \pi^e) \tag{14}$$

To solve (13) and (14) jointly for π_0 and δ_0, we rewrite the equations by:

$$\delta_0^* = A + B(\pi_0 - \pi^e) \tag{15}$$

And:

$$\pi_0^* = C + D\delta_0 \tag{16}$$

Whereby:

$$A = \frac{a\beta}{a\beta^2 + b}(y^* - \bar{y}) - \frac{b}{a\beta^2 + b}(\bar{\theta} - \theta^*)$$

Which is equal to the value for δ_0^* we found in the first setting under commitment. The sign of A is determined by the trade-off between the beneficial effects on welfare of a smaller output gap and the negative effects of an accumulation of debt (we assumed that $\bar{\theta} > \theta^*$ and $\bar{y} < y^*$) and the relative effectiveness of the macroprudential policy tool.

B is given by:

$$B = \frac{b - a\alpha\beta}{a\beta^2 + b}$$

Whereby we have assumed that $a > 0$ and $b > 0$, which are the relative weights assigned to the output gap and leverage in the loss-function. Furthermore, we have assumed that $\alpha > 0$ and $\beta > 0$, which are parameters for the relative effect of unexpected inflation and the macroprudential policy tool respectively. The sign of B cannot be determined in this stage, as it is depending on the values of the discussed parameters.

Furthermore:

$$C = \frac{a\alpha}{1 + a\alpha^2 + b}(y^* - \bar{y}) + \frac{b}{1 + a\alpha^2 + b}(\bar{\theta} - \theta^*) + \frac{a\alpha^2 + b}{1 + a\alpha^2 + b}\pi^e$$

Due to the fact that we assume that $\bar{\theta} > \theta^*$ and $\bar{y} < y^*$ and that therefore $\pi^e \geq 0$, we can conclude that $C > 0$.

And:

$$D = \frac{b - a\alpha\beta}{1 + a\alpha^2 + b}$$

D is composed of the same (all positive) parameters as B. Therefore, the sign of D is likewise depending on the relative effectiveness of the macroprudential tool, the effect of unexpected inflation and the relative weight in the loss-function. This makes the actual sign of D similarly depending on the actual values of these parameters.

When we subsequently solve equations (15) and (16) for δ_0^*, this results in:

$$\delta_0^* = A + B(C + D\delta_0) - B(\pi^e)$$

Rewriting gives:

$$\delta_0^* = A + BC + BD\delta_0 - B(\pi^e)$$

Or:

$$\delta_0^* - BD\delta_0 = A + BC - B(\pi^e)$$

Which results in:

$$\delta_0^* = \frac{A + BC - B(\pi^e)}{1 - BD} \tag{17}$$

2.3 Setting 3

This paragraph describes the setting of two policymakers, optimizing their respective loss-functions under discretion.

We assume that both authorities have their own separate objectives and act under discretion. Again, we set π^* equal to zero for simplicity. The loss-function for the central bank is given by:

$$L_{CB} = \frac{1}{2}(\pi)^2 \quad (18)$$

The macroprudential authority has a mandate for financial stability and output. Its loss function is therefore given by:

$$L_{MA} = \frac{a}{2}(y - y^*)^2 + \frac{b}{2}(\theta - \theta^*)^2 \quad (19)$$

When the central bank minimizes (18) subject to (2) to (6), this results in the following loss-function:

$$L_{CB} = \frac{1}{2}(\pi_0)^2$$

Minimization of this loss function results in the following first order condition for π_0:

$$\pi_0 : 0 = \pi_0$$

This leads to the optimal value of π_0:

$$\pi_0^* = 0 \quad (20)$$

When the macroprudential authority incorporates (2) to (6) in loss-function (19), this results in:

$$L_{MA} = \frac{a}{2}(\bar{y} + \alpha(\pi_0 - \pi^e) + \beta\delta_0 - y^*)^2 + \frac{b}{2}(\bar{\theta} - (\pi_0 - \pi^e) + \delta_0 - \theta^*)^2$$

Minimization of this loss function results in the following first order condition for δ_0:

$$\frac{\partial L}{\partial \delta_0} : 0 = a(\bar{y} + \alpha(\pi_0 - \pi^e) + \beta\delta_0 - y^*) * \beta + b(\bar{\theta} - (\pi_0 - \pi^e) + \delta_0 - \theta^*)$$

Rewriting gives:

$$a\beta(\bar{y} - y^*) + a\alpha\beta(\pi_0 - \pi^e) + a\beta^2\delta_0 + b(\bar{\theta} - \theta^*) - b(\pi_0 - \pi^e) + b\delta_0 = 0$$

Or:

$$-(a\beta^2 + b)\delta_0 = a\beta(\bar{y} - y^*) + b(\bar{\theta} - \theta^*) + a\alpha\beta(\pi_0 - \pi^e) - b(\pi_0 - \pi^e)$$

Which leads to:

$$\delta_0^* = \frac{a\beta}{a\beta^2 + b}(y^* - \bar{y}) - \frac{b}{a\beta^2 + b}(\bar{\theta} - \theta^*) + \frac{b - a\alpha\beta}{a\beta^2 + b}(\pi_0 - \pi^e) \qquad (21)$$