Master's Thesis

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Unconventional Monetary Policy
An Application to the Eurozone

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Abstract : This thesis examines the theoretical underpinnings of unconventional monetary policy and the challenges central banks face when they have to employ unconventional monetary policy measures in practice. The theoretical and empirical justification behind unconventional monetary policy is laid out, as well as an overview of recent unconventional monetary policy measures undertaken by central banks around the world, with an emphasis on the European Central Bank and the Federal Reserve. A Dynamic Stochastic General Equilibrium model is used to assess the implications of banking sector turmoil and unconventional monetary policy for the central bank of a currency union.

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List of abbreviations

DSGE	Dynamic Stochastic General Equilibrium
ECB	European Central Bank
Fed	Federal Reserve
QE	Quantitative Easing
MEP	Maturity Extension Programme
MBS	Mortgage-backed Securities
TALF	Term Asset-Backed Securities Loan Facility (TALF)
CPFF	Commercial Paper Funding Facility
ABMLF	Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility
ABCP	Asset-Backed Commercial Paper
LSAP	Large-scale Asset Purchases
SMP	Securities Markets Programme
TDWP	Term Discount Window Programme
VAR	Vector Autoregression

Chapter 1

Introduction

When in the summer of 2007 the US housing market bubble burst, a long period of macroeconomic and price stability, spanning over two decades, that became known as the ”Great Moderation” was about to come to an abrupt end. What followed was the worst economic downturn since the ”Great Depression”.

Central banks reacted aggressively, slashing interest rates in order to avert further deterioration of economic activity. As the recession deepened, despite aggressive measures by central banks, it became evident that conventional monetary policy measures wouldn't suffice to restore economic activity and avert another crisis of similar magnitude as the Great Depression.

The familiar concept of the ”liquidity trap”, once a mere theoretical possibility became a daunting reality. During ”normal” times monetary policy by central banks consists mainly in choosing a target for the very short-term interest rate and the effective communication of the central bank's policy stance [Cùrdia and Woodford (2010)]. At the same time, properly functioning money markets are an essential component in the transmission mechanism and hence in the effective conduct of monetary policy.

Yet, central banks soon came up against the effective lower bound on the policy rate but also money markets under substantial distress.

The series of central bank actions that followed the onset of the financial crisis in 2007 challenged long-standing beliefs about the nature and role of central banking and monetary policy in general, especially during times of severe disruption in financial markets. Central banks adopted a series of non-standard measures that came collectively to be known as ”unconventional monetary policy” and signified a significant departure from the standard practice of monetary policy.

Signalling its desired interbank rate by engaging in open market operations in the overnight interbank market was no longer enough. Central banks became actively involved in credit intermediation in the wholesale market and engaged in large scale asset purchases in specific money markets. Their balance sheet expanded considerably and they assumed a much more active role in money markets.

The purpose of this thesis is to provide an overview of the unprecedented actions central banks had to employ, examine the rationale behind these non-standard policy actions, assess their effectiveness and finally use a DSGE model that incorporates an active banking sector in the context of a currency union in order to evaluate the effectiveness of unconventional monetary policy in mitigating financial turmoil and restoring the flow of credit as well as its impact on the evolution of key macroeconomic variables.

Chapter 2

Unconventional Monetary Policy: When and why

A sound monetary-policy framework needs to meet two objectives: maintaining price stability and promoting the utilization of the economy's resources at the highest attainable level [Svensson (2011)]. The former is an integral part of the mandate of every central bank, while the later is one of the stated objectives outlined in the mandate of central banks such as the Federal Reserve and an implicit consideration in the conduct of monetary policy of others. In normal times monetary policy consists in the central bank signalling its desired overnight interbank rate that banks use to meet reserve requirements and settle transactions by engaging in open market operations and clearly communicating its stance on monetary policy. This is what is usually called the central bank's main policy rate.

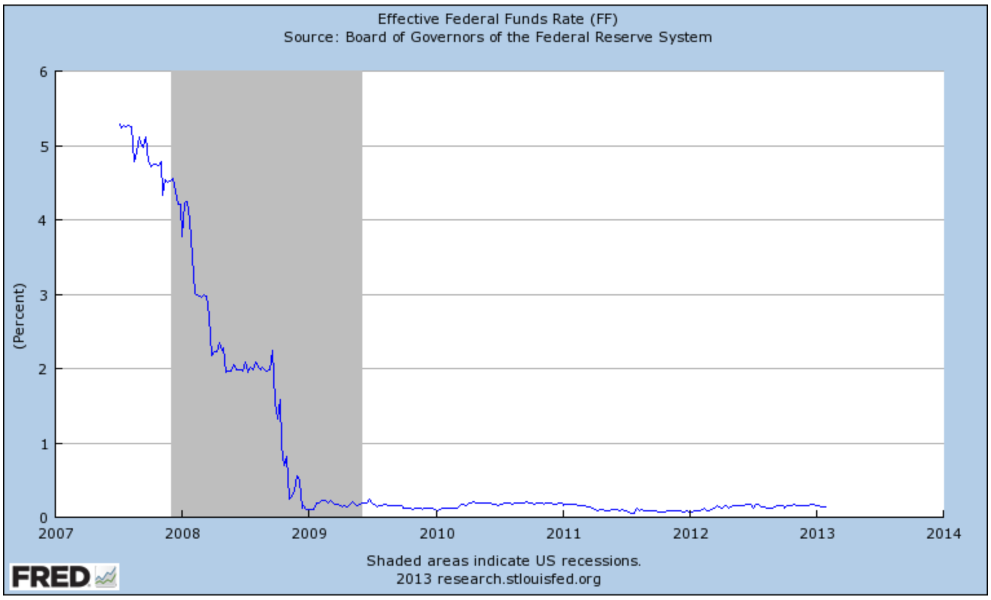
The effectiveness of monetary policy, however, is not without limits. During the recent financial crisis, it became evident that under certain circumstances a central bank may find itself unable to meet its mandate using conventional monetary policy instruments. Under such circumstances, it is forced to resort to unconventional monetary policy measures. When the zero lower on the policy rate becomes binding and the transmission mechanism of monetary policy is seriously impaired, a central bank has to part ways with the convenience and safety of conventional monetary policy.

We now turn to a detailed discussion of the fundamental problems that would lead a central bank to employ unconventional policy measures.

2.1 The effective lower bound

The problem of the effective lower bound in times when the economy is still in need of additional stimulus has featured prominently in the literature. During downturns, central banks engage in open market operations in order to bring down the overnight interest rate for uncollaterized loans in the interbank market as a means to provide the economy with the necessary monetary stimulus and boost economic activity. That was indeed the case during the initial stages of the recent severe economic downturn that became known as the "Great Recession". Figure **??** shows the sharp and sustained decline in the federal funds rate. Eventually, the Fed was unable to reduce the federal funds rate any further once the zero lower bound was reached.

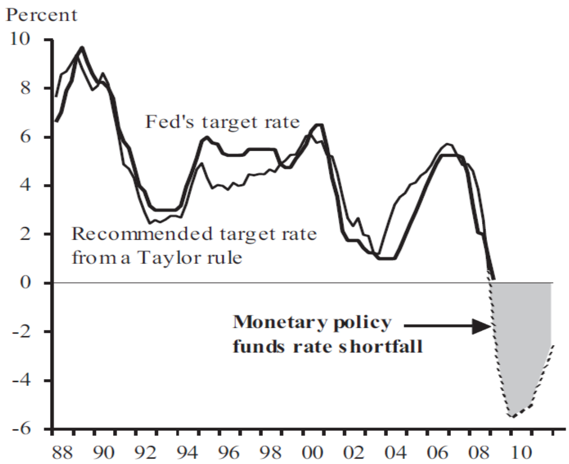
Figure 2.1: The evolution of the federal funds rate



Source: Federal Reserve Economic Data

Yet, when the shock to the economy is severe enough the central bank may find itself unable to reduce its policy rate below the effective lower bound while the economy is still in need of additional help. The central bank might find itself in what is called a "liquidity trap". At that point a central bank's main monetary policy instrument becomes invalidated and the central bank faces severe impediments to the conduct of monetary policy. Figure **??** shows the monetary policy funds rate shortfall faced by the Federal Reserve.

Figure 2.2: Federal funds shortfall



Source: Rudebusch (2009)

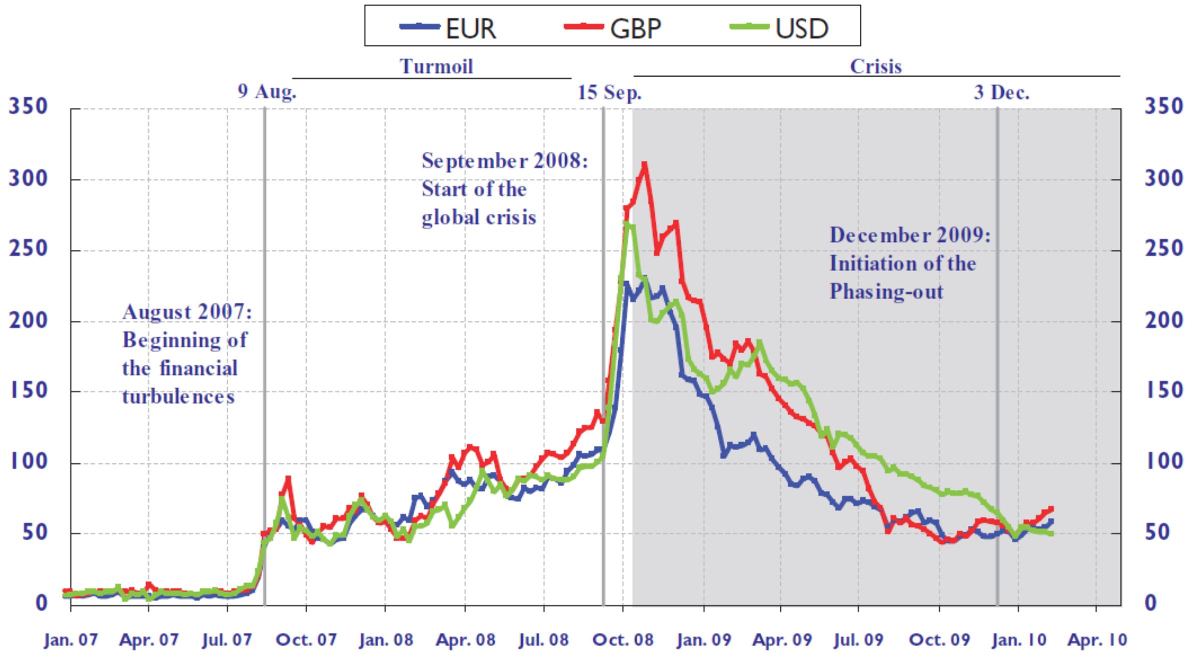
The figure illustrates that according to empirical estimates of the Fed's Taylor rule, by the end of 2009 its policy rate should have been reduced at -5% , if the effective lower bound wasn't binding[Rudebusch (2009)]. Since at the zero lower bound government bonds and cash become perfect substitutes, it becomes evident that in a similar the policy rate is no longer an effective monetary policy instrument.

2.2 Problems with the transmission mechanism

Another obstacle to the efficient conduct of monetary policy during times of crisis is issues related to the transmission mechanism of monetary policy. A seriously impaired transmission mechanism that renders monetary policy ineffective is an issue that came into prominence during the recent financial crisis, when financial turmoil seriously hampered the transmission channels of "conventional monetary policy". The recent financial crisis highlighted that a central bank may find itself seriously constrained in pursuing its monetary policy targets, even before the effective lower bound on the policy rate has become binding.

Monetary policy is based on the premise that the policy rate is used as a benchmark for other key interest rates and changes in the policy rate will have an impact on the relevant interest rates for households and businesses. By shifting the policy rate, the central bank is expecting that the subsequent rise or fall in the financing cost of firms and households will boost real spending and prevent an economic slump or prevent the economy from overheating. During normal times academic research and empirical evidence corroborate that this is indeed the case. However, when money markets are not functioning properly, when panic prevails and limited participation in markets becomes widespread, the transmission mechanism of monetary policy may become seriously impaired and the central bank may find its capacity to implement its monetary policy stance severely diminished. As Cùrdia and Woodford (2010) note, the question for a central bank in this kind of situation is how its interest rate policy should be affected by the fact that other key interest rates no longer co-move with its policy rate in a way they typically had in the past. Figure **??** shows the surge in money market spreads following the onset of the financial crisis in the Euro area, the United Kingdom and the United States.

Figure 2.3: Money Market Spreads in the Euro Area, United Kingdom And The United States



Source: Trichet (2010)

It becomes evident that money market spreads had skyrocketed at unacceptably high levels and that shifting the policy rate would no longer have the desired impact on other key interest rates.

2.3 The central bank's role as a lender of last resort

The role of the central bank as a lender of last resort has been a recurring theme in monetary economics, going back to Bagehot (1873). Freixas (2009) notes the potential of contagion of what initially are isolated cases of illiquidity or insolvency. A liquidity or solvency crisis of a limited number of banks can spill over to the entire banking sector through feedback effects induced by "fire sales" that drive down the value of banks' assets, can bring about a domino effect that will trigger a systemic crisis.

Injecting liquidity when it's most needed, in order to avert widespread panic and a "fire sale" of assets that would undermine the solvency of financial institutions, while a number of factors at play such as information assymetries prevent anyone else from doing so, in order to prevent a seizing up of the interbank market induced by a liquidity shortage from turning into a systemic crisis, is another key responsibility of a central bank in times of crisis. That was one of the main considerations of central banks while engaging in liquidity providing operations in a number of financial markets.

Chapter 3

Unconventional Monetary Policy in Practice: The Fed and the ECB

Up until the recent financial crisis, the Bank of Japan was the most prominent example of a central bank of an advanced economy that faced a binding zero lower bound on its policy rate and found itself in a liquidity trap. As a result, it was also the first central bank, with the exception of an isolated incident dubbed 'Operation Twist' in 1961, engineered by the Kennedy administration and the Fed, that had to resort to unconventional monetary policy measures.

When central banks have to resort to unconventional policy measures, optimal policy design requires policymakers to take into account the financial structure of their nation's economy in order to ensure the efficient and uninhibited provision of liquidity and credit to households and businesses. Differences in the financial structures of their economies led central banks to employ different policy measures and intervene in different markets. As Borio and Disyatat (2009) underline the Fed intervened directly in non-bank credit markets due to the market-oriented structure of the US financial system, while the ECB placed greater emphasis on propping up the euro area's banking system, since bank-based intermediation in predominant in the region. According to Favero et al. (1999) available data indicate that the share of bank loans in total debt liabilities of non-financial firms for euro area countries range from 77 per cent in Spain, to 80 and 85 in France and Germany, up to as much as 95 per cent in countries such as Italy. In the U.S., on the other hand, this share is only about 30 per cent. In the following section we provide a short overview of the non-standard policy actions undertaken by the Federal Reserve and the European Central Bank.

3.1 The Federal Reserve's response

Since the US financial system was the 'Ground Zero' of the global financial crisis, the Federal Reserve was the central bank most actively engaged in unconventional monetary policy. The Fed employed a vast array of unconventional monetary policy measures in order to alleviate the severe distress in the US financial system. As the structure of the US financial system is market-oriented and the shadow banking system features prominently in it, the Federal Reserve had to set up various facilities in order to ensure the efficient provision of liquidity and prevent a domino effect that would lead to a systemic collapse.

The first facility set up by the Fed was the Term Discount Window Programme (TDWP), in order to eliminate the discount rate premium and extend the maximum maturity of emergency loans made available to banks through the Discount Window. On December 12, 2007 the Fed introduced the Term Auction Facility. It was intended to satisfy banks demand for funds and alleviate the stigma associated with resorting to the Discount Window for term funding [Armantier et al. (2008)]. On the same day, in order to satisfy the increasing demand for US dollars, the Federal Reserve announced that it would establish foreign exchange swap lines with the ECB and the Swiss National Bank. Reciprocal Currency Agreements were meant to reduce the rollover risk institutions faced and increase the predictability of funding costs that could in turn relieve funding pressures on funding markets in the United States [Fleming and Klagge (2010)]. Moreover, in order to provide long-term liquidity to primary dealers the Fed introduced the Single - Tranche Open Market Operations Programme and the Primary Dealers Credit Facility [Cecioni et al. (2011)].

Since the collapse of Lehman Brothers was a crucial turning point in the recent financial crisis, the Fed expanded its unconventional policy measures substantially. The Term Asset-Backed Securities Loan Facility (TALF) was introduced in order to improve the liquidity of the financial system and enhance the flow of credit. It differed from standard central bank liquidity enhancing operations since it was geared towards providing support for market-based credit intermediation, as opposed to the traditional banking sector, and in particular the market for securitized credit [Sack (2010)].

The objective of the Commercial Paper Funding Facility (CPFF) was to support the commercial paper market, granting access to the Fed's discount window even to non-bank financial entities, the issuers of commercial paper and address temporary liquidity distortions in the commercial paper market [Adrian et al. (2010)]. Another facility set up by the Fed was the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility. The ABMLF was designed to enhance the liquidity of the asset-backed commercial paper (ABCP) market and support money market funds by allowing them to liquefy assets to meet the increasing demands for redemption without engaging in "fire sales" of their assets.

In order to support the credit markets for housing, the Fed engaged in purchases of debt and mortgage-back-securities issued by government-sponsored agencies totalling up to $200 billion and $1.5 trillion respectively. Furthermore, when the effective lower bound on its policy rate was reached, in two rounds of quantitative easing it increased its holdings of long-term Treasury securities by $900 billion in what was termed "Large-Scale Asset Purchases" [Cecioni et al. (2011)].

3.2 Unconventional monetary policy and the ECB

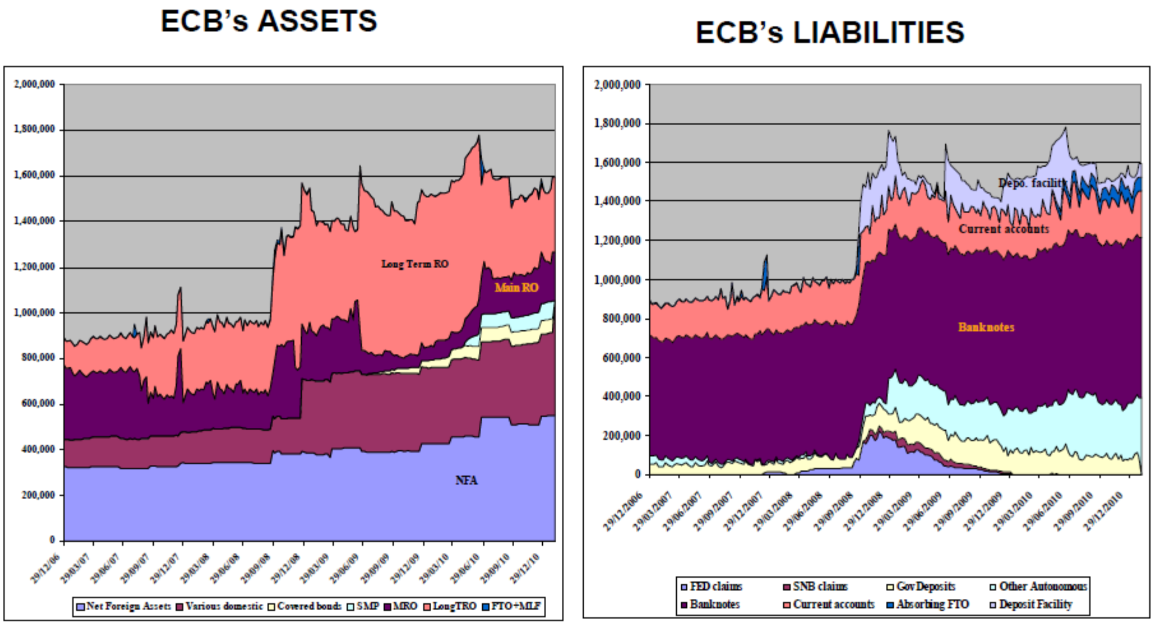
In order to facilitate the flow of credit to businesses and households, the ECB adopted a number of non-standard policy measures that were meant to complement the aggressive reduction in interest rates, accommodate financial conditions and overcome problems with the efficient provision of credit and liquidity to the economy due to severe problems with financial markets and institutions as a consequence of the financial turmoil [Trichet (2009)].

The ECB's nonstandard policy measures did not constitute a significant departure from its usual modus operandi. One can distinguish five pillars in its approach:

- The introduction of fixed rate tenders and full allotment for its main refinancing operations.
- The lengthening of the maturity of its refinancing operations.
- A €60 billion covered bonds purchase programme.
- Extending the list of assets eligible to be used as collateral.
- The introduction of the Securities Markets Programme, involving purchases of euro area private and public securities.

It becomes evident from figure **??** that the balance sheet of the ECB expanded significantly as a result of its unconventional monetary policy measures.

Figure 3.1: Liabilities and assets of the ECB



Source: Constâncio (2011)

By extending the list of eligible collateral and introducing fixed rate tenders and full allotment as well as lengthening the maturity of its main refinancing operations the ECB sought to prevent a dry-up of liquidity in the banking sector and reduce funding costs for euro area banks. The extension of eligible assets to be used as collateral also allowed banks of countries such as Greece to maintain access to the ECB's main refinancing operations.

At the same time, the ECB's Long-Term-Refinancing operations have helped banks to implement the necessary deleveraging that accompanies a financial crisis in an orderly fashion, by reducing funding risks and avoiding the "fire sales" of banks' assets that would have had an adverse impact on the solvency of the entire banking sector. Moreover, the Securities Markets Programme(SMP) was aimed at alleviating the significant pressures that were building up in the market for sovereign bonds for many euro area countries, allowing governments to maintain market access while implementing the necessary structural reforms and fiscal consolidation measures [González-Páramo (2012)]. By doing so it also prevented a significant reduction in the valuation of banks' assets.

While ECB policymakers claim that their actions were guided solely by economic considerations, one could possibly argue that another reason for the ECB's more contained response compared to central banks like the Fed or the Bank of England could be attributed to the fact that the ECB also faced institutional constraints that limited the scope of its unconventional monetary policy measures owing to the Maastricht Treaty and the Eurozone's very nature as a monetary union of sovereign nations.

Table 3.1 provides a comparison of the ECB's policy actions compared to those of other major central banks.

Table 3.1: The ECB versus other major central banks

Measures	ECB	Others
Liquidity provision and increased role of intermediation in the money market		
- Fixed full rate allotment	✓	✗
- Broadening of eligible collateral	✓	✓
- Long term repo operations	✓	✓
- Inter-central bank FX swap lines	✓	✓
- Modification of discount window facility	✗	✓
- Broadening of counterparties	✗	✓
- Securities lending, exchange with illiquid assets	✗	✓
Quantitative easing		
- Outright purchases of assets to change their yields	✗	✓
Credit easing		
- Credit and purchase of assets of particular agents or market segments	✓	✓
- Commitment to future path of interest rates	✗	✓

Chapter 4

The transmission mechanism of unconventional monetary policy

Tracing out the transmission mechanism of unconventional monetary policy is a natural starting point for understanding how and to what extent unconventional monetary policy measures are effective in mitigating financial turmoil and restoring the flow of credit in financial markets. The two main channels that have been proposed regarding the transmission mechanism of monetary policy are the signalling and the portfolio-balance channels.

4.1 The signalling channel

Expectations management has always been a crucial part of monetary policy. Forward guidance consists in the central bank communicating to the public its conditional forecast about the expected future path of the policy rate in order to affect agents' expectations about the future path of the policy rate and the stance of monetary policy. Thus, the central bank is signalling to markets its intentions about the future stance of monetary policy. In reality, forward guidance may not be that unconventional. For a number of central banks communication to the public of their expectations about the likely future course of action was part of their conventional monetary policy toolkit even before the recent financial crisis. Indeed that has been the case for the Reserve Bank of New Zealand, Norges Bank, the Riskbank and the Czech National Bank[Svensson (2011)].

Clear communication on the part of the central bank becomes even more important during a financial crisis. There is an extensive literature on potential responses to a "liquidity trap" and the role of expectations and central bank credibility features prominently. Assuming rational agents, what matters for the spending decisions of households and firms is the expected future path of a number of key economic variables, not merely their current values. If a central bank can credibly commit to a higher inflation rate in the future, it can drive the expected real interest rate down stimulate aggregate demand, , even when the zero lower bound on the nominal interest rate becomes binding[Krugman (1998)]. Walsh (2009) notes that the New Keynesian model, the dynamic macroeconomic model that has become the workhorse for monetary policy analysis, provides a number of key insights about the importance of expectations and how a central bank by affecting expectations about the future path of the policy rate can overcome the zero lower bound problem. In the basic New Keynesian model the key determinant of agents' decisions is expectations about the future path of policy. A central bank that can credibly commit to an expected future path of the policy rate may be able to overcome the zero lower bound constraint by affecting expectations about long-term rates.

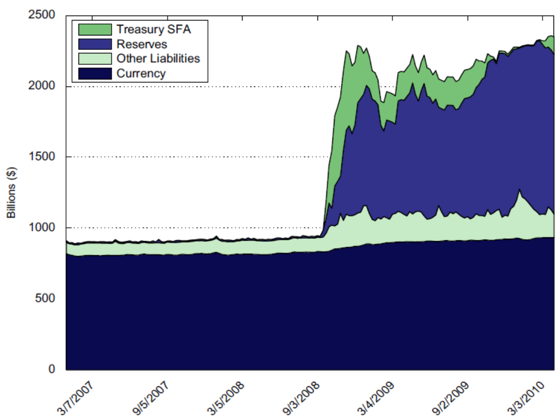
Bernanke (2012) notes how the Fed's communication policy and firm policy stance was effective in shifting the expectations of professional forecasters as well as investors about the likely date that the federal funds rate would begin to rise and the Fed would begin implementing its exit strategy.

4.2 The portfolio-balance channel

The portfolio-balance channel involves the central bank making heavy use of its balance sheet in order to expand the quantity of reserves in the banking system and engage in outright purchases of securities and other financial instruments.

Figure ?? shows the expansion of the Fed's liabilities from 2007 to 2010.

Figure 4.1: Liabilities of the Federal Reserve



Source: Cúrdia and Woodford (2011)

A key assumption underlying this channel is imperfect substitutability of assets. Regulatory constraints and increased transactions costs as well as information asymmetries render certain types of assets less attractive to certain classes of investors. Hence, changes in the net supply of different assets may have an impact on the yield and price structure of those assets. That was the rationale behind the Fed's purchases of mortgage-backed securities. Furthermore, there's also a rebalancing effect in play. As investors change the composition of their portfolios, the price and yield of other assets should be affected as well. This could induce an easing of financial conditions and boost economic activity via similar transmission channels as for traditional monetary policy [Bernanke (2012)]. Borio and Disyatat (2009), on the other hand, note the implications of imperfect asset substitutability on the liability side of the market for the effectiveness of unconventional monetary policy and how it affects the valuation of assets. Central bank intervention could lead to an easing of financial conditions by providing liquidity at more attractive terms than prevailing market conditions would allow, hence restore lending and credit flows and reflating asset prices.

Joyce et al. (2012) provide a detailed account of how imperfect asset substitution can have an impact on asset yields and in turn real activity.[1] Investors that have long-dated liabilities, such as pension funds and insurance companies, prefer to match the term structure of their liabilities with assets of analogous maturity. With their increased cash holdings from selling government bonds to the central bank, they are likely to purchase other long-dated assets such as corporate bonds, due to their preference for long-dated assets in order to match their long-dated liabilities. With central bank acquisitions of long-dated assets lowering term risk in the aggregate, the risk premium required by investors should fall and the prices of risky assets, such as corporate bonds and stocks, should rise thereby lowering yields. This should allow corporations access to better credit terms, leading to an accommodation of credit conditions. Any capital gains that would result would be rebated to households, in essence the owners of those risky assets, consequently increasing their wealth and as a result increased household spending combined with new investments on the part of firms would bolster aggregate demand.

As a final note, Borio and Zhu (2008) suggest the existence of yet another channel of transmission for monetary policy, what they call the ”risk-taking channel”. This channel works through the effect central bank interventions have on investors’ appetite for risk. The phenomenon known as ”flight to safety” and a decreased appetite for risk on the part of investors are common features of financial crises. By reducing perceived risks, central bank intervention can induce productive risk-taking and accommodate financial conditions.

[1]the authors examine the case of gilt purchases by the Bank of England, but their argument holds in general.

Chapter 5

Evidence on the effectiveness of monetary policy

The question of the actual impact unconventional policy measures have had is crucial for central banks in order to gauge the effectiveness of their interventions, assess whether or not they have had a considerable impact on the real economy and in shaping the future conduct of monetary policy. A number of research attempts sought to analyze the response of markets to unconventional monetary policy measures and their effect, if any, on real macroeconomic variables.

5.1 Event-based studies

Krishnamurthy and Vissing-Jorgensen (2011) using an event study methodology find that QE1 and QE2 were successful in lowering nominal interest rates on Treasuries, agency debt and highly-rated corporate bonds. However, their findings imply that the effects for lower-grade corporate bonds were much smaller. Moreover, they conjecture that quantitative easing is effective in lowering yields on mortgage-backed-securities only when involving outright purchases of MBS and not just Treasury purchases.

Meaning and Zhu (2012) using monthly data from January 1990 to June 2011 estimate an error correction model of the dynamics of the 10-year Treasury bond and find a sizeable impact of the Fed's Maturity Extension Programme on the 10-year government bond yield, comparable to that of the large-scale asset purchase programmes.

Swanson (2011) undertaking a high-frequency event-study approach of 'Operation Twist', a policy similar to the Federal Reserve's Maturity Extension Programme, engineered by the Kennedy administration and the Federal Reserve in 1961, finds statistically significant, yet moderate effects of 'Operation Twist' on longer-term Treasury yields of about 15 basis points. The effect on corporate bonds, however, was even more limited. Since both programmes are similar in nature and scope, it is reasonable to conclude that the MEP had similar effects.

5.2 VAR estimates

Gambacorta et al. (2012) estimate a panel VAR with monthly data from eight advanced economies over the sample period from January of 2008 to June of 2011, in order to examine the macroeconomic effectiveness of unconventional monetary policy measures adopted by central banks since the onset of the crisis. They find a temporary positive effect on output and the price level. They conclude that unconventional monetary policy measures enacted by central banks provided temporary support to the ailing economies of their countries during the financial crisis.

Peersman (2011) using a structural VAR model finds evidence that unconventional monetary policy measures by the ECB, such as quantitative easing, could potentially have significant output and inflationary effects, thus suggesting a promising important role for these types of policy measures for the ECB's monetary policy arsenal.

Fahr et al. (2011) assess the effectiveness of the ECB's unconventional monetary policy measures employing a VAR analysis. Their findings suggest that the ECB's intervention succeeded in supporting the economy of the euro area and averting a disorderly deleveraging of the financial sector as well as further downward pressure on price stability and the risk of deflation.

Giannone et al. (2012) estimate a VAR model using a monthly dataset spanning from January 1999 to April 2011. Performing a number of counterfactual exercises they find that the ECB's policy measures were able to mitigate, but not completely offset, the effects of the economic downturn. They conclude that the ECB's non-standard measures had a moderate, yet significant impact on macroeconomic activity.

Baumeister and Benati (2010) employ a Bayesian time-varying parameter structural VAR, in order to examine the effects of large scale assets purchases by central banks that bring about a compression in the yield spread in the context of a binding zero lower bound on the policy rate. They find that a compression in the long-term yield has a substantial impact on output and inflation. Moreover, their estimates of the policy counterfactual suggest that absent central bank intervention, the UK and the US would have experienced an output collapse and deflationary pressures of the same scale as the output collapse and deflationary spiral that occurred during the "Great Depression".

It should be noted that perhaps the overall macroeconomic impact of the European Central Bank's interventions is harder to estimate, as the deteriorating fiscal position of a number of Eurozone countries during the second stage of the financial crisis submitted the banking system and the economy of the euro area to additional strain. Additionally, the sovereign debt crisis is still in full swing.

As a word of caution against being overly optimistic over these preliminary positive research findings, Bernanke (2012) notes that "while there is substantial evidence that the Federal Reserve's asset purchases have lowered longer-term yields and eased broader financial conditions, obtaining precise estimates of the effects of these operations on the broader economy is inherently difficult, as the counterfactual–how the economy would have performed in the absence of the Federal Reserve's actions–cannot be directly observed". The same holds true for every other central bank and economy.

Chapter 6

Unconventional Monetary Policy in the DSGE Literature

Most of the academic research involving Dynamic Stochastic General Equilibrium models focused on the role of financial frictions and the banking system on business cycles and the propagation of financial turmoil throughout the economy.

While not dealing with the issue of unconventional monetary policy explicitly, tracing the driving force behind financial shocks and how they affect the financial system and subsequently the real economy is a necessary condition for understanding the channels through which unconventional monetary policy can mitigate the effects of financial turmoil and suggest the appropriate policy actions.

The seminal paper by Bernanke et al. (1999) has been used as a fundamental building block in an attempt to depart from the assumption of perfect financial markets and incorporate financial frictions in standard DSGE models. Another highly influential paper that introduced credit frictions was Kiyotaki and Moore (1997). These papers developed models that introduced financial frictions from the demand side of the market, by means of a costly state verification framework.

In the DSGE literature recent attempts to embed unconventional monetary policy in a structural model based on optimizing agent behaviour and examine its effectiveness and the potential transmission mechanisms include Gertler and Karadi (2011), Gertler and Kiyotaki (2010), Dib (2010), Christiano et al. (2010) and Cúrdia and Woodford (2011).

In order to motivate imperfect financial markets, information asymmetries among agents, incentive compatibility constraints and limited participation in credit markets play a major role in these models.

Gertler and Karadi (2011) develop a DSGE model with a financial sector that collects funds from households and extends credit to firms. Financial frictions are introduced positing an agency problem for external funds raised in the deposit market. Bankers are tempted to diverge bank funds to their households whenever the participation constraint is not binding, i.e. whenever the value of divertible funds exceeds the bank's net worth. The model avows to the effectiveness of credit policy by the central bank in moderating the contraction brougth about by a negative shock to the economy. Since an important constraint during times of crisis is the effective zero bound on the short-term nominal interest rate, the model sets out to explain the implications of this constraint for the effectiveness of monetary policy. When imposing a binding zero lower bound on the policy rate in their model, the net benefits from credit policy are enhanced.

Gertler and Kiyotaki (2010) introduce an interbank market by assuming that banks on different locations("islands") face different investment opportunities to finance, hence their demand for funds differs. They examine the various non-standard facilities set up by the Fed and the Treasury since the onset of the financial crisis, and especially the collapse of Lehman Brothers in 2008, such as direct lending to the private sector, the provision of liquidity to the banking system and injections of capital into banks by the Treasury. In their model non-standard policy measures are effective in dampening the adverse effects on output induced by financial turmoil. However, as they stress, the net benefits from central bank intervention are increasing in the severity of the crisis, consequently it should be reserved for exceptional circumstances, when the standard monetary policy instruments available to a central bank are not sufficient to produce the desired outcome.

Dib (2010) augments a DSGE model with a banking sector that features two types of banks. Savings banks collect deposits and proceed to buy government bonds or extend credit in the interbank market. Lending banks raise bank capital and engage in interbank borrowing in order to finance loans to firms or purchase government bonds. The model incorporates capital requirements by assuming a Leontief "production function for loans". The model features a quantitative easing shock, an injection of central bank funds into lending banks, as well as a qualitative easing shock, a swap of bank loans for government bonds. The model's key finding is that, in contrast to other models with bank capital, with capital requirements imposed by regulatory standards, the banking sector mitigates the effects of various shocks to the economy. Furthermore, unconventional monetary policy, by providing banks with ample liquidity at attractive terms and removing risky assets from their balance sheet in exchange for risk-free government bonds, has a positive impact on real activity.

Cúrdia and Woodford (2011) extend a standard New Keynesian model with a perfectly competitive banking sector. Banks collect deposits, make loans and choose the quantity of reserves to hold at an interest-bearing account at the central bank. The central bank engages in interest-rate policy, the standard monetary policy tool, reserve-supply policy, setting the rate of interest on reserves in order to induce banks to hold the desired amount, and credit policy, directly extending credit to the private sector. Their model's implications question the effectiveness of quantitative easing, i.e. expanding the central bank's balance sheet. Credit policy, however, can be welfare-improving when financial markets are under substantial distress. Despite that, they warn that merely the fact that the zero lower bound constraint becomes binding is not by itself a sufficient condition to justify active credit policy by the central bank and that specific market conditions for certain classes of financial instruments should also be taken into account, in addition to currently prevailing macroeconomic conditions, in order for the central bank to decide on what the appropriate policy response may be. At the same time, they suggest that a central bank's ability to pay interest on reserves should be an effective tool in fending off any inflationary pressures that could arise as a result of active credit policy, even when the economy fully recovers.

In the model of Christiano et al. (2010) an elaborate New Keynesian DSGE model as in Christiano et al. (2005) is augmented with a perfectly competitive banking sector as in Chari et al. (1995). Banks borrow from savers and extend working capital and long-term investment loans to firms. They find that financial shocks account for a substantial portion of aggregate fluctuations, with the risk shock being they key determinant behind the volatility of investment and conclude that the behaviour of the banking sector is always important for the economy, even in normal times and that the liquidity preferences of financial intermediaries can have a significant real impact. Their findings suggest that the Fed should have switched to a money-based rule targeting the growth rate of M2 and engaged in quantitative easing from the last quarter of 2008, in order to stabilize the economy.

In conclusion, with regards to the current status of DSGE modelling, while the standard New Keynesian model had become the workhorse for monetary policy analysis, the revived interest in the importance of the financial sector brought about by the recent financial crisis and the need to incorporate financial factors in DSGE models that are used for policy analysis has led to various attempts to introduce the salient features of the financial sector in dynamic macroeconomic models. Nevertheless, there is not yet a consensus on which aspects of banking and financial intermediation are the most important and should become an integral part of the new benchmark DSGE model[Vlcek and Roger (2013)]. A new standard DSGE model that incorporates financial factors has not yet emerged. The development of a new, more sophisticated, dynamic macroeconomic model that will be able to capture the intricacies of the financial sector and become the new benchmark and policy workhorse is a priority for future research.

Chapter 7

An open economy DSGE model

7.1 The Model Economy

In this section a New Keynesian DSGE model incorporating an active banking sector, in the framework of a currency union, is used in order to assess the impact and efficacy of central bank interventions in the interbank market, after an adverse external shock to the default probability of banks leads to a substantial increase in financing costs in the wholesale market and subsequently impairs the efficient provision of credit to firms.

All countries in the union are assumed symmetric, with agents in each country acting in an identical way. The model includes a variety of nominal frictions, from sticky prices and wages to imperfectly competitive banks that set interest rates in a staggered fashion. Trade among union countries takes place in the form of a differentiated final good, that can be used either for consumption or investment purposes, assembled by final goods producers that combine both domestic as well as imported wholesale goods. The central bank is injecting liquidity in the banking system in order to mitigate the effects of an adverse shock to the solvency of banks that increases the default probability in the interbank market.

7.2 Households

There is a continuum of households $h \in [0, 1]$ in each country in the union. Households consume, save and supply labour. They seek to maximize their discounted lifetime utility given by the following constant relative risk aversion utility function:

$$\max_{[C_t, L_t]} E_t \sum_{s=0}^{\infty} \beta^s \left[(C_t^h - H_t)^{1-\gamma_c} (1-\gamma_c)^{-1} - (L_t^h)^{1+\gamma_l} (1-\gamma_l)^{-1} \right] \tag{7.1}$$

where γ_c is the coefficient of relative risk aversion and γ_l is the inverse of the elasticity of work effort with respect to the real wage. As in Smets and Wouters (2003) H_t represents an external habit relative to aggregate past consumption, given by $H_t = h_t C_{t-1}$. Utility is increasing in consumption and leisure and subject to the following budget constraint:

$$c_t + d_t = w_t L_t + (1 + r_t^d) d_{t-1} + \Pi_t^b \tag{7.2}$$

The budget constraint states that consumption and deposits supply in the current period must be financed by the household's labour income, the gross interest earned on deposits in the previous period and since households are the owners of banks as well as any profits accruing to the household from the banking sector.

The first order conditions for the household's problem with respect to consumption and deposit demand are given by:

$$(c_t^i - H_t)^{-\gamma_c} = \lambda_t \tag{7.3}$$

$$1 = \beta \frac{\lambda_{t+1}}{\lambda_t} R_t^d \tag{7.4}$$

where $R_t^d = 1 + r_t^d$ is the gross interest on deposits held from period $t-1$ to t.. Equation 7.3 is the marginal utility of consumption, while equation 7.33 is the condition determining optimal deposit demand. Combining the two first order condition yields the standard consumption Euler equation, taking into account the presence of the external habit:

$$(c_t^i - H_t)^{-\gamma_c} = \beta R_t^d (c_{t+1}^i - H_{t+1})^{-\gamma_c} \tag{7.5}$$

7.2 Wage setting

Households supply differentiated types of labour in the labour market and thus hold some degree of monopoly power. Following Smets and Wouters (2003) households set wages in a staggered fashion. Each period a fraction $1-\xi_w$ of households are allowed to reoptimize wages. The remaining fraction ξ_w that are not allowed to reoptimize, index wages to past inflation as follows:

$$w_t = \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} w_{t-1} \tag{7.6}$$

the degree of indexation is determined by a parameter $\gamma_w \in [0, 1]$, with $\gamma_w = 1$ implying perfect indexation to past inflation. When the degree of indexation is equal to zero, $\gamma_w = 0$, there is no indexation and the wage of households who are not able to reoptimize in the current period is set according to the prevailing wage in the last period. Aggregate labour demand is given by a Dixit-Stiglitz type aggregator function over the different types of labour:

$$N_t = \left[\int_0^1 (L_t^h)^{1/(1+\lambda_w)} \, dh \right]^{1+\lambda_w} \tag{7.7}$$

and the aggregate nominal wage is given by:

$$W_t = \left[\int_0^1 (w_t^h)^{-1/\lambda_w} \, dh \right]^{-\lambda_w} \tag{7.8}$$

Households set wages in order to maximize the difference between the marginal return to working and the subjective cost of working, given by the marginal disutility of labour. Formally, they seek to maximize (7.1) subject to (7.2) and (7.6). The first order condition for the optimal wage yields:

$$\frac{\tilde{w}_t}{P_t} E_t \sum_{s=0}^{\infty} (\beta \xi_w)^s \left(\frac{\left(\frac{P_t}{P_{t-1}}\right)^{\gamma_w}}{\left(\frac{P_{t+s}}{P_{t+s-1}}\right)} \right) \frac{\lambda_{t+s} L_{t+s}^h}{1+\lambda_w} = E_t \sum_{s=0}^{\infty} (\beta \xi_w)^s U_{l,t+s} L_{t+s}^h \tag{7.9}$$

where λ_{t+s} is the marginal utility of consumption, equation (7.3) and $U_{l,t+s}$ is the marginal disutility of labour.

It follows that the aggregate wage evolves according to a weighted average of the optimal wage set by the fraction of households who are able to reoptimize wages in period t and the previous period's wage, chosen by households who are not able to reoptimize, taking into account indexation.

$$W_t = \left[\xi_w \left(\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} W_{t-1} \right)^{-1/\lambda_w} + (1-\xi_w)(\tilde{w}_t)^{-1/\lambda_w} \right]^{-\lambda_w} \tag{7.10}$$

7.3 Goods market structure

In order to motivate sticky prices in a currency union framework, we assume that wholesale goods firms sell their output in perfectly competitive markets to intermediaries who repackage wholesale goods at no cost and resell them to final goods producers. Price setting in a staggered fashion is introduced at the level of intermediaries, whose price setting behaviour is subject to frictions a là Calvo (1983). This is a similar modelling device as in Christensen et al. (2009).

7.3 Firms

Firms combine labour and capital to produce output using a constant returns to scale Cobb - Douglas production function:

$$Y_t = L_t^{\alpha} K_t^{1-\alpha} \tag{7.11}$$

where L_t is labour and K_t is the capital stock.

Optimal factor demand implies the equalization of the ratio of factor prices to their marginal productivity:

$$\frac{W_t}{r_t^k} = \frac{1-\alpha}{\alpha}\frac{K_t}{L_t} \tag{7.12}$$

Cost minimization leads to the following familiar marginal cost function associated with a Cobb - Douglas production function:

$$mc_t = \left(\frac{r_t^k}{\alpha}\right)^{\alpha}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha} \tag{7.13}$$

where r_t^k denotes the rental rate of capital and W_t the wage rate.

The law of motion of capital is given by:

$$K_t = (1-\delta)K_{t-1} + \left(1 - S\left(\frac{I_t}{I_t{-}1}\right)\right) I_t \tag{7.14}$$

where δ is the depreciation rate of capital, I_t denotes aggregate investment and $S(\cdot)$ is an investment adjustment cost function. As in Smets and Wouters (2003) the adjustment cost function is increasing in the rate of change in investment and equals zero in steady state. Its first derivative is also zero in steady state,$S'(\cdot) = 0$, hence adjustment costs depend only on the second derivative of the investment adjustment cost function.

The Financial Accelerator: Bernanke et al. (1999) incorporate credit-market imperfections into a New Keynesian DSGE model by introducing an agency problem between borrowers and lenders in the spirit of the costly state verification framework of Townsend (1979). In their model financial frictions arise due to the potential divergence of interests between lenders and borrowers.

Entrepreneurs are risk-neutral and at time t purchase capital for use at time $t+1$. They finance capital acquisitions partly by their own net worth, N_t, and the remainder, $B_t = Q_{t-1}K_t - N_t$, by applying to a bank for a loan. In order to motivate borrowing and prevent entrepreneurs from becoming fully self-financing they face a constant probability of exit, γ, in each period, implying that an entrepreneur's expected lifetime is $1/1-\gamma$. Optimal capital demand requires that the expected marginal return to capital, given by:

$$E_t\left\{R_{t+1}^k\right\} = E_t\left\{\frac{\frac{P_t^w}{P_t^d}\alpha\frac{Y_{t+1}}{K_{t+1}} + (1-\delta)q_{t+1}}{q_t}\right\} \tag{7.15}$$

be equated to the external financing costs firms face, hence the following relationship between the return to capital and the external finance, must hold:

$$R_t^k = \Psi\left(\frac{n_{t+1}}{q_t k_{t+1}}\right) r_t^b \tag{7.16}$$

Entrepreneurial net worth is given by the difference between earnings on capital over the external finance cost and is given by

$$V_t = R_t^k Q_{t-1} K_t - r_t^b \left(Q_{t-1} K_t - N_t\right) \tag{7.17}$$

On aggregate the evolution of entrepreneurs evolves net worth is given by:

$$N_t = \gamma V_t + (1-\gamma) z_t \tag{7.18}$$

where, following Christensen and Dib (2006), z_t, is a startup subsidy entrepreneurs who enter the market in period t receive from those who die and exit. In order to allow newly entering entrepreneurs to set up business Bernanke et al. (1999) assume that entrepreneurs provide labour in the general labour market and consume their residual net worth when exiting. Christensen and Dib (2006) take a different route and allow entrepreneurs who enter receive a startup subsidy from the residual wealth of entrepreneurs who die and exit the market.

It follows from the analysis above that with the introduction of credit-market imperfections a change in the funding conditions firms face could generate real effects by impacting on investment and capital accumulation.

7.3 Intermediaries

Domestic Intermediaries: There is a continuum of intermediaries in every country χ in the union indexed by j, distributed over the unit interval ($j \in [0,1]$). Intermediaries repackage wholesale goods at no cost for resale to final goods producers using a CES production technology described by:

$$Y_t^d = \left[\int_0^1 Y_t^d(\phi)^{\frac{\epsilon_d - 1}{\epsilon_d}}\right]^{\frac{\epsilon_d}{\epsilon_d - 1}} \tag{7.19}$$

Cost minimization on behalf of final goods producers leads to a non-linear demand function for each brand of domestic intermediate goods. Price setting is subject to frictions á la Calvo, hence only a fraction, $1-\xi_t$ of intermediaries are allowed to reset prices in every period. The intermediaries' problem is to choose the optimal price in period t, taking into account the probability that this price will stay fixed for a number of periods in the future. Formally, they maximize:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \lambda_{t+s} \left[\frac{P_t^d(j)}{P_{t+s}} - mc_{t+s}(j) \right] Y_{t+s}^d(j) \tag{7.20}$$

subject to the demand function for their brand of differentiated composite good:

$$Y_t^d(j) = \left(\frac{P_t^d(j)}{P_t^d} \right)^{-\epsilon_d} Y_t^d \tag{7.21}$$

where Y_t^d denotes aggregate domestic production of intermediate goods.
The first order condition to the intermediary's problem shows that the optimal price is determined as a markup over marginal cost:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_r)^s \lambda_{t+s}^E \left\{ P_t^d(j) - \left(\frac{\sigma}{\sigma - 1} \right) mc_{t+s}(j) \right\} Y_{t+s}^d(j) = 0 \tag{7.22}$$

The presence of Calvo-type frictions implies that the domestic price level evolves according to:

$$(P_t^d)^{1-\epsilon_d} = \left[\xi_p (P_{t-1}^d)^{1-\epsilon_d} + (1 - \xi_p)(\tilde{P}_t^d)^{1-\epsilon_d} \right] \tag{7.23}$$

Imports: In an analogous way in other countries in the union foreign intermediaries buy output from foreign wholesale producers in order to produce a composite good for export to final goods producers abroad. The composite import good is a CES composite of foreign wholesale goods aggregated according to:

$$Y_t^f = \left[\int_0^1 Y_t^f(\phi)^{\frac{\epsilon_f - 1}{\epsilon_f}} \right]^{\frac{\epsilon_f}{\epsilon_f - 1}} \tag{7.24}$$

where $Y_t^f(\phi)$ is the composite intermediate good of each intermediary in the foreign country.
Price setting is constrained by the usual Calvo mechanism. Formally, their optimization problem involves maximizing the following profit function:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_p)^s \lambda_{t+s} \left[\frac{P_t^{im}(j)}{P_{t+s}} - mc_{t+s}(j) \right] Y_{t+s}^{im}(j) \tag{7.25}$$

subject to the demand function for their brand of import good:

$$Y_t^f(j) = \left(\frac{P_t^f(j)}{P_t^f}\right)^{-\epsilon_f} Y_t^f \tag{7.26}$$

with Y_t^f denoting aggregate supply of foreign intermediate goods.
The first order condition to the importers' optimization problem yields the optimal price of the imported good as a markup over the foreign marginal cost:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_r)^s \lambda_{t+s}^E \left\{ P_t^{im}(j) - \left(\frac{\sigma}{\sigma-1}\right) mc_{t+s}(j) \right\} Y_{t+s}^{im}(j) = 0 \tag{7.27}$$

It follows that the evolution of the foreign price level, and consequently the price level of imports, is given by:

$$(P_t^f)^{1-\epsilon_f} = \left[\xi_p (P_{t-1}^f)^{1-\epsilon_f} + (1-\xi_p)(\tilde{P}_t^f)^{1-\epsilon_f}\right] \tag{7.28}$$

7.3 Final goods producers

Final goods assemblers combine domestic and foreign goods to costlessly produce final retail goods using the following production function:

$$y_t = (y_t^{im})^{\mu} (y_t^d)^{1-\mu} \tag{7.29}$$

where y_t^{im} and y_t^d are imported and domestic goods respectively and μ is the share of imported goods in the production of final goods. Final goods can be used for consumption or as capital goods for investment purposes.

If we define the terms of trade as the ratio of the domestic price level to the foreign price level, $ToT_t = \frac{P_t^d}{P_t^f}$, and the Consumer Price Index as $CPI_t = (P_t^d)^{1-\mu}(P_t^f)^{\mu}$, then the solution to the final goods producers cost minimization problem yields the following demand functions for domestic and foreign goods,

$$y_t^d = \left[\left(\frac{\mu}{1-\mu}\right) ToT\right]^{-\mu} Y_t \tag{7.30}$$

$$y_t^{im} = \left[\left(\frac{\mu}{1-\mu}\right) ToT\right]^{1-\mu} Y_t \tag{7.31}$$

7.4 Banks

As in Gerali et al. (2010) banks hold some degree of monopoly power in setting interest rates on deposits and loans, with deposit and loan demand given by a Dixit - Stiglitz type CES function. Following the same modelling device we posit a two - tier banking sector, with a retail branch setting interest rates in the retail market and a wholesale branch active in the interbank market.

Loan and deposit demand is derived assuming that in order to obtain a unit of deposits and loans, firms and households differentiate their deposits and loans across different banks. Optimization on behalf of households leads to the following non-linear demand functions for individual bank loans $b_t(\tau)$ and deposits $d_t(\tau)$:

$$b_t(\tau) = \left(\frac{r_t^b(\tau)}{r_t^b}\right)^{-\epsilon_t^b} b_t \tag{7.32}$$

$$d_t(\tau) = \left(\frac{r_t^d(\tau)}{r_t^d}\right)^{-\epsilon_t^d} d_t \tag{7.33}$$

7.4 Wholesale banking

The wholesale branch of the bank is active in the interbank market, managing the bank's liquidity position. It collects wholesale deposits and issues loans in the interbank market. The wholesale branch's problem is to maximize the following profit function:

$$\max_{\{B_t,D_t\}} E_t \sum_{t=0}^{\infty} \beta^P \left[(1-s_t)R_{t-1}^{IB}B_{t-1} - B_t - (s_t - \bar{s})B_t + D_t - R_{t-1}^d D_{t-1} + CB_t\right] \tag{7.34}$$

subject to $B_t = D_t$

where B_t and D_t are wholesale loans and deposits respectively and s is the probability of default on interbank lending that is defined as a stochastic AR(1) process that evolves, in logs, according to $s_t = \rho_s s_{t-1} + \epsilon_t^s$. CB_t denotes liquidity injections from the central bank, proportional to outstanding interbank loans, $CB_t = \upsilon B_t$. As in Dib (2010) the probability of default is constant in the steady state. We assume that monitoring costs are increasing in the probability of default and proportional to outstanding interbank loans.

Assuming that the central bank remunerates reserves at the policy rate[1], the deposit rate in the interbank market is determined by the central bank's policy rate, hence $R_t^d = r_t$ Combining the first order conditions to the wholesale branch's optimization problem, the interbank rate is determined endogenously as an increasing function of the policy rate, monitoring costs and the default probability on interbank lending:

$$r_t^{IB} = \frac{r_t + (s_t - \bar{s})}{1 - s_t} \tag{7.35}$$

The central bank's intervention in the interbank market is increasing in the spread between the interbank rate and the policy rate and described by the following equation:

$$\upsilon_t = \nu(r_t^{IB} - r_t) \tag{7.36}$$

where $\nu \in [0, 1]$ is a parameter determining the intensity of the central bank's intervention.

7.4 Retail banking

Loan rate setting: The retail branch sets interest rates on loans and deposits in a staggered fashion. Employing once again the familiar Calvo-type frictions assumption, each period a fraction $1 - \xi_r$ of banks are allowed to reset interest rates, while for the rest of the banks interest rates remain fixed. In choosing the optimal interest rate, banks take into account the possibility that they won't be able to reset interest rates in the next period and for a number of periods ahead.

Formally, the retail branch's optimization problem with respect to the optimal loan rate is described by,

$$E_t \sum_{s=0}^{\infty} (\beta\xi_r)^s \lambda_{t+s}^b \left\{ \tilde{r}_{t+s}^b(j) - r_{t+s}^{IB}(j) \right\} b_{t+s}^s(j) \tag{7.37}$$

subject to the demand function for bank loans, equation (7.32).

The first order condition for the optimal interest rate on loans yields:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_r)^s \lambda_{t+s}^b \left\{ \tilde{r}_{t+s}^b(j) - \left(\frac{\epsilon_t^{bs}}{\epsilon_t^{bs} - 1} \right) r_{t+s}^{IB}(j) \right\} b_{t+s}^s(j) = 0 \tag{7.38}$$

Since not all banks are allowed to reset interest rates in every period it follows that the

[1] or as in Gerali et al. (2010) that banks have access to unlimited finance by a lending facility at the central bank

effective interest rate on loans evolves according to:

$$r_t^b = \left(\xi_r (r_{t-1}^b)^{1-\epsilon_t^{bs}} + (1-\xi_r)(\tilde{r}_t^b)^{1-\epsilon_t^{bs}}\right)^{\frac{1}{1-\epsilon_t^{bs}}} \tag{7.39}$$

Deposit rate setting : The retail branch collects deposits from households that subsequently transfers to the wholesale branch. The wholesale branch remunerates them at the prevailing policy rate. The retail branch's optimization problem is described by:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_r)^s \lambda_{t+s}^b \left\{\tilde{r}_{t+s}^d(j) - r_{t+s}(j)\right\} d_{t+s}^s(j) = 0 \tag{7.40}$$

subject to deposit demand (7.33).

The first order condition with respect to the deposit rate yields:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_r)^s \lambda_{t+s}^b \left\{\tilde{r}_{t+s}^d(j) - \left(\frac{\epsilon_t^d}{\epsilon_t^d - 1}\right) r_{t+s}(j)\right\} d_{t+s}(j) = 0 \tag{7.41}$$

Hence, the effective interest rate on deposits is described by:

$$r_t^d = \left(\xi_r (r_t^d)^{1-\epsilon_t^{\kappa}} + (1-\xi_r)(\tilde{r}_t^d)^{1-\epsilon_t^{\kappa}}\right)^{\frac{1}{1-\epsilon_t^{\kappa}}} \tag{7.42}$$

7.5 Goods market clearing and monetary policy

Goods market clearing at the country level requires:

$$Y_t^{\chi} = C_t^{\chi} + I_t^{\chi} + IX \tag{7.43}$$

The resource constraint states that output in each country can be allocated between consumption, investment and exports.

Since the terms of trade between union countries are irrelevant for the determination of union-wide output, it follows that goods market clearing for the union as a whole requires:

$$Y_t = C_t + I_t \tag{7.44}$$

The central bank sets its policy rate according to a Taylor-type rule, featuring interest rate smoothing and given, in log-linearized form, by:

$$r_t = \rho r_{t-1} + \rho_\pi \pi_{t-1} + \rho_y y_{t-1} + e_r \tag{7.45}$$

where ρ captures the degree of interest rate smoothing, ρ_π is the coefficient on inflation and ρ_y is the coefficient on last period's union-wide output. As in Iacoviello (2005) the central bank is responding to last period's deviation of output and union inflation rate from their steady state values in setting its policy rate. Otherwise, the equation determining the nominal risk-free rate is fairly standard. Since the central bank's task is to stabilize inflation for the union as a whole, it follows that the relevant measure of inflation for the conduct of monetary policy is given by a weighted average according to the relative weight of each country:

$$\pi_t^u = j\pi_t^d + (1 - j)\pi_t^f \tag{7.46}$$

7.6 Calibration and model solution

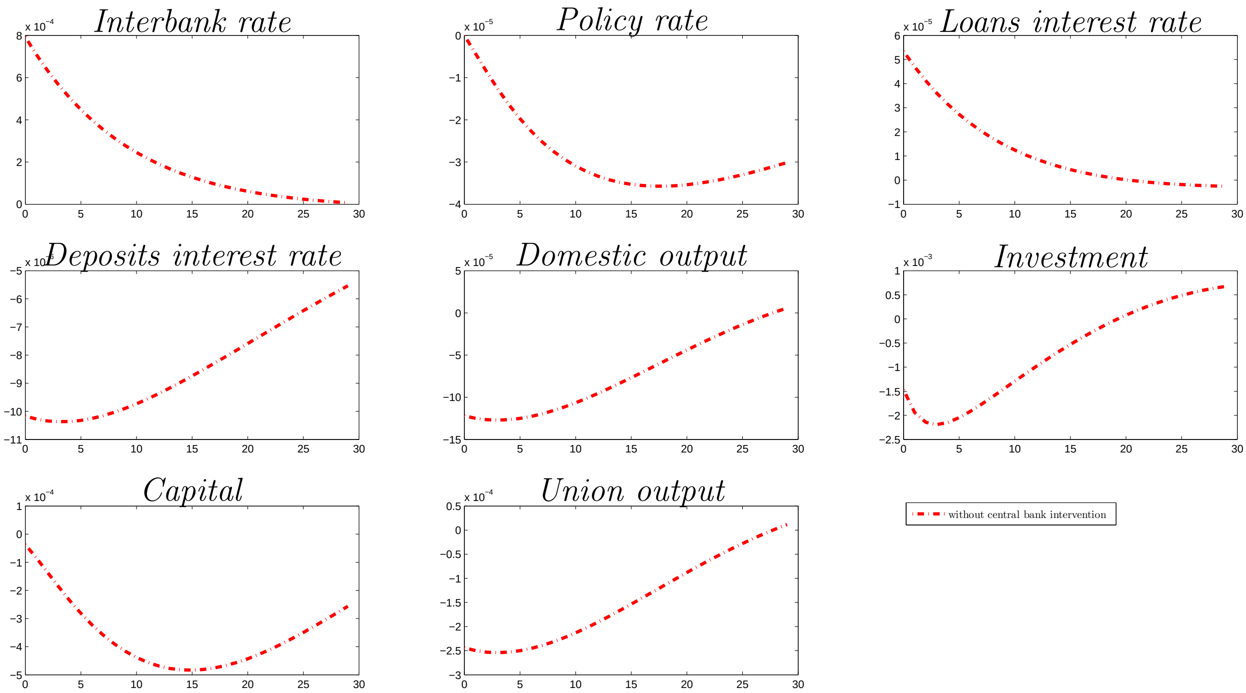
The standard parameters are calibrated using conventional values in the literature. The value of the discount factor β is set to 0.99, the share of capital in national income, α, to 0.3 and capital depreciation δ is 0.025. The values of the coefficient of relative risk aversion, γ_c , the inverse of the elasticity of work effort with respect to the real wage, γ_l, and habit persistence h are set according to the median values of the estimated parameters in Smets and Wouters (2003), to 1.353, 2.4 and 0.573 respectively. The steady-state ratio of capital to net worth of firms and the survival rate of entrepreneurs are set in line with Bernanke et al. (1999) to 2, implying a steady state leverage ratio of 0.5, and 0.9728 respectively. As in Christensen and Dib (2006) the gross steady-state risk premium, S is set to 1.0075. The parameters determining the degree of price and wage stickiness are set following Smets and Wouters (2003) to 0.908 and 0.737, while the degree of interest rate stickiness is set to 0.915 and the share of the domestic economy, j, in the relevant inflation measure for the central bank to 0.5. The coefficients determining the central bank's degree of interest rate smoothing, its "taylor rule" and its response to output are set according to Smets and Wouters (2003) to to 0.958, 1.688 and Gerali et al. (2010) to 0.35, respectively. The share of imports is calibrated to 0.4, thus the model exhibits home bias.

The model is log-linearized about the nonstochastic zero inflation steady state and model simulations are performed using Dynare.

7.7 Counterfactual and the transmission mechanism

Understanding the model's implications for the behaviour of the model economy with and without central bank intervention requires evaluating the model's response to the policy counterfactual, i.e. examining the trajectory of the model's variables to an exogenous shock when the central bank's only response is limited to adjusting the policy rate. Figure 7.1 shows the impulse response functions to a 10% increase in the default probability in the interbank market, without central bank intervention in the interbank market.

Figure 7.1: Impulse responses to a 10% increase in the interbank market default probability(% deviations from steady state).

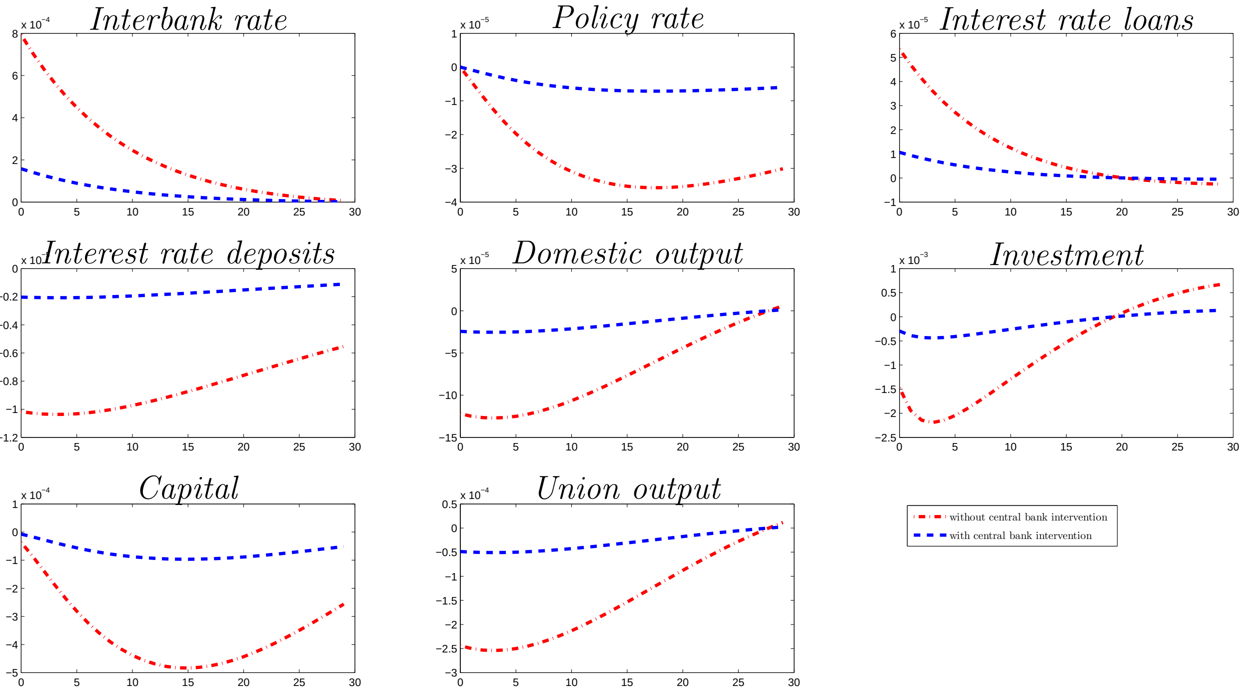


A negative shock to the default probability in the interbank market leads to increased funding costs for borrowing banks, since lending banks need to be compensated for the increased default credit risk they face. This, in turn, leads to an increase in the loan rate and consequently the external financing cost for firms. As a result investment and capital accumulation falls, which has an adverse impact on domestic and consequently union-wide output.

7.8 Central bank intervention

We now turn to the case when the central bank intervenes in the interbank market in response to the shock. Central bank intervention appears effective in mitigating the negative consequences of the shock to the default probability on loans in the interbank market. By injecting liquidity, absorbing risk and accommodating financial conditions, the central bank contains the spillover from the financial sector to the real economy. Since lending banks now have access to better terms of funding than currently prevailing in the market, the response of the interbank rate to the default probability shock is muted. As a consequence of the above, external finance costs for firms, in this case, do not increase substantially, thus they are able to maintain investment and capital accumulation. As a result the fall in output is diminished. It becomes obvious from Figure 7.2 that central bank intervention can be quite effective in restoring the flow of credit, accommodating financial conditions and consequently boosting economic activity. Figure 7.2 shows the impulse response functions to a 10% increase in the default probability in the interbank market to the interbank rate with central bank intervention, when the parameter ν determining the intensity of its intervention is set to $= 0.10$.

Figure 7.2: Impulse responses to a 10% increase in the interbank market default probability with Central Bank intervention(% deviations from steady state).



Chapter 8

Conclusions

Recent developments have challenged long-standing beliefs regarding monetary policy. The importance of the financial system and the feedback effects between the financial structure and the real economy have become more evident and that, inevitably, has been reflected in recent academic research as well as the policy debate regarding the appropriate policy actions from policymakers in turbulent times. Central banks and polcymakers were forced to sail in uncharted waters.

Before the "Great Recession", financial stability and the functioning of the financial system in general often took a back seat in policy discussions and macroeconomic research. While there have been a number of prominent papers regarding financial frictions and their implications for the real economy, most notably Bernanke et al. (1999) and Kiyotaki and Moore (1997), financial frictions were not incorporated in modern macroeconomic models and the assumption of perfect financial markets was a common feature of DSGE models. Kocherlakota (2010) suggests that one of the main reasons for that were the conceptual and computational challenges, as incorporating financial factors in modern macroeconomic models greatly increases their complexity.

Regarding the question of whether unconventional monetary policy actually worked, there is preliminary empirical evidence and academic research supporting the efficacy of unconventional monetary policy measures in mitigating the effects of financial distress. As Williams (2011) notes this has far-reaching implications for one of they key variables regarding the conduct of monetary policy, the inflation target of the central bank. If unconventional monetary policy is effective in overcoming the zero lower bound constraint, then the need for an inflation cushion, that would allow a central bank further reductions in the policy rate in critical circumstances, is diminished.

However, it has become obvious that unconventional monetary policy is not without caveats. Its implementation in practice poses a number of issues that warrant further research and force central bankers to tread with caution. Bernanke (2012) underlines the fact that there is a great deal of uncertainty surrounding both the costs and the benefits of unconventional monetary policy. Policymakers' experience with these tools remains limited and the potential benefits of unconventional monetary policy must be weighted against its potential costs.

A number of fundamental questions about the role of central banks arise, since unconventional monetary policy greatly expands the scope of central bank interventions and the role of the central bank. Furthermore, there is not yet a definitive answer with regards to any potential unintended consequences from a policy actions, yet untested through the course of time, that policymakers had to devise as events in financial markets unfolded.

Another fundamental issue that will attract great interest in future monetary policy discussions is whether unconventional monetary policy measures should become a standard part of a central bank's monetary policy toolkit and under which circumstances. The ongoing debate about monetary policy during turbulent times and the critical role of central banks will shape the future of monetary policy.

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