Three Essays in Modern Macroeconomics and Monetary Policy

Florian Urbschat

University of Munich

March 2018

Three Essays in Modern Macroeconomics and Monetary Policy

Inaugural-Dissertation

zur Erlangung des Grades

Doctor oeconomiae publicae (Dr. oec. publ.)

an der Ludwig-Maximilians-Universität München

2018

vorgelegt von

Florian Urbschat

Referent:	Prof. Dr. Gerhard Illing
Korreferent:	Prof. Dr. Timo Wollmershäuser
Promotionsabschlussberatung:	11. Juli 2018

Datum der mündlichen Prüfung: 05. Juli 2018
Namen der Berichterstatter: Gerhard Illing, Timo Wollmershäuser, Florian Englmaier

To Ilona.

Contents

Acknowledgements

This doctoral thesis would not have been possible without many colleagues, friends, and family members who supported me on my endeavour, sometimes on a large, sometimes on a small scale.

First and foremost, special gratitude is owed to my supervisor, Gerhard Illing, who gave me the freedom to discover my own research interests, provided continuous support at all stages of my dissertation, helped me with honest advice, and always had an open door for me and my academic needs. Our frequent discussions over lunch or other occasions have been an inspiration and shaped me and my economic thinking. I would further like to thank Timo Wollmershäuser and Florian Englmaier for their insightful comments, valuable advice and for kindly agreeing to serve on my committee as second and third supervisors, respectively.

I am also very much indebted to my co-authors Nikolay Hristov and Sebastian Watzka with both of whom it has been a pleasure to work with. The numerous discussions we had significantly enhanced the quality of chapter 2 and 4. In addition, without the bank data set provided by the Research Data and Service Centre of the German Bundesbank I would not have been able to write chapter 3. Several Bundesbank employees, most notably Harald Stahl, provided technical assistance to me while working with this huge data set or understanding some of the nebulous parts of German bank accounting law.

Many thanks also goes to my current and former colleagues from the Seminar for Macroeconomics who made the working environment not just stimulating and inspiring but also much fun: Sebastian Horn, Matthias and Jonas Schleg(e)l, Thomas Siemsen, Peter Zorn, Sascha Bützer, Franziska Hünnekes, Alexander Schwemmer, or Alexander Schramm. Without several of these colleagues and friends I would not have benefited from numerous helpful comments and insightful debates on Macro, Monetary Policy, Finance, and Game of Thrones*.

Moreover, I am thankful to many colleagues at the Faculty. First of all, to Julia Zimmermann. It was a great pleasure to share an office with her for almost 5 years and to work on the structural development of the Munich Graduate School of Economics. Second, in their restless and diligent work, Julia, Manuela Beckstein and Agnès Bierprigl provided supported on many organisational issues, especially with respect to a large number of travel and other reimbursements forms, which was highly appreciated. Third, I am thankful to several fellow Ph.D. students from the MGSE — too many too included them all — who made the working environment very pleasant in many respects. Special thanks goes to Brendan Shanks who kindly agreed to proof-read this work for typos and grammatical errors.

*Humiliatingly, I admit defeat over an intense debate at the end of Season 5 if Jon Snow is really dead. He is not.

Finally, I would like to thank my friends and family in Hamburg who provided just the right amount of distraction from academic work in Munich when it was needed. Especially, I am thankful to my parents, Monika and Peter, for their invaluable support throughout my whole life. Most importantly, my greatest gratitude goes to my wife, Ilona. These words would have never been written without your support, your advice, and your enduring love.

This work is devoted to you.

Florian Urbschat, Munich in February 2018

List of Figures

List of Tables

Chapter 1

General Introduction

1.1 Preface

Roughly ten years after the outbreak of the financial crisis, growth in the Euro Area seems finally back on track. Not only the growth rates of the gross domestic product (GDP) are rising with an average Euro Area growth rate of more than 2% in 2017, also inflation rates have recovered and are getting more in line with the target region of the European Central Bank (ECB) at close but below 2%. Even more reassuring is the reduction of unemployment rates in several troubled economies such as Spain where the unemployment rate has decreased from its high in 2013 of more than 25% to roughly 16% in 2017. However, while the recovery is still fragile in southern Euro Area countries, many northern and central European countries are already entering the boom period of the business cycle.

Many arguments can be made when attempting to explain the current recovery. On the one hand, some economist would stress the importance of the structural reforms undertaken by periphery countries. On the other hand, other economist would highlight the role of the ECB and its decisive intervention during the Euro crisis and the unconventional monetary policy (UMP) measures taken in the recent years. While this doctoral thesis does not aim to give a fully comprehensive answer to these questions, it tries to modestly contribute to the on-going academic discussion by investigating three aspects of the bigger picture. Specially, this thesis consists of three self-contained chapters each examining a recent topic in modern macroeconomics and monetary policy.

The first two chapters study different aspects of the ECB's unconventional monetary policy measures. Whereas the first chapter uses an event study to examine the effects of the quantitative easing (QE) programme by the ECB on Euro Area bond yields, the second chapter considers the effect of potentially unintended side effects of such policy measures with respect to bank profitability and bank risk-taking. Finally, the third chapter of this dissertation looks at a very old, yet also very recent discussion in the field of macro-economics, namely the real effects of a minimum wage introduction. Using a DSGE model the final chapter attempts to analyse the case of Germany where a minimum wage was introduced in 2015. The remainder of this introduction outlines each chapter in more detail.

1.2 Chapter Outline

Chapter 2

In 2014, the Euro Area experienced very low inflation rates which raised concerns among policy makers that the Monetary Union might tumble into a deflationary spiral. In order to show full commitment to their inflation target rate the European Central Bank started a large scale asset purchase programme, the so called Asset Purchase Programme (APP) which was gradually introduced from September 2014 onwards. The second chapter of my dissertations studies the short-term reaction of financial markets after press releases on the APP. In doing so, the chapter uses event study methodologies to analyse the development of bond yields and spreads around these press releases. More precisely, the chapter estimates different asset price channels by quantifying the cumulative decrease of spreads and by running event regressions for several Euro Area countries. While in principle several channels could be at work, the

chapter largely focuses on the signalling channel, measured by the overnight index swap (OIS) rate, and the portfolio rebalancing channel, which is proxied by the so called conditional bond-OIS spread. In fact, under the regulations of the Asset Purchase Programme several government bonds are excluded from purchases as they trade below the deposit facility. Consequently, our analysis is under the condition that the yield of the individual bond is above this threshold.

The evidence in this chapter suggests that the effects on yield and spread reduction were most pronounced for the initial announcement on the Public Sector Purchase Programme (PSPP) but declined afterwards for additional announcements. This finding could be explained by several arguments. First, one possible explanations is that the ECB was not able to genuinely surprise markets, especially for later announcements. Second, while in the beginning the self-imposed regulations were not binding to a large degree, the institutional set-up of the APP became increasingly burdensome over time. Third, as argued by Eggertsson and Woodford (2003) the closer bonds are trading to the zero lower bound (ZLB) the portfolio rebalance channel becomes less relevant as agents become indifferent between holding cash and bonds. In this respect, the chapter contributes to the unresolved discussion if quantitative easing is an effective tool at the zero lower bound.

Moreover, while yield reductions were larger for periphery countries' bonds such as Italy or Spain than for core countries' bonds such as German Bunds, our evidence suggests that this stronger reduction is mostly due to a decreasing risk component of southern bonds. In fact, once controlling for this implicit credit risk reduction we find mild effects from portfolio rebalancing for all countries. However, the results of this chapter should be interpreted with care. While they do suggest that the portfolio rebalancing had only mild effects on the yield of Euro Area government bonds, in particular for core country bonds, this does not necessarily imply that the APP by the ECB in general has proven ineffective. In fact, the announcement of the ECB's asset purchases might still have had an impact on the real economy via the expectation channel reducing real interest rates, the reduction of overly high risk premia in markets, or via the exchange rate channel.

Chapter 3

After the second chapter of my dissertation examined the specific short-term impact of a quantitative easing programme on financial markets and government bond yields, the third chapter analyses potential unintended side effects of such unconventional monetary policy measures in a more general sense. Following several unconventional policies measures by the ECB (most notable being the introduction of a negative interest rates policy (NIRP) and the start of a quantitative easing programme) many concerns have been raised regarding the stability of banks in the Euro Area. In fact, the spread between short- and long-term interest rates can have a systematic effect on profits, risk-taking, and the financial soundness of banks. As a direct result of the actions by the ECB, both ends of the yield curve have been lowered. On the one hand, breaking through the zero lower bound at the short end of the yield curve leads to additional charges on short-term bank assets. On the other hand, the QE programme lowers the slope of the yield curve and, thus, erodes banks' net interest margin (NIM) over time.

To study how banks are exactly affected, the third chapter of this Ph.D. thesis employs a large micro

level data set of 1600 German banks to examine the impact of these policy measures on bank profitability and bank risk-taking. The data set is provided by the German Bundesbank and entails all monthly balance sheet statements and all yearly profit and loss statements from every German bank holding a banking license between 2003 and 2016. As pointed out by Eggertsson, Juelsrud, et al. (2017) and Heider et al. (2017) there is evidence to believe that banks are differentially affected by negative interest rates depending on their business model. In particular, banks with a large share of deposit could find it harder to pass through negative rates to their customers. Therefore, a central contribution of this chapter is to focus on the heterogeneity regarding different bank business models and how this affects the pass-through of monetary policy at negative interest rates.

Indeed, negative interest rates are a mostly uncharted territory with several economists arguing that banks should be mostly unaffected as they, for instance, could substitute deposit financing with wholesale funding. Moreover, banks might even benefit from these unconventional measures due to lower refinancing costs and capital gains from assets holdings (see e.g. Brunnermeier and Koby (2017) and Jobst and Lin (2016)). Therefore, the general structure of this empirical chapter is to take all common pro and contra arguments in the literature seriously and to study their empirical relevance.

The findings indicate that banks, on the one hand, do not engage in excessive risk-taking, benefit from the current low refinancing rates, and face lower loan loss provisions due to the positive macro-economic environment and low interest burden. On the other hand, only a few large banks experience capital gains from the current high in asset prices, which is mostly due to the conservative German accounting law and differences in banks' business models. Moreover, smaller banks especially face an increasing short-term liquidity overhang and a rising interest rate risk. In sum, this suggests that German banks have so far only been mildly negatively affected as they also profit from UMP in some dimensions.

However, these results come under an important caveat. As the analysis is based on balance sheet and profit and loss statements it is entirely backward looking. Therefore, it remains unclear how long the positive aspects of QE and NIRP can prevail before they are outweighed by the long-term negative impact on banks. In particular, smaller banks are subject to increasing interest rate risk which, on the one hand, arises from increasing short-term liabilities and, on the other hand, comes from an increase in the average interest rate fixation. Put differently, for the same reason that banks now can benefit from lower refinancing rates, in a few a years this might pose enormous challenges especially to smaller banks which typically do not hedge their interest position on the international markets. Therefore, there is increasing evidence that monetary policy works contractionary at negative rates if banks have a high share of deposit funding.

Chapter 4

In contrast to chapter 2 and 3, which use modern empirical methods to answer contemporary questions of monetary policy, chapter 4 tries to answer one of the oldest questions in the macroeconomic field using modern dynamic stochastic general equilibrium (DSGE) models. More precisely, it uses an occasionally binding constraint in a DSGE model to model the introduction of a minimum wage. After a very long debate, a minimum wage of 8.50 EUR was introduced in Germany in early 2015 which so far did not lead to large job losses. Comparing Germany to other advanced European Union (EU) countries, the most

likely explanation for this is that the German minimum wage is rather low, i.e. it is often not binding as the competitive wage rate for many tasks is higher. However, following the large influx of refugees and migrants in late 2015 the competitive wage rate is likely to fall as a result of this positive labour supply shock. Since it is likely that the majority of migrants first enter into the unskilled sector, standard economic theory predicts a drop in the wage rate for the unskilled labour market making the minimum wage binding.

Using a one sector closed economy DSGE model with skilled, medium skilled, and unskilled households the fourth chapter studies the effects of a positive labour supply shock on an occasionally binding minimum wage in a dynamic fashion for a competitive and a monopsony labour market. Besides the contribution of modelling the minimum wage as only occasionally binding downward rigidity (which it is by its very definition) using the tool proposed by Guerrieri and Iacoviello (2015), a second novelty of our model is that we try to generalise the static equilibrium monopsony model of Manning (2003) into a DSGE framework.

The results suggest that a moderate minimum wage reduces macro volatility and smooths consumption. In addition, the results show that due to monopsony, the wage that is offered by firms to unskilled workers is lower in steady state relative to the neoclassical benchmark case were neither firms nor unskilled workers have market power. Still, the dynamics of the model are unaffected by monopsony, i.e. a positive labour market shock still translates to a lower wage rate. However, with respect to the minimum wage this chapter shows that a direct modelling of the monopsony approach by Manning (2003) is not sufficient to generate a positive effect from a moderate minimum wage. In order to do so, additional labour market frictions as in the search-and-matching literature are needed.

Chapter 2

Quantitative Easing in the Euro Area - An Event Study Approach[*†]

[*]This chapter is based on joint work with Sebastian Watzka

[†]Acknowledgements: We are thankful to Klaus Adam, Markus Brunnermeier, Guglielmo Caporale, Paul de Grauwe, Gerhard Illing, and Michael Weber for valuable advice. We also appreciate helpful comments and suggestions by the participants of the CESifo Macro, Money & International Finance Conference 2017, the EEA 2017 Lisbon Conference, the VfS Annual Conference 2017, the Belgrade Young Economist Conference, the RGS Econ 10th Doctoral Conference, and the Macroeconomics Seminar at the University of Munich. Finally, we acknowledge research assistance by David Gramke and Patrick Weiß. Any remaining errors are the responsibility of the authors.

2.1 Introduction

After a severe drop in inflation rates and medium-term inflation expectations during 2014, the European Central Bank gradually introduced the Asset Purchase Programme (APP) with a total monthly purchase volume of between 60 and 80 billion EUR[1]. In fact, headline inflation plunged to -0.6% in January 2015, with core inflation, excluding more volatile goods such as oil or energy prices, showing a clear downward trend since 2013 as outlined in Figure 2.1. Even more importantly, the 5y5y inflation forward swaps, the ECB's preferred measure of medium term inflation expectation, started declining in 2014, threatening inflation expectations becoming de-anchored. Being in danger of missing its inflation target in the medium-run, the ECB gradually introduced the APP and consequently emphasised that the ultimate aim of this quantitative easing (QE) programme is to fulfil its mandate of maintaining price stability. Accordingly, the ECB officially stated that "[the Asset Purchase Programme] will help to bring inflation back to levels in line with the ECB's objective"[2].

Comparing the ECB's policy to other major central banks like the Fed or the Bank of England, both of these institutions have introduced various conventional and unconventional monetary policy measures during the global financial crisis of 2008-09, including large QE programmes. Whereas these central banks purchased domestic government bonds on a large scale early on, the ECB during the financial crisis rather focused on buying covered bonds and provided exceptional liquidity measures to banks[3]. Because some member countries in the Euro Area were worried about potentially strong effects on inflation, other unintended consequences, or the compatibility of a QE programme with European law, the European Central Bank avoided large purchases of government bonds during the initial phase of the financial and European debt crisis.

The early stage of unconventional monetary policy measures after 2008 has been studied intensively in the literature. Three main conclusions can be drawn: First, the strongest reaction of financial markets is expected to occur upon announcement of the stock of purchases, while the effects from the actual execution of the programme are minor in comparison. These two effects are often referred to as "stock" versus "flow" effects. Second, among several possible channels proposed by the literature "narrow channels" (targeting just a few assets) usually seem to have stronger effects compared to "broader channels" (aiming to affect also other market segments via spill-over effects). Finally, asset purchase programmes that were conducted in times of stressed markets and high uncertainty seem to have a stronger impact than programmes that were announced when market conditions were relaxed[4]. In this respect, it is important to note that the European Central Bank started its QE programme in times when financial markets were relatively calm suggesting rather minor effects from it.

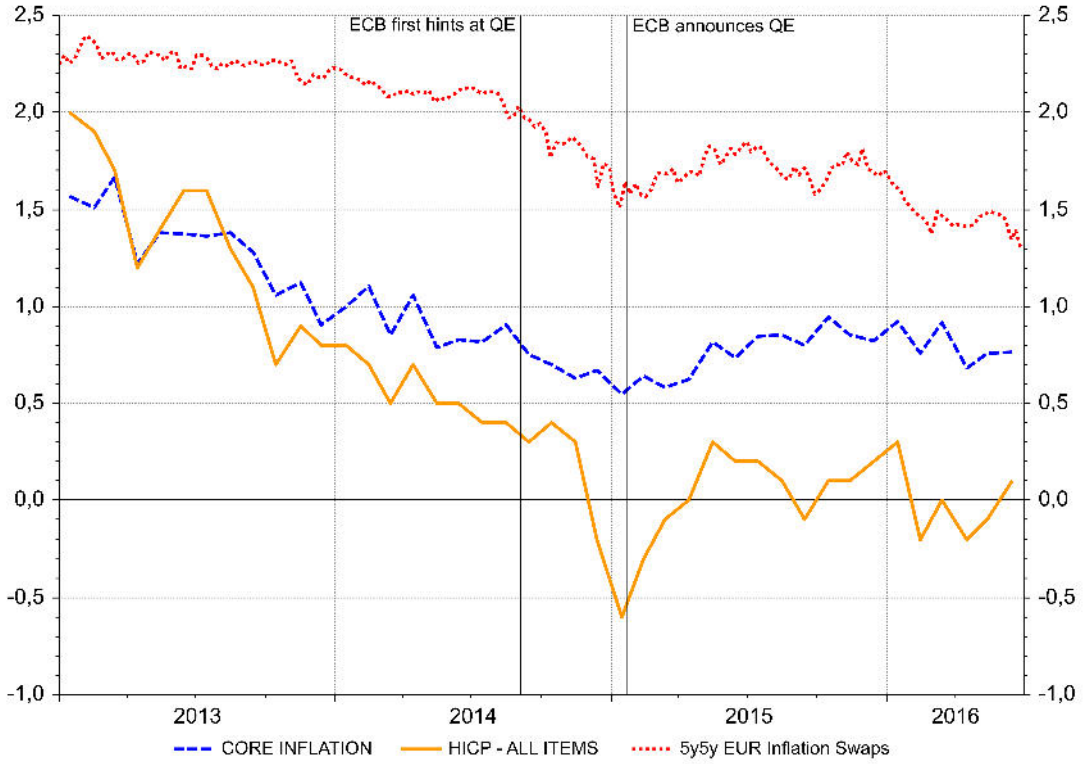
[1] The initial size of 60 billion EUR per month was increased to 80 billion EUR in March 2016 and lowered again to 60 billion EUR in December 2016. See Section 2.2 and Section 2.5 for details.

[2] See https://www.ecb.europa.eu/explainers/tell-me-more/html/asset-purchase.en.html.

[3] These encompassed three-year loans to eligible banks, unlimited liquidity provisions via a fixed-rate full-allotment procedure, or lowering the deposit rate to zero. Only after the outbreak of the European debt crisis did the ECB start to purchase government bonds in 2010 under the Securities Markets Programme (SMP). However, the SMP is usually not regarded as a full blown QE programme.

[4] For a more detailed discussion see, for instance, Krishnamurthy and Vissing-Jorgensen (2011), D'Amico and King (2013), Joyce and Tong (2012), and Altavilla, Carboni, et al. (2015).

Figure 2.1: Inflation and Inflation Expectation in the Euro Area



Source: Datastream. Vertical lines indicate important events.

As it remains too early to judge the wider impact of the APP on macroeconomic conditions in the Euro Area, this chapter examines if the ECB has been successful in achieving the intermediate goal of lowering long-term bond yields. Reducing these yields should flatten the yield curve, lead to more credit to the real sector, increase aggregate demand, and ultimately also increase inflation. To find some first evidence whether this necessary pre-condition has been achieved, we use an event study methodology to examine the effects of APP press releases on bond yields. More precisely, we systematically search for key ECB policy announcements and consider how selected Euro Area bond yields were affected by different asset price channels. Most importantly, we examine how the conditional bond-OIS spread, a proxy for the effect of portfolio rebalancing[5], changed during our events.

Our analysis suggests that the ECB's policy had strong and desired effects on financial markets at the very beginning, but less so subsequently. As a result of the portfolio rebalancing channel and a potential reduction in credit and liquidity risk premia, we estimate a cumulative reduction in yields of Euro Area government bonds ranging from 85.80 basis points (BPS) for Portugal to only 5.91 BPS for Germany. In our view, possible explanations for such mild effects for some Euro Area countries are the timing of the APP and the strict self-imposed regulations by the ECB. Notably, the ECB decision to not buy bonds

[5]Under the assumption that assets are not perfect substitutes Tobin (1969), among others, argued that a change in the relative supply of a specific asset, e.g. due to an intervention by the central bank, must result in a change in the relative expected return of the asset, all else equal. Suppose the QE policy of the central bank leads to a rise in the price for a long-term government bond and, hence, to a drop in the expected return of an investor's portfolio. Keeping the desired expected return of her portfolio constant, the investor now needs to buy other assets with broadly similar characteristics in terms of risk or maturity to maintain the overall expected return of her portfolio. Thus, via the *rebalancing* of investors' portfolios the price and yield of other assets are also changing.

trading below the deposit facility could potentially dampen positive effects from the APP[6]. In contrast, the much stronger reductions for periphery countries like Portugal or Italy suggest that markets implicitly also lowered the risk premia for these countries. Put differently, countries with a higher yield reacted stronger to APP announcements compared to countries having a low yield already near the zero lower bound.

The remainder of this chapter is organised as follows. Section 2.2 describes some important institutional details of the ECB's QE programme. Section 2.3 reviews the large and growing literature on different QE programmes and their success so far. Section 2.4 describes the theoretical considerations for measuring the portfolio rebalancing channel by the bond-OIS spread. Section 2.5 outlines the data set in detail with special focus on identifying event dates. Next, the reaction of bond markets is presented in Section 2.6 followed by event regressions in Section 2.7. Section 2.8 concludes.

2.2 APP Institutional Details

Due to the incomplete integration of the current monetary union in the Euro Area the Asset Purchase Programme conducted by the ECB has some important regulations and characteristics with respect to its design. As we will argue, some of these regulations may seriously dampen the desired effects of the APP.

To begin with, the APP is actually an umbrella term for four different purchase programmes: the Third Covered Bond Purchase Programme (CBPP3), the Asset Backed Securities Purchase Programme (ABSPP), the Public Sector Purchase Programme (PSPP), and the Corporate Sector Purchase Programme (CSPP). In total, the ECB's asset purchases under the APP have a target rate of 60 to 80 billion EUR per month, which accumulated to 1,084,583 million EUR in June 2016. Table 2.1 summarises the main features of each programme while Figure 2.2 illustrates the cumulative purchases over time, indicating that the in terms of scale the PSPP is by far the largest.

Even though the programmes differ considerably by size and scope they also share some common features. First of all, all APP programmes are in principal open-ended and are intended to continue until the ECB sees the inflation rate back on a sustained inflation path in line with the ECB's target rate of close to but below 2%. As a benchmark the APP was initially intended to last at least until September 2016, which has already been extended twice, first, to March 2017 and, a second time, to December 2017.

Secondly, important aspects to note are the regulations concerning hypothetical losses from the ECB's asset purchases. Unlike a national central bank the ECB is not owned by a national government but by all the national central banks from each member state. Taking into account this unique institutional structure of the Euro Area, the majority of the asset purchases are conducted in the home market of each national central bank according to its respective capital share in the ECB. Subsequently, in case of a hypothetical default of e.g. a single Portuguese government bond bought by the Banco de Portugal, only the Banco de Portugal would incur the respective loss for this bond[7]. Note, however, a smaller part of

[6] In fact, the ECB has eased this constraint in the monetary policy decision of December 2016 by stating that under the APP purchases with a yield below the deposit facility "will be permitted to the extent necessary". See https://www.ecb.europa.eu/press/pressconf/2016/html/is161208.en.html

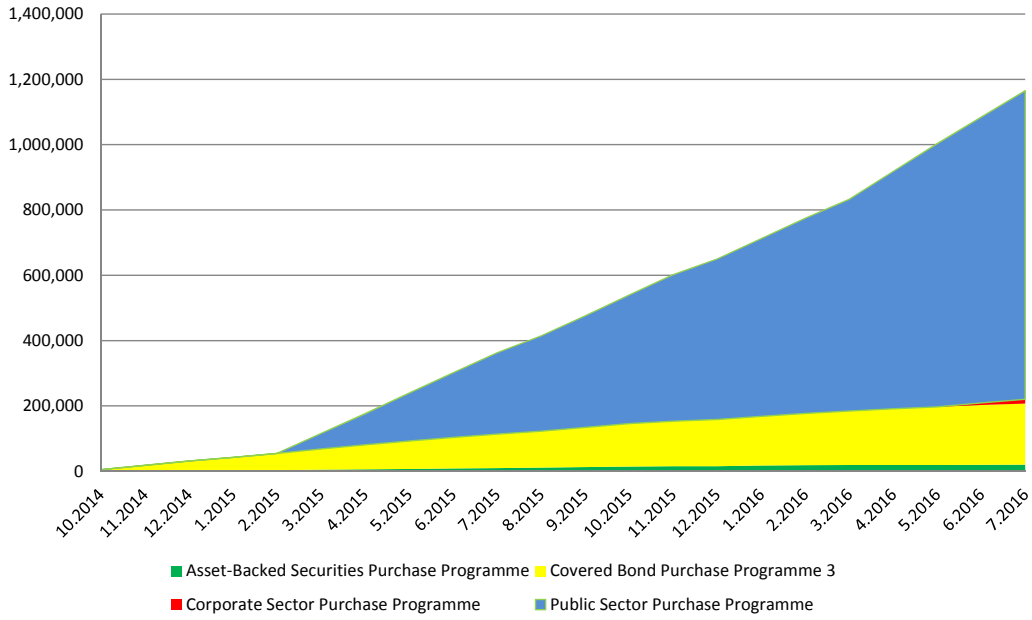
[7] Given no other national central bank bought the same bond.

Table 2.1: Asset Purchase Programme Overview

Programme	Monthly Net Purchases	Total Holdings	In Percent	Start of Programme
CBPP3	3,258	183,377	16.02	October 2014
ABSPP	854	19,607	1.75	November 2014
PSPP	69,658	875,201	81.09	March 2015
CSPP	6,816	6,398	1.13	June 2016

Source: ECB; holdings at amortised cost, in million EUR, at month end.

Figure 2.2: History of Cumulative Purchases under the APP



Source: ECB; holdings at amortised cost, in million EUR, at month end.

asset purchases of about 20% are conducted directly by the ECB. Hypothetical losses to these purchases are subject to loss sharing.

Since the PSPP is by far the largest programme it is the main focus of this chapter. As the intended goal of the programme is to lower long-term government bond yields, the ECB initially intended to buy only mid- and longer-term bonds with a remaining maturity of 2 to 30 years[8]. Yet, not all bonds bought by the ECB are government bonds. In fact, roughly 10% of bonds purchased are international organisations and multilateral development banks such as the EU or the European Investment Bank. Also, there is a long list of regional governments or recognised government institutions, such as the German KfW or the French Caisse, which are eligible for the bond buying programme[9]. As already indicated the issue of collective liability and risk sharing is sensitive in the case of the ECB. Therefore, in order to avoid potential trade-offs in case of default, the ECB initially only bought bonds up to 33% per issuer and 25% per issue of a single bond, the idea being not to have a blocking minority in collective action clause assemblies. To increase flexibility, this rule was gradually increased to 33% per issue for public entities, subject to a case-by-case verification, and 50% of issuer *and* issue share for international organisations and multilateral development banks. Since the ECB does not publish a full list of bonds (and respective shares) bought, it remains unclear how strong this constraint might constrain the hands of the ECB[10].

[8] Recently, the maturity has been lowered to one year.
[9] Also note that ECB currently does not purchase any Greek government bonds.
[10] Some authors predicated that the ECB could hit these limits for e.g. German Bunds around March 2017 (see for

Additionally, another aspect jeopardising a successful implementation of the PSPP is the current negative interest and yield environment. In order to avoid large losses from bond purchases, the ECB vowed to a self-imposed regulation of not buying bonds trading at a yield below the deposit facility rate. The ECB was the first large central bank to introduce negative interest rates by lowering the deposit facility to -0.1% in June 2014. Afterwards, the deposit facility has been lowered gradually down to -0.4% in March 2016. For details see Figure A.1 and A.2 in the Appendix. As we see in Section 2.5, under this constraint a large and increasing number of bonds are not eligible for the APP programme[11]. We argue that these tight self-imposed regulations seriously constrain the ECB in a successful implementation of their QE programme especially for Euro Area core countries.

2.3 Literature Review

A very large and continuously growing literature exists on the effects of quantitative easing programmes. Since the start of the first QE programme by the Bank of Japan in 2001 the topic raised increasing academic attention (see for instance Ugai (2007) for an early empiric assessment). However, the number of academic papers exploded after the financial crisis of 2008-09 when the US Fed, the Bank of England, the Bank of Japan, and the European Central Bank all started various kinds of asset purchasing or unconventional monetary policy measures. A strict categorisation of different approaches in the literature is obviously difficult. Nevertheless, we can loosely group the literature into three different strands: theoretical, long-term empirical and short-term empirical.

A first stream of literature considers how large asset purchasing programmes can be built into standard New Keynesian models, which mostly suggest the irrelevance of such a policy as in Eggertsson and Woodford (2003)[12]. One such approach can be found in Cúrdia and Woodford (2011). Generalising the findings of Eggertsson and Woodford (2003), the authors show that targeted asset purchases can be effective if financial markets are sufficiently disrupted, i.e. if private-sector financial intermediation is inefficient. However, QE can still be irrelevant if the central bank conducts pure quantitative easing (buying Treasury securities) rather than credit easing (lending directly to the private sector), or if the central bank cannot change people's believe about the future interest rate policy. A second approach is the limitation of arbitrage, often modelled by assuming some kind of segmented asset markets, e.g. due to preferred-habitat motives as in Vayanos and Vila (2009). One example is Chen et al. (2012) where the authors aim to simulate the second large scale asset purchase programme by the Fed, by augmenting a standard DSGE model (with nominal and real rigidities) with segmented bond markets. According to the authors, their paper "wants to give QE programs a chance" [Chen et al. (2012), p. 290] by assuming that heterogeneous preferences for assets of different maturities exist leading to such kind of asset market segmentation. This implies that the long-term interest rate plays a role in determining aggregate demand distinctly from the expectation of short-term rates. Therefore, even if the central

instance Claeys, A. Leandro, et al. (2015)). Yet, this early assessment does not included later changes to policies as mentioned above. More recent studies, such as Claeys and L. Leandro (2016), suggest that purchases of German bonds will be constraint between April 2017 and March 2018. However, in December 2016 the ECB announced that purchases for bonds below the deposit facility "will be permitted to the extent necessary", which again relaxes this constraint.

[11] See also Figure 2.3.

[12] The necessary condition for this is to break the Wallace's irrelevance theorem, see Wallace (1981).

bank has already lowered the short-term rate to zero for an extended period and, thus, is constraint by the ZLB, its monetary policy could still have a positive impact on the macro economy by directly influencing current long-term rates. By using a counterfactual evaluation of what would have happened in the absence of the Fed's QE programme Chen et al. (2012) find a modest increase in GDP of less than a third of a percentage point while inflation barely changes with or without the intervention.

A second stream of literature focuses on the long-term impact of quantitative easing. These papers often make use of various kinds of VAR estimators to study the effects on financial markets and the real economy. Examples include Schenkelberg and Watzka (2013) for the Bank of Japan, Boeckx et al. (2014), and Lewis et al. (2015) for the ECB, or Kapetanios et al. (2012) for the Bank of England. An interesting cross country analysis focusing on the long-term effects of QE is Gambacorta et al. (2014). In their paper, the authors evaluate different unconventional monetary policies from eight advanced economies and their effects on the real economy by estimating a panel VAR model with monthly data. Arguing that the global financial crisis has been an important common factor in the business cycle of the sample countries, the authors try to exploit the cross-country dimension and focus on a rather short time span from January 2008 to June 2011. By using a mean group estimator and following the standard approach of Pesaran and Smith (1995) to account for cross-country heterogeneity in e.g. monetary policy design Gambacorta et al. (2014) find that, if the central bank is at the ZLB, an exogenous increase in its balance sheet translates to a temporary increase in output and consumer prices.

Finally, a third stream of literature examines the short-term effects on financial markets. Many papers do so by the means of event studies, or term structure models, or both. See for example Krishnamurthy and Vissing-Jorgensen (2011), Gagnon et al. (2011), D'Amico and King (2013), and Chodorow-Reich (2014) for the Fed policy, Eser and Schwaab (2016) and Szczerbowicz (2015) for unconventional monetary policy programmes in the Euro Area, or Christensen and Krogstrup (2014) for the Swiss National Bank. Also, some authors focus on international spill-over effects on other financial assets due to QE announcements such as Neely (2015) or Fratzscher et al. (2014). Our work is most closely related to Joyce, Lasaosa, et al. (2011) who examine the impact of the Bank of England's QE policy on British gilts. More precisely, their event study investigates how QE announcements by the Bank of England have affected government bond markets in the short-run and how this has translated more widely to the prices of other financial assets. Using a two-day window, they find that asset purchases by the Bank of England could have lowered medium- to long-term gilt yields by about 100 basis points cumulatively, which mostly results from the portfolio rebalancing effect.

Recently, several papers have been issued on the Asset Purchase Programme by the ECB. Darracq Paries et al. (2016) augment a DSGE model with a segmented banking sector and calibrate their model to the Euro Area and the APP. Using a term structure model, Altavilla, Carboni, et al. (2015) find that the impact of the APP on asset prices was sizeable. Unfortunately, their observation period ends in March 2015. In addition, the main focus of Andrade et al. (2016) and Blattner and Joyce (2016) is on the impact of the APP on the duration risk channel and banks' capital relieve, and on net bond supply and changes in duration risk, respectively. Another work closely related to this chapter is De Santis (2016) who also examines the effects on Euro Area government yield relying on Bloomberg news of the APP. In contrast to this chapter, he focuses on the general *monthly* reduction in yields and his observation period ends in

October 2015.

To summarise, many authors do seem to find a positive impact of asset purchase programmes on financial markets at least in the short-run. This is especially the case in times of financial crisis and general uncertainty. However, the longer-term effects on the real economy are less clear. One reason for this is the fact that it is empirically more difficult to clearly identify the effects of a QE policy on the macro economy separately from other policies happening at same time. Moreover, from a theoretical point of view there is no clear consensus in the literature if and how asset purchase programmes may be transmitted to the real economy.

2.4 Measuring Asset Price Channels

With the introduction of a full scale QE programme the ECB aims to fulfil its mandate of maintaining price stability. Given this target of bringing inflation back on track, it might not be apparent why we focus on financial markets. From an econometric point of view, measuring the wider impact of the APP on general asset prices or macro-economic variables for a longer-term is a difficult task since it is very hard to disentangle it from other influences. This is especially true for a not fully integrated monetary union of different countries where uncoordinated national fiscal policies or regulations might support or counteract a common monetary policy. Moreover, even in the case of a fully integrated domestic fiscal policy, the transmission mechanism of a QE programme to the macro economy could be subject to long lags or be polluted by other policies and developments be it domestic or international. Thus, we should expect to see the most direct and clearest impact of the APP on the financial markets. If the QE programme by the ECB does not prove to be effective on the financial markets, it is rather unlikely it will be effective on the rest of the economy. Put differently, one might interpret a positive response of asset prices as a necessary but not a sufficient condition for the APP to reach its ultimate goal of raising inflation to normal levels via the asset price channel.

Therefore, in this chapter we try to answer the question if this necessary condition has been satisfied. In doing so, we build on a similar methodology as in Joyce, Lasaosa, et al. (2011) and apply it to the Euro Area taking into account the specific institutional set up of the Euro Area and large cross-country heterogeneity. More precisely, we try to identify the strength of the portfolio rebalancing channel using the government bond-OIS spread. In this framework, we think of four different channels from which the Asset Purchase Programme by the ECB could have a potential impact on government bond prices, namely the signalling channel, the portfolio rebalancing channel, the liquidity premium channel, and the credit risk channel.

The *signalling channel* – sometimes also labelled as the policy news or macro news channel – reflects all new information that market participants learn from ECB press releases or policy announcement about the economy or the ECB's reaction function. Typically, after a policy announcement the President of the ECB, Mario Draghi, explains the decision of the Governing Council in a press conference and explains how the Council sees the underlying state of the economy. Thus, this channel also captures the expectation formation of economic agents about future ECB policy rates. Note that this definition is rather broad and, therefore, includes the expected path of future short-term interest rates. Hence, as

market participants are revising their perception of future term premia, this channel also directly effects a range of other financial variables such as government bond yields, the OIS rate, or even the exchange rate. However, the overall sign of this channel is uncertain in general. In fact, it could be either positive or negative depending on whether market participants pay attention to the decreased policy rates in the short-term, or, if they fear increased inflation in the future.

The second channel, which influences the yield of government bonds directly, is the *portfolio rebalancing channel*. This channel refers directly to the response of investors who rebalance their portfolio after the announcement of the European Central Bank to purchase government bonds on the secondary market. The change in the relative expected return of the asset also changes the expected return of the whole portfolio of the investor. Therefore, as a result of imperfect substitutability between long-term government bonds and money the QE policy of the central bank can also indirectly affected the price and yield of other assets. More specifically, the ECB purchases of mid- and longer-term government bonds are expected to reduce yields on these bonds and, thus, also boost investors demand for alternative long-term investments. Moreover, since investors are now certain that future ECB purchases will happen on a large scale, the effects of this channel are likely to occur very shortly after the announcement and not just over time when actual purchases are made. In general, this channel could be persistent and potentially significant as it depends on the outstanding *stock* of bond purchases, which is considerable in the case of the Euro Area[13].

Additionally, a central bank could improve the functioning of bond markets via the *liquidity and credit risk premium channel*. In principle, the potential presence of the ECB in bond markets as a major buyer should decrease the risk premia for illiquidity of certain government bonds. The working of this channel has been best illustrated by Mario Draghi's famous "Whatever-it-takes" speech in July 2012 in the height of the Euro Area debt crisis. Even though the OMT programme[14] to this day never bought a single Euro Area government bond, the very announcement was sufficient to substantially reduce the liquidity risk premia on Spanish or Italian government bonds. Since investors knew that they could always sell their bonds to the ECB when required, it was significantly less costly for them to acquire them in the first place. Nonetheless, it is usually argued that this channel should be rather weak during normal times when government bond markets are deep and liquid. Put differently, this channel is likely to be temporary and the strength should depend on the (potential) *flow* of purchases. As the Public Sector Purchase Programme was announced during calm times, we would expect only minor effects from it, especially for Euro Area core countries.

In our assessment how the APP has influenced Euro Area government bond yields, we utilise the bond-OIS spread. An Overnight Index Swap (OIS) is a financial contract where a predefined fixed interest rate is swapped for a floating interest rate, which is usually linked to a compounded overnight interbank interest rate such as the Fed funds rate or the EONIA. Since the counterparties only swap the flow of interest payments but not the principal, credit risk is not an important factor in an OIS contract[15].

[13]However, in traditional New Keynesian models the portfolio rebalancing channel is non-existing at the ZLB since zero interest rate government bonds and money deposits are considered to be substitutes for investors. The only possibility how QE could be effective in this type of models is by changing the expected path of future short-term rates via the signalling channel. As we want to examine the strength of the portfolio rebalancing channel, we are implicitly assuming financial markets to be incomplete or imperfect while being agnostic about the exact source of the friction.

[14]Formally announced two month later in September 2012.

[15]This feature has made it popular to interpret the LIBOR-OIS spread as a premium for overnight counterparty risk.

Moreover, as the OIS market is very large and liquid[16], and, as contracts are also collateralised we view the OIS rate as a proxy for the risk free rate.

More importantly, as OIS contracts involve swaps of interest payments their rate should not be directly influenced by a change in the expected supply on government bond markets (i.e. the portfolio rebalancing channel). Instead, their rate should capture the change in the expected path of future short-term rates (i.e. the signalling channel). Therefore, changes in the bond-OIS spread reflect the effects from the portfolio rebalancing channel. This concept should become clearer when looking at the decomposed standard expression for bond yields.

First, we break down the yield of a government bond into the expected path of future short-term interest rates, an instrument specific premium, and a general term premium

$$y(bond)_t^{n,i} = \left(\frac{1}{n}\right) \sum_{j=0}^{n-1} \mathbb{E}_t(r_{t+j}) + ISP(bond)_t^{n,i} + TP(bond)_t^n, \tag{2.1}$$

where $y(bond)_t^{n,i}$ represents the $n-$period maturity yield of the government bond from country i and $\mathbb{E}_t(r_{t+j})$ is the expected path of the one period risk-free short-term rate. Additionally, $ISP(bond)_t^{n,i}$ reflects an instrument specific term premium which is due to the bond specific effects of country i. More precisely, this term captures any credit or liquidity premia of country i, but, also any effects from short-term supply/demand imbalances. Furthermore, $TP(bond)_t^n$ denotes a term premium due to uncertainty about future short-term interest rates.

In a second step, we decompose the yields implied by OIS contracts in a similar fashion

$$y(OIS)_t^n = \left(\frac{1}{n}\right) \sum_{j=0}^{n-1} \mathbb{E}_t r_{t+j} + \underbrace{ISP(OIS)_t^n}_{\text{negligible: } \approx 0} + \underbrace{TP(OIS)_t^n}_{=TP(bond)_t^n}, \tag{2.2}$$

where $y(OIS)_t^n$ equals the $n-$period maturity rate of an OIS contract. Again $\mathbb{E}_t(r_{t+j})$ reflects all expected future risk-free short-term rates, while $ISP(OIS)_t^n$ denotes the instrument-specific premium. As described above, the OIS rate is considered to be a risk-free rate due to the absence of credit or liquidity risk, which is why this term is assumed to be negligible and close to 0. Finally, $TP(OIS)_t^n$ refers to a conventional term premium due to uncertainty. In general, the uncertainty about future short-term interest rates should be same for both the OIS and the government bond market. Hence, $TP(OIS)_t^n$ equals $TP(bond)_t^n$.

Finally, subtracting (2.1) from (2.2) yields a proxy for the portfolio rebalancing effect

$$Sp_t^{n,i} = y(bond)_t^{n,i} - y(OIS)_t^n = ISP(bond)_t^{n,i}. \tag{2.3}$$

As both the expected path about future short-term rates $\mathbb{E}_t(r_{t+j})$ and the term premium due to uncertainty $TP(OIS)_t^n = TP(bond)_t^n$ cancel out, the spread yields the instrument specific premium $ISP(bond)_t^{n,i}$. Under the assumption that credit and liquidity premia on government bonds are negligible and not di-

[16]This is certainly true for short and medium maturities. Indeed, the market for longer maturities is not as large and, thus, may involve minor liquidity risk.

rectly affected by APP announcements[17] a change in the spread $Sp(bond)_t^{n,i}$ reflects demand/supply changes from QE announcement via the portfolio rebalancing channel for any given event day.

Moreover, given the specific institutional set up of the APP and the fact many bonds cannot be bought under current ECB regulations if the yield is below the deposit facility, we calculate the change in $Sp(bond)_t^{n,i}$ as the conditional bond-OIS spread defined as

$$\Delta Sp_t^{n,i} = Sp_{t+1}^{n,i} - Sp_t^{n,i} \qquad \text{if } y(bond)_{t-1}^{n,i} > DF_t. \tag{2.4}$$

Suppose a one day window for a given event date t. When using daily data, a change in the spread $\Delta Sp_t^{n,i}$ can only be affected by APP purchases if the closing yield on the day before the announcement $y(bond)_{t-1}^{n,i}$ was above the new deposit facility DF_t valid from day t onward. As Figure 2.3 reveals in detail in the next section, on several event days specific bonds have to be excluded from our analysis because they traded below the deposit facility and hence were not eligible for APP purchases. Note, however, that in some instances bonds being previously ineligible in $t-1$ can become eligible on event day t if the deposit facility itself has been lowered.

2.5 Data Set and Events

In this chapter, we use daily yield data for nine different Euro Area countries: five so called core countries (Belgium, Finland, France, Germany, and the Netherlands) and four so called periphery countries (Ireland, Italy, Portugal, Spain). More precisely, for each country we look at zero coupon benchmark bonds ranging in maturity from 2 to 10 years. To calculate the bond-OIS spread we match each benchmark bond with the corresponding OIS rate[18]. For the regression analysis we also include daily CDS premia and bid-ask spreads for each country and maturity. Additional control variables are the VSTOXX volatility index and a 10 year US treasury benchmark bond. All this data is taken from Datastream.

Our data is matched with news announcements of several macroeconomic variables for each country. The news data is taken from the calendar function of the publicly available website tradingeconomics.com. A detailed list of these macro news variables can be found in Section 2.7.

A crucial step in any event study is to choose "the right" events. One idea could be to look at 5y5y inflation swaps as they are an important indicator of inflation expectations for central banks. Large deviations from the inflation target could make it more likely that the ECB will introduce a QE programme. However, the movements of inflation swaps are highly correlated with the price of oil which makes it hard to find a direct link to QE speculations[19]. More commonly, authors such as Szczerbowicz (2015) and Gagnon et al. (2011) look at official press releases, announcements, and decisions made by the central bank to identify events. However, we believe that this approach is likely to underestimate the number of relevant events for two reasons. First, looking only at official releases does not indicate

[17] Clearly, this is a crucial assumption especially for some Euro Area countries. Despite the assumption being certainly credible for Germany it is shakier for e.g. Portugal or Italy as credit risk is higher and bid-ask spreads are more volatile for southern countries. In fact, we have found that credit risk is influenced by our events. Thus, we cannot exclude the possibility of a contemporaneous reduction in credit risk. This holds especially for Italy, Portugal, and Spain. We try to tackle this issue later, see discussion below in Section 2.5 and 2.7.

[18] In principle, all zero coupon benchmark bonds are available also at longer maturities of up to 30 years. Unfortunately, the longest maturity available for the OIS rate is 10 years, which limits our analysis accordingly.

[19] See Figure A.1 in the Appendix.

anything about the novelty of the information. If news are already widely anticipated by the market asset price do not tend to react too much, since the "new" information was already priced in[20]. Secondly, adding to this argument, looking only at actual decision does not capture the building of expectations *prior* to an announcement. In fact, expectations of market participants about an upcoming decision could be influenced by e.g. press releases on the latest unemployment numbers or even by dinner speeches from the central bank's president.

An alternative popular approach in the literature to identify events is to look at news databases such as Lexis Nexis, Factiva, or Bloomberg News and to consider only these dates which yield the highest number of articles on a specific search query. This approach is for instance taken by Altavilla, Carboni, et al. (2015) and De Santis (2016). Proponents of this identification strategy often argue that this procedure better captures the expectation formation by markets and the surprise component. However, in our view this idea might also have potential downsides. Since newspapers often have a backward looking introduction, which might lead to a hit under a given search query despite the news article not reporting anything new, this method is likely to overestimate the truly relevant numbers of events. In other words, just because a central bank's press release is newsworthy does not reveal anything about the surprise to the new piece of information[21]. Therefore, a potential concern with this approach is that the number of news articles seems to be highly correlated with *any* Governing Council meeting, again leading to a potential over identification of events[22].

This chapter, follows the event identification method of Fratzscher et al. (2014) to find a total of 10 event dates. In particular, we look at *all* ECB press releases from January 2014 to June 2016 and try to verify the informational value by simultaneously reviewing if these releases were covered by the Financial Times on first three pages on the next day. If this is the case, we regard this press release to be major news and include it in our list of event days illustrated shortly in Table 2.2 and in more detail in the Appendix in Table A.1 and A.2.

One advantage of this method is that we are more likely to consider only truly relevant event days. Suppose a monetary decision was widely anticipated by the market, the Financial Times would most likely report about this decision, but it would probably not do it on the first three pages containing only the most relevant news of the day. On the contrary, even if during a ECB press conference no new decision with respect to monetary policy was announced but, instead, Mario Draghi hinted that the Governing Council is likely to reconsider its action in its next meeting, it is more likely that the Financial Times would cover such an event on the first three pages[23].

Given this event identification strategy we broadly distinguish between two kinds of events. The first group being labelled as "announcement effects" refers to actual QE decisions made and covered by the Financial Times on the first three pages. The second group of events is labelled as "speculation effects"

[20] Unless the new piece of information strongly surprise market participants.

[21] For example, the search query "Quantitative Easing <or> QE <or> Asset Purchase Programme <and> Draghi <or> ECB <or> European Central Bank" on Lexis Nexis delivers the highest number of hits on the 22nd of January 2015 (the day of the PSPP announcement). However, already the third highest number of hits indicates that the 05th of March 2015 (the next ECB Council Decision *after* the PSPP announcement) would be an important event. Yet, nothing was announced nor expected to happen at this Governing Council meeting so shortly after the previous announcement in January 2015. Instead, many newspapers referred to the important announcement from the previous meeting.

[22] Please find this alternative approach in Figure A.2 in the Appendix.

[23] One potential drawback of this approach could be that our events are not truly exogenous. For instance, if there are large movements in the markets the FT could simply try to give an *ex post* explanation for these movements on the next day. While we cannot fully exclude this possibility note that *any* news based event study would be subject to this concern.

Table 2.2: Event Days from ECB Press Releases and Financial Times Headlines

Date	Kind	Summary
05.06.2014	ECB monetary policy decisions	The Governing Council decided on a combination of measures • Lower the deposit facility by 10 basis points to -0.10% • *Intensify preparatory work for purchases in the ABS market*
04.09.2014	**ECB monetary policy decisions**	The Governing Council decided to • Lower the deposit facility by 10 basis points to -0.20% • Announce the ABS Purchase Programme (ABSPP) • Announce the Covered Bond Purchase Programme (CBPP3)
14.01.2015	ECB press release	We take note of the *European Court of Justice Advocate General's legal opinion* in the OMT case. This is an important milestone in the request for a preliminary ruling, which will only be concluded with the judgement of the Court
22.01.2015	**ECB monetary policy decisions**	ECB announces expanded APP • ECB purchases bonds issued by Euro Area central governments, agencies and European institutions (PSPP) • Combined monthly asset purchases of €60 billion
03.09.2015	**ECB monetary policy decisions**	The Governing Council decided to keep the key ECB interest rates unchanged. • Increase the issue share limit from 25% to 33%, subject to a case-by-case verification
22.10.2015	ECB monetary policy decisions	The Governing Council decided to keep the key ECB interest rates unchanged. Draghi: *"Adjust the size, composition and duration of QE"*
03.12.2015	**ECB monetary policy decisions**	The Governing Council decided to • Lower the deposit facility by 10 basis points to -0.30% • Extend the APP until the end of March 2017, or beyond • Include regional and local governments in the PSPP list
21.01.2016	ECB monetary policy decisions	The Governing Council decided to keep the key ECB interest rates unchanged. Draghi: *"There are no limits to our action"*
18.02.2016	ECB press release	The minutes show the Governing Council was *unanimous* in concluding that its current policy stance *"needed to be reviewed and possibly reconsidered"*.
10.03.2016	**ECB monetary policy decisions**	The Governing Council decided to • Lower the deposit facility by 10 basis points to -0.40% • Expand the monthly purchases of APP from €60 billion at present to €80 billion. • Increase the issuer and issue share limits from 33% to 50% for international organisations and multilateral development banks • Announce purchases of investment-grade bonds issued by non-banks in the corporate sector (CSPP)

Green: announcement effects (new QE announcement and Financial Times P.1-3).
Yellow: speculation effects (no new QE announcement, but Financial Times P.1-3).

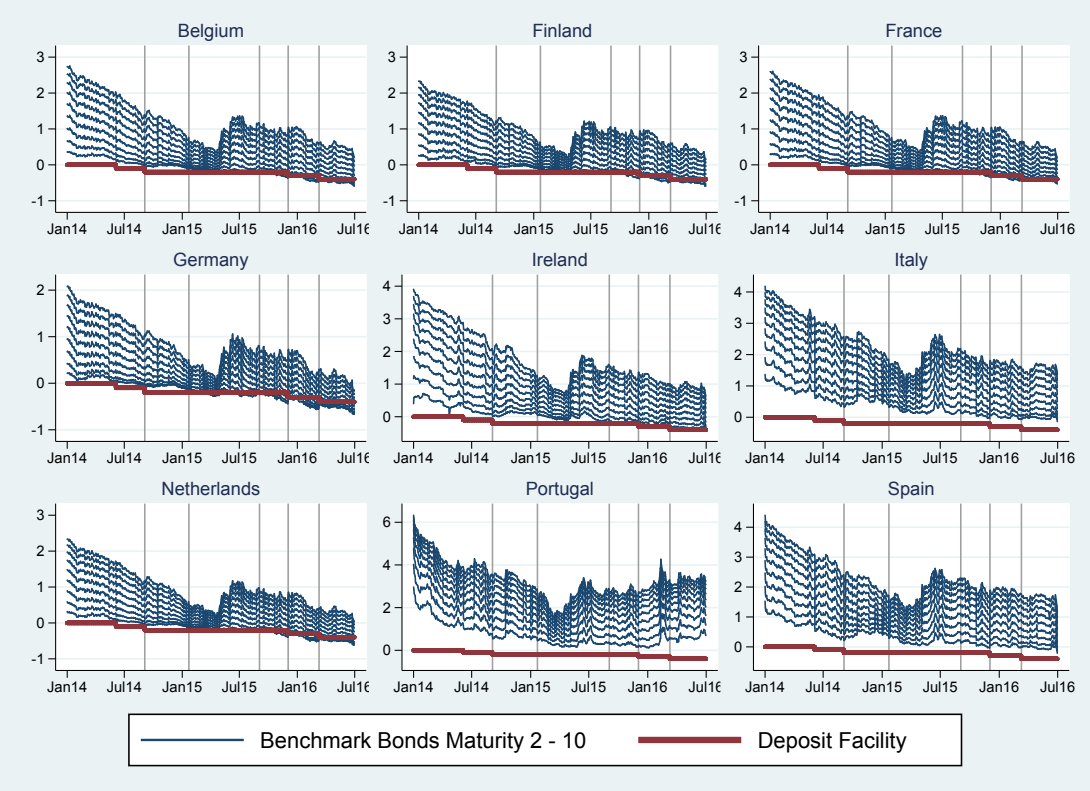
and refers to ECB press releases or announcements with no new decision which were, nonetheless, covered by the Financial Times on the next morning on the first three pages[24].

2.6 Descriptive Analysis

As a result of the prolonged (near) zero interest policy by several major central banks interest rates around the globe are at historic lows. Some governments such as Germany or Japan have even issued 10 year bonds with a negative yield. Therefore, the general downward trend in yields observed in Figure 2.3 is not surprising. Despite yields of different Euro Area countries being at different levels, most countries in our sample show the same strong downward trend with some 10 year bonds of Euro Area core countries being close to 0. The temporary increase across yields for Euro Area countries during the summer of 2015 can be explained by the Greek default at that time and renewed fears of a breakup of the Euro Area. After a new rescue package had been agreed upon by European policy makers, the general downward trend continued for most core countries. At the end of our sample in June 2016 even bonds with a maturity of

[24]To illustrate this, consider for example the 14th of January 2015. On this day the ECB issued a short press release commenting on the European Court of Justice Advocate General's legal opinion in the OMT case. Even though the ECB did not announce anything specific in this press release the Financial Times reported about it on the next day on page 3 with the headline "Legal ruling paves way for Euro-zone easing". Since the Advocate General recommended the court to approve the OMT programme many market participants interpreted this as the removal of an important legal hurdle before the potential announcement of a QE programme on the next Governing Council decision one week later.

Figure 2.3: Zero Coupon Benchmark Bonds



Source: Datastream. Vertical lines indicate announcement dates.
Y-axis shows bond yield. Note the different Y-axis scaling.

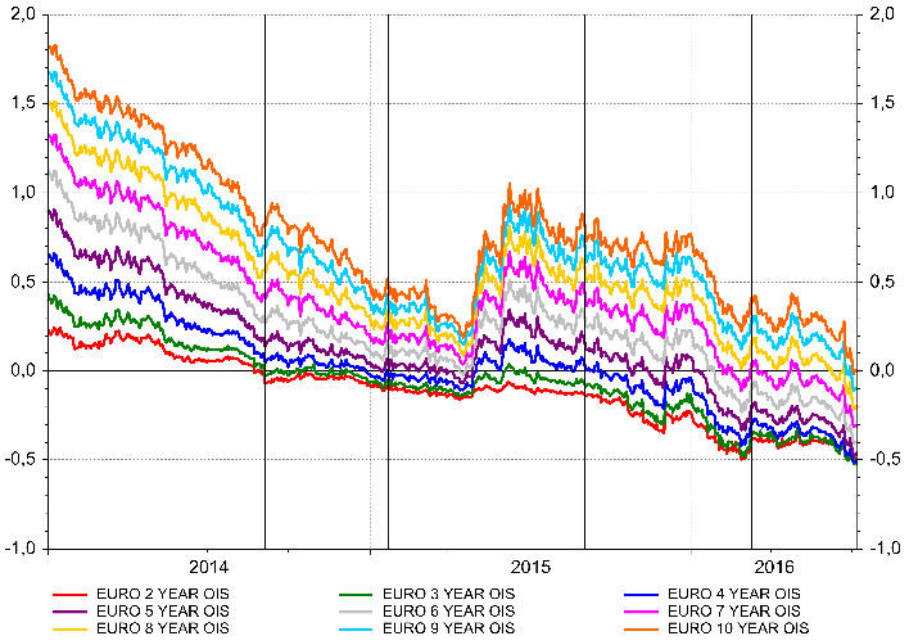
10 years trade at a yield of below 1% for these core countries. In contrast, the yields of countries at the periphery remained roughly stable after the Greek rescue package with 10 year yield being around 1% to 2%. Only Portugal exhibited higher yields. The second aspect to note about Figure 2.3 is that some core country bonds, especially the ones ranging in maturity from 2 to 5 years, trade already below the deposit facility, which implies they cannot be bought under ECB's regulations.

As a result of the general downward trend in yields and the main refinancing rate of the ECB being close to or at 0%, OIS rates showed a similar development in the period investigated. Figure 2.4 illustrates a very similar behaviour of OIS rates compared to the ones described above. Since an OIS contract is nothing but a swap of a fixed versus a floating interest rate (such as the EONIA), the OIS rate is predominantly influenced by the expected path of future short-term interest rates. Therefore, for a given maturity a negative EONIA-OIS rate can be interpreted as reflecting market expectations that negative EONIA rates remain for an extended period of time.

As shown in Section 2.4 in Equation (2.3), one can calculate the spread between Euro Area government bonds and OIS rates to obtain a proxy for portfolio rebalancing. Figure 2.5 displays the spread over the whole period of investigation. There are a few issues that should be highlighted.

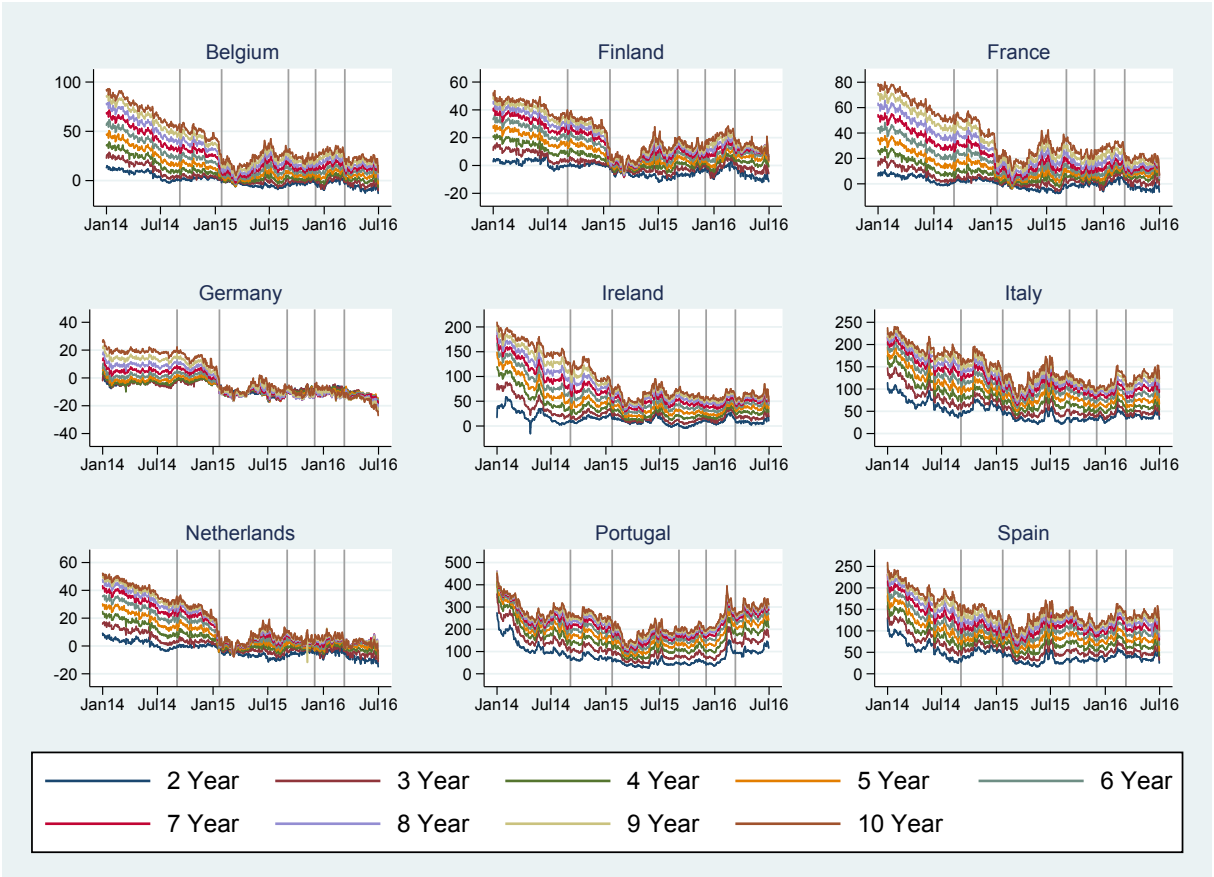
First, the APP pushed down yields of all nine countries shortly after the announcement of the PSPP in January 2015 and, thus, strongly narrowed the bond-OIS spread across all maturities showing the direct impact of the portfolio rebalancing channel. Second, bond-OIS spreads for shorter maturities enter and remain in negative territory in many core countries. In particular, this is the case for Belgium, Germany,

Figure 2.4: Euro OIS Rates



Source: Datastream. Vertical lines indicate announcement dates. Y-axis shows implied OIS yield.

Figure 2.5: Daily Bond-OIS Spread by Country



Source: Datastream, own calculations. Vertical lines indicate announcement dates. Y-axis shows bond-OIS spread in BPS. Note the different Y-axis scaling.

and the Netherlands. Third, in times of enhanced market stress during the Greek default in June 2015 spreads for German Bunds remained largely negative and narrow across maturities highlighting the safe-haven role of German Bunds. On the other hand, spreads for all other countries increased again, both in terms of bond-OIS spreads and spreads across maturities. This is most pronounced for Italy, Portugal, and Spain. Fourth, after the enlargement of the PSPP in March 2016 from 60 billion EUR to 80 billion EUR spreads for longer maturities narrowed again.

Most notable in Figure 2.5 is the case of Germany where spreads turn and remain negative even at a 10 year maturity. Negative bond-OIS spreads for Germany were already observed during times of high market stress as in the financial crisis of 2008-09 or during the European debt crisis in 2012, yet, only for shorter maturities. At that time the negative spread was largely interpreted as flight-to-liquidity[25] and flight-to-safety considerations by the markets buying German short-term Bunds on a large scale[26]. Taken together, we interpret this phenomenon as a mix of the direct impact from the APP, decreasing the spread for most countries across different maturities, and flight-to-safety considerations by the markets for the German case keeping bond-OIS spreads negative even for longer maturities and during the Greek crisis.

Figure 2.6 and Figure 2.7 take a closer look at how the yield curve of the OIS rate (signalling channel) and the yield curve of bond-OIS spreads (proxy for portfolio rebalancing channel) developed around the event days over a two day window. In fact, selecting the window length is subject to a trade-off in any event study. On the one hand, we want to give markets sufficient time for revising their expectations and to fully understand the impact of the APP on asset prices. Given the novelty of the APP and its unique institutional set-up, we think it is appropriate not to consider high frequency data but rather look at the broader picture. On the other hand, if windows are too large they could be polluted by other information. In this case, we would not only measure the desired effect of the QE programme but also other developments in the market, which are incorporated into asset prices. As a robustness test we also consider one day or three day windows[27]. This changes the results quantitatively but not qualitatively.

In terms of cumulative changes over all identified events Figure 2.6, in a nutshell, illustrates that in the beginning the APP had sizeable effects on the expected future rates but these positive effects decreased over time with every additional QE announcement having less or even negative effects[28].

To explain Figure 2.6 in greater detail, first note that each symbol illustrates the change for one maturity of the OIS rate on a given event date over a two day window. Put differently, the cumulative change in the OIS rate is plotted as the ordinate and the corresponding maturity for each rate as the abscissa with each colour being the change in the yield curve for one event date. Secondly, as outlined in Section 2.5 we roughly distinguish between actual announcements (solid symbols) and so called speculations effects (hollow symbols).

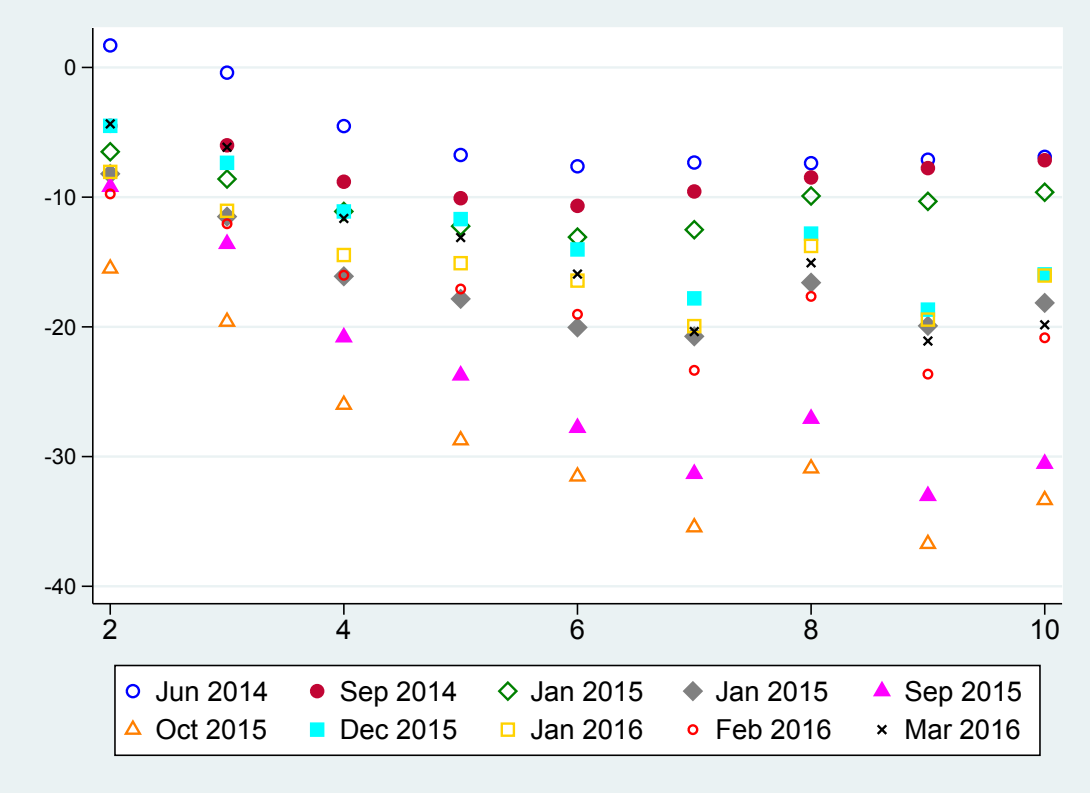
[25] Accordingly, also the spread of German Bunds against the German KfW increased significantly even though these two have effectively the same issuer.

[26] Hence, one might discuss the role of the OIS rate as *the* risk free rate. In our view, both German Bunds and the OIS rate can be seen as a risk free rate but more in the sense of a complementary. For a more detailed discussion see also ECB (2014). As the purpose of this event study is to measure the impact of the APP on Euro Area bonds, and as OIS rates are not directly affected from the portfolio rebalancing channel it would not make sense, in our view, to take German Bunds as the risk free rate.

[27] See Figure A.3 in the Appendix.

[28] Note that in some events ECB financing rates have also changed. As these two distinct announcements happened at the very same time, we cannot distinguish between the effects conventional and unconventional monetary policy. However,

Figure 2.6: Signalling Channel: Cumulative Total Change in OIS Rate



Source: Datastream, own calculations. Hollow symbols indicate speculation effects, solid indicate announcement effects. X-axis shows maturity, Y-axis shows the reduction of OIS rate in BPS. Hence, a group of symbols illustrates the cumulative change in the yield curve.

At first, the APP was rather efficient as each event lowered the yield curve in cumulative terms. Not surprisingly, one of the strongest reductions in the yield curve stemming from the signalling channel occurred after the announcement of the PSPP in January 2015[29] especially for longer maturities. This trend continued until October 2015 where no policy change was announced but Mario Draghi hinted the next Governing Council's meeting is likely to "adjust the size, composition and duration of QE". However, the December announcement in 2015[30] proved to have largely disappointed markets as shown by a strong rise in the cumulative yield curve to levels even above these of January 2015 for shorter maturities. Afterwards, each event merely had a minor effect on the yield curve. Even the increase of the APP from 60 to 80 billion EUR in March 2016 seemed to have again disappointed markets as the cumulative yield curve rose relative to its level in February 2016.

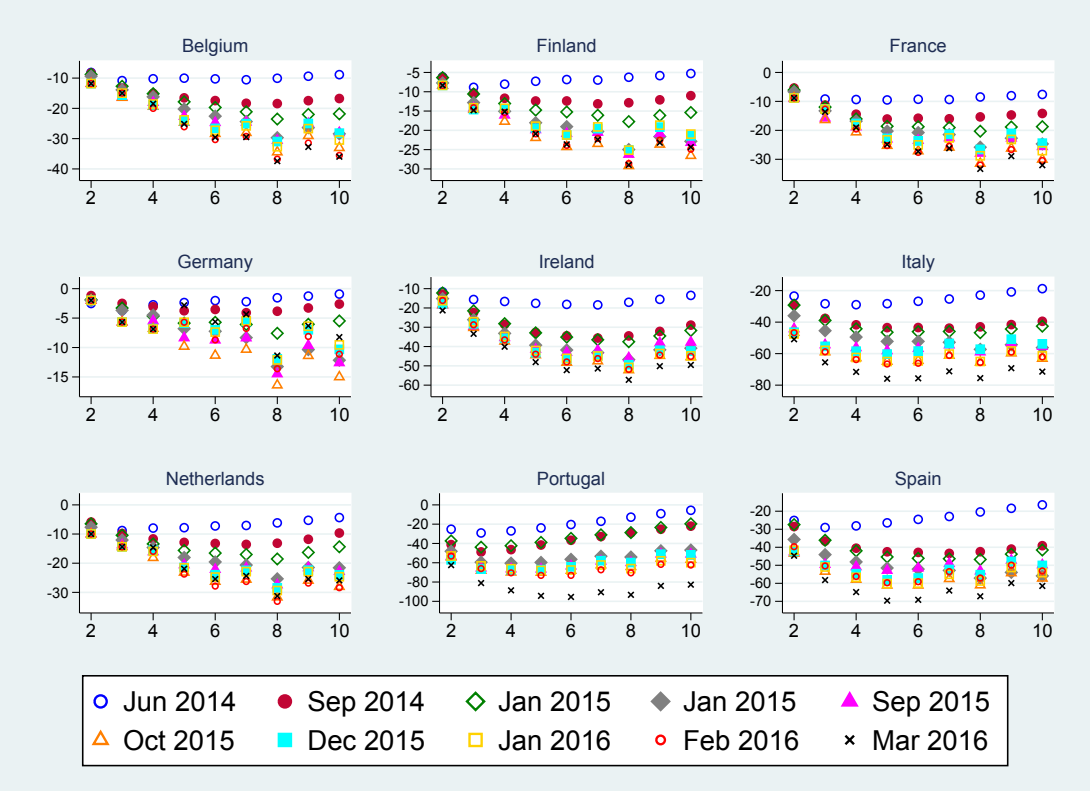
The overall effectiveness of the APP gives similar results when examining the cumulative change in bond-OIS spreads in Figure 2.7. In general, Figure 2.7 confirms the impression from Figure 2.6 suggesting a mildly positive impact on bond yields from QE policy which are, however, diminished with every additional announcement over time. Importantly, we measure a stronger reduction in the yield curve for Ireland, Italy, Portugal and Spain, whereas the reduction is less pronounced for Euro Area core countries of Belgium, Finland, France, and the Netherlands. For Germany we measure the weakest

as both are important for the signalling channel we do not consider this a problem.

[29] Denoted by the difference between green hollow diamonds and grey solid diamonds.

[30] Denoted by the difference between orange hollow triangles and turquoise solid squares.

Figure 2.7: Portfolio Rebalancing Channel: Cumulative Total Bond-OIS Spread



Source: Datastream, own calculations. Hollow symbols indicate speculation effects, solid indicate announcement effects. X-axis shows maturity, Y-axis shows the reduction of the bond-OIS spread in BPS. Hence, a group of symbols illustrates the cumulative change in the yield curve. Note the different Y-axis scaling.

reaction in terms of the bond-OIS spread, suggesting the reduction of bond yields stems mostly from the signalling channel but not from the portfolio rebalancing channel.

In particular for short-term bonds of two or three years, the evidence suggests that the portfolio rebalancing channel has lowered the yield by only 11.81 BPS for Belgium or 8.35 BPS for Finland. In the case of Germany the cumulative change is lowest with a reduction of only 1.98 BPS. In contrast, countries at the periphery seem to be much more affected by the portfolio rebalancing channel with 2 year Italian and Portuguese bonds being reduced by 50.86 BPS and 62.45 BPS, respectively. For longer maturities the portfolio rebalancing has lowered the yield curve in most core countries by roughly 25-35 BPS, with the exception of Germany. Again, long-term bonds of Ireland, Italy, Portugal and Spain have been affected much more. The strongest reduction we measure is a decrease of 95 BPS in 6 year benchmark bonds for Portugal.

One disadvantage of this method is that we cannot directly disentangle changes in the bond-OIS spread resulting from portfolio rebalancing from changes in the underlying credit or liquidity risk due to potential macro spill-over effects. Both could potentially influence $Sp(bond)_t^{n,i}$ which would, therefore, not only represent effects from the portfolio rebalancing channel. In other words, as market participants could interpret a QE announcement by the ECB as an implicit way of easing fiscal conditions for member states or, alternatively, as lowering the likelihood of a breakup of the Euro Area, we cannot excluded the possibility of changes in the perceived credit risk for a given country. In particular, this is likely to be

Table 2.3: Cumulative Impact of APP Press Releases on Selected Maturities in BPS

	2 Year	5 Year	10 Year	Average
Belgium	-11.81	-25.14	-35.96	-26.17
Finland	-8.35	-20.89	-24.34	-20.19
France	-8.81	-24.89	-32.04	-23.78
Germany	-1.98	-2.82	-8.23	-5.91
Ireland	-21.26	-48.05	-49.54	-44.81
Italy	-50.86	-75.94	-71.41	-69.67
Netherlands	-9.98	-21.90	-25.88	-21.46
Portugal	-62.45	-94.29	-82.68	-85.80
Spain	-44.68	-69.63	-61.45	-62.11
OIS	-4.35	-13.11	-19.84	-14.17

the case for periphery countries. We try to disentangle these effects in the next section.

Table 2.3 summarises the cumulative effects for all events for some selected maturities. Accordingly, we see the strongest average (across maturities) reduction in yields from portfolio rebalancing for Portugal (85.80 BPS), followed by Italy (69.67 BPS) and Spain (62.11 BPS). In total, German yields have only been lowered by 5.91 BPS. Note, however, that one would expect stronger effects from portfolio rebalancing for longer maturities of 20 or 30 years which we, unfortunately, cannot measure. Also, we find rather small effects from the signalling channel measured as the change in OIS rates.

One explanation for the weak effects on Euro Area core countries' bonds could be the institutional set up of the APP such as the ECB's regulation of not purchasing bonds below the deposit facility. Even though we do see the expected decreases for early announcements, cumulative spreads do often not react to later announcements, especially for German Bunds at several shorter maturities. This is due to the imposed condition that the yield of a bond has to be above the deposit facility. Also the regulations with respect to the issue and issuer limit described in Section 2.2 could undermine the market's credibility in the ECB's ability of successfully implementing its QE programme. This might be one reason for the weaker response at later events.

An alternative explanation for why we measure such mild effects for core countries is that the ECB mostly bought longer-term bonds which we would not observe in our data set. Unfortunately, the ECB does not publish much details about the bonds bought other than some aggregate information. However, the ECB claims that its interventions are intended to be market-neutral with respect to maturity[31], i.e. there is no bias towards any specific maturities. Also, the weighted average maturity bought, which is published by the ECB, is comparably low for counties such as Germany and mostly stable in the observation period suggesting that this explanation is unlikely to hold[32].

In our view, the most likely explanation for the weak effect on German Bunds is that the portfolio rebalancing channel might not have worked to the same extent as for other countries. As theory suggest, portfolio rebalancing can only work if assets are not perfect substitutes, i.e. if investors have a preferred habitat motive, whereas, if assets are perfect substitutes quantitative easing is doomed to fail at the zero lower bound. Given the exceptional standing of German Bunds investors might consider them as being closer to a perfect substitute of the risk free rate than other government bonds, for which we measure stronger effects. In contrast, countries with higher bond yields did show a more pronounced reduction

[31]For more details see the ECB's website https://www.ecb.europa.eu/mopo/implement/omt/html/pspp-qa.en.html.
[32]See Figure A.4 in the Appendix.

suggesting that the portfolio rebalancing channel work more effectively for these countries.

2.7 Regression Analysis

In order to provide a more detailed analysis, we run several event regressions in a similar spirit as in Szczerbowicz (2015) and Altavilla, Carboni, et al. (2015). Event regressions assume that markets are informationally efficient meaning that new pieces of information immediately enter into prices of stocks or bonds. Therefore, assuming that price movements are essentially characterized by a random walk in the absence of information using standard OLS techniques provides a reliable estimator to measure the significance of a single event day. Following this general approach, we proceed in two steps. In a first event regression, we measure how core and periphery bond yields were affected by each identified APP press release separately. In fact, most APP releases positively surprised the markets, leading to a drop in bond yields. Yet, some releases led to an increase in bond yields as markets were largely disappointed by the new piece of information. In a second regression, we group all identified events together into a single dummy variable to measure the average effect from QE on each country. In doing so, we also estimate the relative strength of the different asset price channels described earlier.

More precisely, in our first model we run separate regressions on the conditional change for each bond yield $\Delta y(bond)^{m,i}_{t|y(bond)_{t-1}>DF_t}$ over a two day window of some selected maturities taking the set of our ten event dummies as explanatory variables. Note that the superscript m distinguishes between core and periphery countries. Also, we include a wide range of control variables to measure the surprise effect of other macroeconomic news announcements during our respective period of interest. This yields the following estimator

$$\Delta y(bond)^{m,i}_{t|y(bond)_{t-1}>DF_t} = \sum_{i=1}^{k} \alpha_i \text{APP}_{i,t} + \sum_{i=1}^{k} \beta_i \text{News}_{i,t} + \gamma\, \Delta y(bond)^{m,i}_{t-1} + \epsilon_t, \tag{2.5}$$

where $\text{APP}_{i,t}$ denotes all our identified APP announcement and speculation events individually, $\text{News}_{i,t}$ represents a term for other news announcements, and ϵ_t is an error term. A detailed overview about other news variables and how they are constructed is provided in the Appendix in Table A.3. Not surprisingly, running several tests for heteroscedasticity and autocorrelation suggest that both are very likely in our data set. The F-Test for the event dummies and control variable coefficients is jointly tested and rejected under the zero-null hypothesis. To correct for both serial correlation and heteroscedasticity in the error terms, Newey-West standard errors for coefficients are used when estimating OLS. Also, $\Delta y(bond)^{m,i}_{t-1}$ denotes a lag to address first order auto-regression.

Table 2.4 shows the results of the basic event regressions for some selected maturities, controlling for the surprise component of a wide range of other macroeconomic news releases. As we are mostly interested in the relevance and general impact for each event day we only show the respective event dummies, suppressing the output of other control variables to examine potential heterogeneous effects among APP press releases[33]. Our results are mostly supportive of the conclusions drawn in the previous

[33]Note that due to serial correlation of the error terms the estimator are not efficient in this case. However, as serial correlation does generally not lead to a bias we do not consider this an issue here.

Table 2.4: Event Regression on the Conditional Change in Bond Yield

	(1) 2 Year	(2) 3 Year	(3) 5 Year	(4) 7 Year	(5) 8 Year	(6) 10 Year
Panel A: Core Countries						
05.06.2014: First purchase hints	-3.945***	-7.383***	-11.66***	-11.54***	-10.71***	-9.098***
04.09.2014: ABS and CBPP3	-5.850***	-7.146***	-8.350***	-7.823***	-6.991***	-5.137***
14.01.2015: ECJ approves OMT	-0.554***	-1.092***	-2.663***	-3.944***	-4.307***	-4.700***
22.01.2015: First PSPP	-3.123***	-4.552***	-7.539***	-10.43***	-11.53***	-12.70***
03.09.2015: Limit increase	-3.458***	-3.754***	-7.223***	-9.956***	-10.84***	-11.86***
22.10.2015: Draghi hints		-6.091***	-6.908***	-7.148***	-7.134***	-6.887***
03.12.2015: Second PSPP		15.86***	20.71***	23.35***	24.13***	24.65***
21.01.2016: Draghi hints		-3.092***	-3.443***	-2.985***	-2.647***	-1.861***
18.02.2016: GC minutes release			-3.245***	-4.889***	-5.564***	-6.417***
10.03.2016: Third PSPP		6.112***	6.082***	4.701***	4.104***	3.248***
Observations	2,013	2,560	3,181	3,240	3,241	3,241
Panel B: Periphery Countries						
05.06.2014: First purchase hints	-12.63***	-15.17***	-16.03***	-14.04***	-12.87***	-9.988***
04.09.2014: ABS and CBPP3	-11.54***	-14.60***	-16.21***	-16.65***	-16.47***	-15.79***
14.01.2015: ECJ approves OMT	1.699**	1.894**	1.162	0.374	0.236	0.567
22.01.2015: First PSPP	-9.654***	-11.90***	-14.54***	-16.51***	-17.40***	-18.95***
03.09.2015: Limit increase	-6.818***	-8.350***	-11.17***	-12.94***	-13.40***	-13.86***
22.10.2015: Draghi hints	-9.163***	-10.65***	-12.37***	-12.43***	-12.26***	-11.97***
03.12.2015: Second PSPP	10.92***	14.90***	20.53***	24.12***	25.30***	26.16***
21.01.2016: Draghi hints	-2.455***	-3.419***	-4.740***	-5.384***	-5.475***	-5.229***
18.02.2016: GC minutes release	-2.995	-5.048*	-6.340*	-6.268*	-6.085**	-5.727**
10.03.2016: Third PSPP	0.852	0.310	-1.901	-2.710	-2.724	-2.662
Observations	2,552	2,596	2,596	2,596	2,596	2,596

Notes: Conditional change of bond yield over a two day window as the dependent variable. The error terms are assumed to be heteroscedastic and possibly serial correlated up to a lag of 250 observations (i.e. daily data). Additional control variables are included but suppressed in output. Time frame is from 01.01.2014 - 30.06.2016. Number of observations varies as the spread is calculated as the conditional spread. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

section. Most events show the anticipated sign of a reduction in yields both for core and periphery countries. The coefficients for periphery countries are usually larger compared to core countries which could be due to an implicit reduction in credit risk for periphery countries. Also consistent with previous findings, some press releases seem to have disappointed the markets leading to an increase in yields. In particular, the December announcement of 2015 has increased the yield for both core and periphery countries by several basis points. For core countries, the 3rd PSPP Announcement in March has also increased the yield whereas it is negative but not significant for periphery countries.

Another finding we can confirm from the previous section is that for the majority of cases the change in the conditional yield is more pronounced for mid-length and longer maturities. In contrast, short-term maturities are usually less affected, if not even excluded from purchases. For example, this is largely the case for the first announcement of the PSPP on the 22$^{\text{nd}}$ of January 2015.

Finally note that there is no output produced for many two year core country bonds at later events due to our prior imposed condition that the yield of a given bond must be above the deposit facility. Currently, we have excluded these bonds as they cannot be bought by the ECB. However, one could also

relax this condition[34].

In order to provide a more detailed analysis on a country specific level, we also estimate the average effect of our ten events by grouping them into one dummy. As illustrated in Section 2.4, the yield of a country's bond can be influenced through several channels by QE announcements. In the following, we proxy the strength of each of these channels for all countries directly by estimating the following equation taking the change in OIS rates (signalling channel), the change in bid-ask spreads (liquidity channel), the change in CDS premia (credit risk channel), and the change in the bond-OIS spread (portfolio rebalancing) over a two day window as the dependent variable. For each country n, this yields the following regression

$$\Delta y^{n,i}_{t|y(bond)_{t-1}>DF_t} = \alpha \,\text{All Events}_t + \sum_{i=1}^{k} \beta_i \text{News}_{i,t} + \gamma \,\Delta y^{n,i}_{t-1} + \epsilon_t, \tag{2.6}$$

where $\Delta y^{n,i}_{t|y(bond)_{t-1}>DF_t}$ denotes each of the four dependent variables (OIS rate, bid-ask spread, CDS premia, and bond-OIS spread), respectively. To address serial correlation of the error terms again Newey-West standard errors are used.

As already discussed, taking the bond-OIS spread to measure the strength of the portfolio rebalancing channel is subject to two crucial assumptions, namely no liquidity and no credit risk for any given bond. In order to account for any unobserved changes in credit or liquidity risk, we include the contemporaneous changes in the country specific daily CDS premia and bid-ask spreads as additional control variables in our event regression. Moreover, to address concerns about potential macro spill-overs, which could influence the perceived unobserved credit risk and the general market sentiment, we also include the Euro Stoxx 50 Volatility Index (VSTOXX) being sometimes referred to as the Fear Index. Including changes in both the VSTOXX index as well as a 10 year US treasury bond also gives the benefit of controlling for any other unobserved market news. In sum, our extended event regressions on the portfolio rebalancing channel for each country n read as

$$\Delta Sp^{n,i}_{t|y(bond)_{t-1}>DF_t} = \alpha \,\text{All Events}_t + \sum_{i=1}^{k} \beta_i \text{News}_{i,t} + \gamma \,\Delta Sp^{n,i}_{t-1} + \sum_{i=1}^{k} \theta_i \Delta X_{i,t} + \epsilon_t, \tag{2.7}$$

where, $\Delta Sp^{n,i}_{t|y(bond)_{t-1}>DF_t}$ is the conditional bond-OIS spread over a two day window and $\Delta X_{i,t}$ denotes all other control variables each defined as the change over a two day window. The results of these estimators are presented in Table 2.5 and 2.6.

One disadvantage of a single event dummy is that positive and negative events can cancel each other out, potentially leaving the average effect insignificantly different from zero. This seems to be the case for the signalling channel proxied by the OIS rate[35].

[34] As a robustness check, we also estimate regressions without this constraint (available upon request). The results indicate that the yields on the excluded bonds actually often increase over the event window rather than decreases. One reason for this unexpected result could be that some investors speculated that the ECB could lower the deposit facility or even abolish the "no purchases below the deposit facility" rule. Thus, speculative investors would have bought such bonds shortly before an event and then, after the unchanged policy was released, sold these bonds again creating downward pressure on prices and increasing the yield.

[35] Intuitively, the signalling channel should be the same for all Euro Area countries. However, since we include several country specific macro news announcements as explanatory variables the coefficients vary slightly among countries.

Table 2.5: Measuring Average Effect of QE From Different Channels

	(1) OIS	(2) Bid-Ask	(3) CDS	(4) Portfolio	(5) Portfolio
Panel A: Belgium					
All Events	-1.050**	-0.688***	-0.505***	-2.336***	-2.194***
Delta Bid-Ask					0.0155
Delta CDS Premia					0.0682***
Delta VSTOXX					0.0610***
Delta US 10y Bond					-2.626***
Panel B: Finland					
All Events	-0.650	0.107*	-0.202***	-1.703***	-1.575***
Delta Bid-Ask					-0.00462
Delta CDS Premia					0.364***
Delta VSTOXX					0.0196
Delta US 10y Bond					0.302
Panel C: France					
All Events	-0.943	-0.249	-0.544***	-1.843***	-1.616***
Delta Bid-Ask					-0.0185*
Delta CDS Premia					0.183***
Delta VSTOXX					0.0869***
Delta US 10y Bond					0.805
Panel D: Germany					
All Events	-0.798	1.272***	-0.469***	-0.499*	-0.796***
Delta Bid-Ask					0.0597***
Delta CDS Premia					-0.0405***
Delta VSTOXX					-0.116***
Delta US 10y Bond					1.493***
Panel E: Ireland					
All Events	-1.012*	3.836***	-0.555***	-2.219***	-1.309***
Delta Bid-Ask					0.0182**
Delta CDS Premia					0.838***
Delta VSTOXX					0.254***
Delta US 10y Bond					-5.290***
Panel F: Italy					
All Events	-0.691	1.130***	-4.736***	-5.183***	-0.526
Delta Bid-Ask					-0.0356***
Delta CDS Premia					0.620***
Delta VSTOXX					0.305***
Delta US 10y Bond					-4.050***

Notes: Change in OIS rate (signalling channel), bid-ask spread (liquidity channel), CDS premia (credit risk channel), and conditional change in bond-OIS rate (portfolio rebalancing channel) each over a two day window as the dependent variable. The error terms are assumed to be heteroscedastic and possibly serial correlated up to a lag of 250 observations (i.e. daily data). Additional news control variables are included but suppressed in output. Extended model is used for the regression on the bond-OIS spread. Time frame is from 01.01.2014 - 30.06.2016. Numbers of observations vary between 5805 and 5030 because the spread is calculated as the conditional spread. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table 2.6: Measuring Average Effect of QE From Different Channels - Cont'd

	(1) OIS	(2) Bid-Ask	(3) CDS	(4) Portfolio	(5) Portfolio
Panel G: Netherlands					
All Events	-0.977*	0.844***	-0.424***	-2.247***	-2.192***
Delta Bid-Ask					-0.0115
Delta CDS Premia					0.0839***
Delta VSTOXX					-0.0122
Delta US 10y Bond					-0.701*
Panel H: Portugal					
All Events	-0.881	-0.104	-5.262***	-6.704***	-1.632***
Delta Bid-Ask					0.0305**
Delta CDS Premia					0.641***
Delta VSTOXX					0.505***
Delta US 10y Bond					-9.785***
Panel I: Spain					
All Events	-1.011**	-4.581***	-3.857***	-5.270***	-0.895
Delta Bid-Ask					0.00455**
Delta CDS Premia					0.752***
Delta VSTOXX					0.260***
Delta US 10y Bond					-5.206***

Notes: Change in OIS rate (signalling channel), bid-ask spread (liquidity channel), CDS premia (credit risk channel), and conditional change in bond-OIS rate (portfolio rebalancing channel) each over a two day window as the dependent variable. The error terms are assumed to be heteroscedastic and possibly serial correlated up to a lag of 250 observations (i.e. daily data). Additional news control variables are included but suppressed in output. Extended model is used for the regression on the bond-OIS spread. Time frame is from 01.01.2014 - 30.06.2016. Numbers of observations vary between 5805 and 5030 because the spread is calculated as the conditional spread. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Decomposing the different effects of APP press releases provides interesting insights in the relative strength of each channel. While the effects resulting from the signalling channel have the expected sign, but are mostly insignificant, the heterogeneous effects of changes in credit and liquidity premia channel are more pronounced in different Euro Area countries. In general, changes in bid-ask spreads and CDS rates are usually smaller for Euro Area core countries, while countries at the periphery have reacted stronger. Portugal, for example, shows an average reduction in CDS rates of roughly 5.3 BPS whereas Finnish CDS premia have been lowered by only 0.2 BPS. While all changes in the CDS premia are significant and show the anticipated sign, this is not true for changes in the bid-ask spread.

Finally, our main variable of interest, the bond-OIS spread as a proxy for portfolio rebalancing in the basic regression, roughly confirms an earlier finding with respect to the average reduction per event day[36]. However, we cannot directly interpret column (4) as the effects from portfolio rebalancing as the instrument specific premium could also be affected by a reduction in credit risk. In fact, the extended model indicates that after controlling for contemporaneous changes in liquidity premia, credit risk premia, and the general market sentiment, yields were on average lowered by only 1.6 BPS for Portugal or 0.9 BPS for Spain via the portfolio rebalancing channel. While for Euro Area core countries the basic and extended regression models do not provide largely different coefficients, suggesting the irrelevance of changes in

[36]See Figure A.3 for comparison.

Table 2.7: Effect of higher Total Purchase to Total Debt ratio

	Change in Bond-OIS	Std. Err.	t-stat
Total Purchases to Total Debt	-2.744***	0.241	-11.38
Change in CDS	0.0305***	0.00229	13.28
Change in bid-ask	-0.580***	0.137	-4.246
Observations	243		
R^2	0.669		

Notes: Change in the conditional bond-OIS rate over a two day window as the dependent variable. Only the PSPP announcements in January 2015, December 2015, and March 2016 are regarded here using pooled OLS. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

credit and liquidity premia for core countries, the differences in coefficients are more pronounced for periphery countries. This evidence indicates that the stronger yield reduction for periphery countries has not only resulted from stronger portfolio rebalancing. Instead, the QE policy of the ECB has reduced the credit risk premia for these countries.

A potential concern with this regression approach could be endogeneity in our regression specification, i.e. high spreads on Euro Area bonds could have induced the ECB to announce the APP. Yet, we believe that this is unlikely to hold for the APP dummy variable for two reasons. First, unlike in previous announcements the ECB has been stressing a lot that the explicit aim of the APP is to bring inflation back on track. Second, even if one does not believe the official version and rather assumes potentially hidden motives in the ECB announcement, such as easing fiscal conditions for some member states, we do not believe that this is likely to be the case. Starting already in 2012 after the "Whatever-it-takes" speech, spreads between Euro Area countries have narrowed significantly and also showed a clear downward trend as exhibited in Figure 2.3. Another issue related to our extended regression could be multicollinearity. As column (3) shows, our event days also have a significant impact on CDS rates implying a correlation between at least two of our explanatory variables. However, the major concern about of multicollinearity, namely an increase in standard errors and, thus, an increase in the likelihood of type II errors, is not relevant in our case as the coefficient of the APP dummy mostly stays significant. Still, multicollinearity could explain why the APP coefficient becomes insignificant for Italy and Spain.

As a final exercise, we examine how the relative size of purchases affected bond-OIS spreads. As indicated in Section 2.2, the actual purchases of the APP are conducted by the national central banks according to the respective capital key of each central bank. Relative to the total debt outstanding, this implies that countries with a larger total purchase to total debt ratio should on average react stronger to APP announcements than others. For comparison note that for the major APP announcement in January 2015 this ratio was 15.37% for Portugal and 7.49% for Italy[37]. The evidence presented in Table 2.7 supports this idea. After controlling for the implicit reduction in credit and liquidity risk, countries with higher purchases relative to their debt have reacted stronger on average.

[37]Details on these ratios can be found in the Appendix in Table A.4.

2.8 Conclusion

In order to fight deflationary trends in the Euro Area the ECB gradually implemented the Asset Purchase Programme from 2014 onwards. This chapter examined the effects of the ECB's QE policy on government bond yields in the Euro Area through an event study.

A difficult task in any event study is to include ex ante expectation formations by market participants before an announcement. We have done so by not merely looking at actual APP decision but also including press releases with relevant information covered by the Financial Times.

Based on an event study on different asset price channels we found that the effects of the APP were strong in the first round but the marginal impact of every additional package decreased over time. Especially for the QE decisions in December 2015 and March 2016 many market participants expected larger packages or the removal of institutional constraints. In sum, we calculated a reduction in the yields of Euro Area government bonds due to a reduction in the instrument specific premia, a potential proxy for the portfolio rebalancing channel, ranging between 85.80 BPS for Portugal and only 5.91 BPS for Germany relative to the absence of the Asset Purchase Programme. Core countries usually have shown weaker responses while the reduction has been more pronounced for periphery countries. Consequently, this finding suggests an implicit reduction of the credit premium for these countries.

In our view, one explanation for such weak effects of the ECB's QE policy compared to the QE programmes by other central banks is that the APP has been announced at calm times, diminishing potential effects from the liquidity premia channel especially for core countries. For comparison Joyce, Lasaosa, et al. (2011) find a reduction of 100 BPS from the Bank of England's QE policy, while Gagnon et al. (2011) find a reduction of yields between 30 and 100 BPS in the US. However, both QE programmes were announced during the financial crisis of 2008-09.

A second explanation is the increasingly burdensome institutional set-up of the APP. In particular, the ECB's rule of not buying bonds trading below the deposit facility could significantly dampen the impact of the APP for shorter maturities.

Finally, as the APP is designed to buy mostly government bonds our results could also be interpreted as evidence in support for the theoretical argument made by Cúrdia and Woodford (2011), where large asset purchase programmes at the zero lowered bound should be ineffective if they are designed as quantitative easing in a narrow sense (pure purchase of government bonds) rather than credit easing (changing the composition of the central bank's balance sheet by lending directly to the distressed private sector, e.g. via purchases of mortgage backed securities). In such a case, the same argument applies as in Eggertsson and Woodford (2003). In fact, the closer Euro Area countries' bonds were to the lower bound, the weaker they have reacted.

However, the effectiveness of the ECB's QE policy must ultimately be judged by the effectiveness of returning inflation to the target rate. In contrast, our analysis suggests that the asset price channel via portfolio rebalancing has not proven successful. Still, there could be real effects on the macro economy via other channels such as forward guidance or the exchange rate channel.

Chapter 3

The Good, the Bad, and the Ugly: Impact of Negative Rates and QE on the Profitability and Risk-Taking of 1600 German Banks[†]

[†]Acknowledgements: This paper was supported by the Research Data and Service Centre of the German Bundesbank, which provided the data. I am thankful to several Bundesbank employees, most notably Harald Stahl, who provided technical assistance related to several data issues. Moreover, I am thankful to Piergiorgio Alessandri, Christoph Basten, Stefan Bender, Peter Bofinger, Markus Brunnermeier, Lukas Buchheim, Jens Eisenschmidt, Hesna Genay, Florian Heider, Joao Granja, Christian Hirsch, Gerhard Illing, Mike Mariathasan, Farzad Saidi, Haresh Sapra, Glenn Schepens, Isabel Schnabel, Michael Weber, Volker Wieland, Jing Cynthia Wu, and Peter Zorn for valuable advice. I also appreciated helpful comments and suggestions by the participants of the MGSE Ph.D. Colloquium 2017, the Macroeconomics Seminar at the University of Munich, the ifo Macro Seminar, the Bundesbank FDSZ Occasionally Research seminar, the 11th RGS Doctoral Conference in Economics, the Chicago Booth Finance Brownbag, and the German Council of Economic Experts. Moreover, research assistance by Eva Franzmeyer is acknowledged. Any errors are the responsibility of the author.

3.1 Introduction

In order to fight deflationary tendencies in the Euro Area, the ECB announced several rounds of unconventional monetary policy (UMP) measures since 2014. Most notable in this respect were the introduction of a negative interest rate policy (NIRP) on bank deposits in June 2014 and the announcement of a quantitative easing (QE) programme in January 2015. While most of the on-going discussion has been focused on the impact on inflation, real GDP growth, or the financial markets, the focus of this paper is on potential side effects of QE and NIRP with respect to bank income, risk-taking, and the pass-through of monetary policy. From a financial stability perspective lowering both the level and the slope of the yield curve is potentially worrisome for two main reasons. First, it could erode bank profits over time reducing their skin-in-the-game and, second, it could lead to more risk-taking by banks.

To shed light on these concerns, this paper uses a large micro level data set of 1600 German banks. The large number of banks allows exploiting heterogeneity as banks in the data set vary in size, degree of internationality, and their business models. This is important for several reasons: First, many of the smaller savings or cooperative banks are a crucial lender to small and medium sized enterprises in Germany and other European countries. Second, these banks rely more on deposits as a funding source and might be more severely hit by NIRP than large global players using various sources of funding. Most importantly, the share of deposits is crucial for the pass-through at negative rates as argued by e.g. Eggertsson, Juelsrud, et al. (2017) and Drechsler et al. (2017). However, most of the existing literature has a much smaller sample of mainly large international banks compared to the one used in this paper[1].

To estimate the effect of NIRP and QE on bank income and loan growth rates this paper proposes three different approaches. The baseline regression uses a Fixed Effect (FE) and Dynamic System Generalised Methods of Moments (System-GMM) estimator with an interaction term between the level of the short-term interest rate and the bank specific ratio of overnight deposits as a source of funding. To assess if going negative is a game changer for banks with a high deposit ratio, a simple dummy is introduced from 2014 onwards. Admittedly, this is a crude measure as these years could be special for many other reasons such as new capital regulations. Therefore, as a second and more innovative approach, I use the implied shadow rate estimated by Wu and Xia (2017) to better account for the strength of UMP. The idea here is to capture both negative rates and the reduction in the slope of the yield curve via QE. Third, as an additional robustness check, I use a difference-in-difference (diff-in-diff) estimator where banks with a high deposit ratio are defined as the treatment group and low deposit banks serves as the control group.

In general, one can think of several channels how monetary policy can influence bank lending and income during normal and unconventional times. The standard monetary transmission channel may influence bank lending in the following way. After a cut in short-term interest rates, banks should pass on lower interest rates to their customers increasing the demand for loans by firms and households (interest rate channel). At the same time, as interest rates and asset prices are inversely correlated, asset prices rise making firms and households more wealthy (wealth channel). Subsequently, banks are also

[1] In addition, German banks are particularly interesting due to the fact that Germany has been subject to vast capital inflows in the recent years via the Target II payment system. Following the announcement of NIRP and QE policies, the Target II imbalances have widened again indicating that most of the excess liquidity enters into the German banking system. Therefore, holding above average excess liquidity relative to their European peers, German banks could be more severely hit by these UMP measures.

more willing to grant additional credit against the higher valued collateral (balance sheet channel). In addition, the rise in asset prices should also boost bank income as they benefit from capital gains on their profit and loss (P&L) statements[2]. As a result, bank equity increases relaxing their equity constraint which facilitates further loan issuance (equity constraint channel). Moreover, with lower interest rates the domestic currency should depreciate which leads to an increase in foreign demand (exchange rate channel). Finally, following the positive economic outlook existing credit lines are likely to have a lower probability of default as firms and households find it easier to roll-over debt (credit channel). Taken together, all the described channels should increase real economic growth and, ultimately, increase inflation. Also, all these developments should boost bank profits and, hence, foster financial stability. However, some authors, such as Borio and Zhu (2012), argue that if rates are too low for too long bank lending could become excessive (risk-taking channel) leading to bubbles in the real sector which in contrast may endanger financial stability.

Although these channels are reasonably well understood in normal times, it is not clear how they behave below the zero lower bound (ZLB). On the one hand, authors such as Brunnermeier and Koby (2017) and Rognlie (2016) argue that there is nothing special about moderate negative interest rates per se. This view is also shared by, for instance, the Swedish and Swiss central banks claiming that the interest rate pass-through continues even with slightly negative rates[3]. The income of financial intermediaries is not determined by the level of the interest rate but rather by the spread between the borrowing and the lending rate, the so called net interest rate margin (NIM). Thus, we may be worried about the flattening of the yield curve but not necessarily about NIRP.

On the other hand, Eggertsson, Juelsrud, et al. (2017) and Demiralp et al. (2017) find that the standard mechanisms of monetary policy cease to function at negative interest rates due to several frictions[4]. While central banks can lower their deposit facility into negative territory leading to higher costs for banks, it is more difficult for banks to pass these additional costs on to their clients and introduce negative interest rates on their deposits. Put differently, whereas the short-term asset side of banks' balance sheets can follow into negative territory, the short-term liability side is floored at zero leading to a under representation of the true refinancing cost for banks[5]. In particular, this is a concern for retail banks with large deposit holdings as a source of financing. In contrast, larger investment banks with greater market power might find it easier to raise other sources of short-term funding, e.g. from wholesale funding or the corporate bond market. Aggregate data from Germany presented in Figure 3.1 suggests that deposit rates on households are in fact constrained by the ZLB whereas interbank lending rates can follow in to negative territory.

Still, the wider impact of negative interest rates is a mostly uncharted territory with several economists

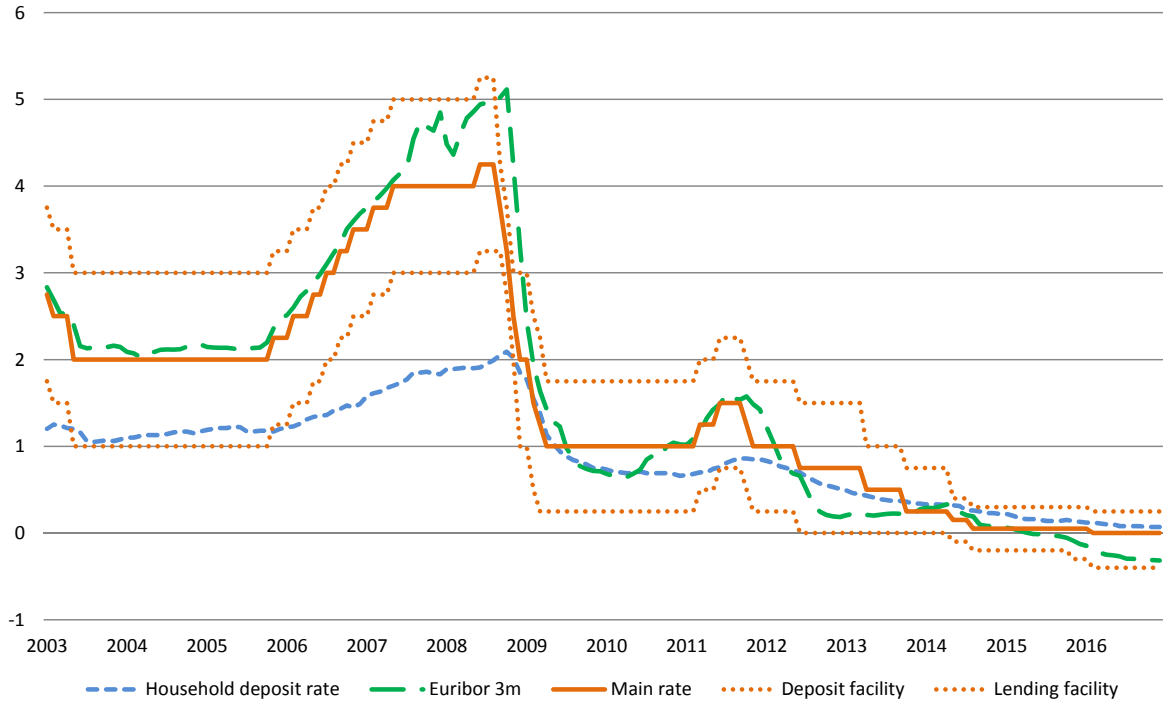
[2]Yet, in practice not all banks benefit equally from capital gains due to different business models and the accounting standards at hand. For example, smaller banks often hold assets to maturity and are thus less likely to benefit from capital gains compared to larger investment banks having a sizeable trading portfolio which is mark-to-market.

[3]See Riksbank (2015) and Jordan (2016).

[4]These frictions can come in various forms. While the existence of currency as cash is the most important one, offering a zero yield outside alternative store of value, some authors also mention institutional constraints such as tax restrictions, legal concerns about negative interest rates for households, or IT barriers in dealing with negative rates. However Bech and Malkhozov (2016) find that most of these technical constraints have been resolved shortly after the introduction of negative rates.

[5]As a rule of thumb the storage costs of cash is lower for smaller amounts. In this context, Scheiber et al. (2016) find that some banks have already introduced negative interest rates for larger firms, which typically need great amounts of liquidity, but not for households.

Figure 3.1: Euribor and Household Deposit Rates



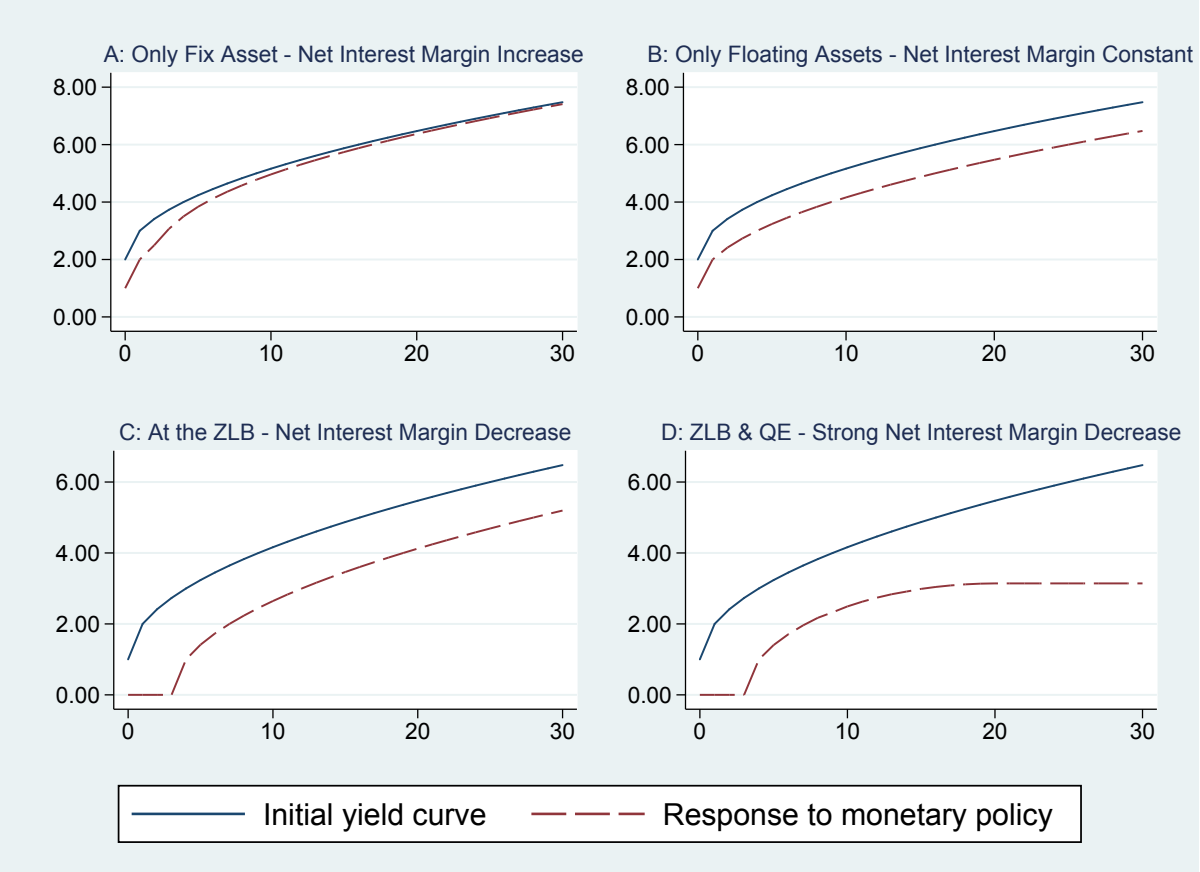
Source: ECB Statistical Data Warehouse, MIR data set. Aggregate overnight household deposit rate for Germany.

making conflicting predictions. Therefore, the general structure of this empirical paper is to take the common pro and contra arguments in the literature seriously and to study their empirical relevance.

The spread between short- and long-term interest rates has a systematic effect on bank profits. It is well understood that banks' intrinsic business model is to borrow short and to lend long. Hence, a positive-sloped yield curve leads to a positive NIM via the classic maturity transformation. It is usually the case that lowering short-term interest rates helps to boost bank profits, since the spread between short-term liabilities and long-term assets widens. Figure 3.2 illustrates the change in the yield curve after a reduction in short-term policy rates in a stylised way. Suppose, as in panel A, a bank with a long-term asset legacy holds only fixed interest paying assets. As these assets continue to pay the old higher interest rates, a decline in the short end of the yield curve increases the profits of this bank due to reduced refinancing costs and a higher margin. In contrast, if the same bank would hold only floating interest paying assets and liabilities, as in panel B, profits are practically unaffected assuming assets and liabilities have the same size, as found by Busch and Memmel (2015). Since the long end of yield curve typically follows the short-term rate over time, a reduction in short-term rates leads to a simple parallel shift of the yield curve. Also note that in the long run, all fixed assets are replaced or rolled over by new assets paying the *current* market interest rate. Hence, panel A usually applies to the short run whereas panel B captures the long run effects all else equal.

However, as for instance argued by Kerbl and Sigmund (2017), breaking through the zero lower bound is a game changer since short-term assets can follow into negative regions while overnight deposits cannot. If banks are charged with a negative interest rate when depositing excess liquidity at the central bank, many of these banks are unable to directly pass these additional costs on to their clients. Subsequently,

Figure 3.2: Lowering a Hypothetical Yield Curve: Impact on Net Interest Margins



Source: Own illustration. X-axis shows maturity, Y-axis shows yield. Numbers are chosen simply for illustrative purposes. Hypothetical old yield curve in blue. Response of yield curve to monetary policy in red.

their NIM narrows as panel C illustrates. In such a situation, banks could either try to change their liability structure (e.g. by switching from deposits financing to wholesale financing), increase interbank lending[6], or charge additional fees (indirectly passing negative rates on to costumers). To which extent these strategies help to mitigate adverse effects of NIRP on interest margins is largely unknown. In addition to NIRP, the QE programme of the ECB is explicitly targeted at long-term maturities flattening the slope of the yield curve. These two measures taken together could reduce the net interest margin of banks considerably as shown in panel D. Therefore, bank profits might be strongly impaired by low NIMs potentially inducing banks to greater risk-taking.

According to the notion of the risk-taking channel[7] an increase in the *quantity* of credit could be accompanied by a simultaneous decline in the *quality* of credit. More precisely, several sources of risk-taking can be identified. Traditional portfolio allocation models predict a negative relationship between risk-taking and monetary policy. Since a lower interest rate on safe assets gives incentives to investors to reallocate their portfolio towards securities with higher yields, the overall riskiness of the portfolio rises. At the same time, a lower risk-free rate also lowers the hurdle rate for some investment projects

[6]However, banks cannot be able to change the aggregate excess liquidity in the system. In fact, some banks might successfully reduce their short-term funding overhang via interbank lending. Yet, this strategy cannot be feasible for the system as a whole. Someone inevitably ends up holding the excess liquidity which is best illustrated by the "hot potato effect".

[7]See Borio and Zhu (2012), Adrian and Shin (2010), or Dell'Ariccia et al. (2014).

which may have a high risk profile. As an increasing number of risky projects are financed by banks the overall quality of the investment pool worsens. In addition, banks could engage in more extensive maturity transformation or raise their leverage due to limited liabilities considerations. The temptation for a hazardous behaviour could be stronger if banks find it hard to generate enough profits via reasonably safe credits. Heider et al. (2017) stress that this behaviour is likely during negative interest rate periods due to a decline in banks' net worth. This undermines their incentives for prudent behaviour and careful screening of borrowers. Moreover, Demertzis and Wolff (2016) point out that when banks earn a smaller margin on credits, they may try to increase volume of credits to counteract the drop in margins. This provides an additional incentive for banks to excessively expand their supply of loans.

However, the *good news* from the evidence presented in this paper is that banks overall do not engage in high risk-taking by granting an excessive amount of credit or by reducing their lending standards. Moreover, following the recent changes in the Basel requirements the majority of banks have improved their leverage ratio over the last years. Regarding their income situation, NIRP does not pose a large cost burden on banks; instead they benefit from the current low refinancing rates and face lower loan loss provisions due to the positive macro-economic environment and low interest burden for borrowers. On the other hand, the *bad news* is that banks neither benefit from increased fee income (as fees are not proportional to deposits) nor from capital gains following high asset prices, which is among others due to the conservative German accounting law. In addition, banks face increasing excess liquidity on the asset side and increasing overnight deposits on the liability side of their balance sheets highlighting the fact that the aggregate liquidity overhang in the system does not vanish. Taking this fact together with the extended interest rate fixation period by banks creates a potential source of risk as the maturity mismatch rises. Moreover, higher deposit ratios are problematic as especially these banks on average have a lower net interest income calling into question the pass-through of monetary policy. While it is true that *average* credit growth rate has increased, this macro-view misses a reshuffling of credit growth from banks with high- to banks with low deposit ratios, which is only revealed by micro level bank data. Therefore, this paper argues that the *ugly truth* is that NIRP and QE are starting to get contractionary for banks with high deposit ratios as they have already reduced their lending growth rates. Also, as many benefits are short-lived it remains unclear how long the positive aspects of QE and NIRP can prevail before they are outweighed by the long-term negative impact on banks and the monetary pass-through. In other words, for the same reason that banks now can benefit from lower refinancing rates, in a few a years when interest rates rise again this might pose great challenges for banks with a large share of low yield and high maturity assets.

The remainder of this paper is structured as follows. Section 3.2 gives an overview on the literature of bank profitability and risk-taking. Afterwards, Section 3.3 provides details about the German banking system and the data set at hand. A descriptive analysis from this data set is presented in Section 3.4 followed by a more in depth regression analysis in Section 3.5 and a simple robustness check in Section 3.6. Finally, Section 3.7 concludes.

3.2 Literature Review

This paper is related to three broadly defined strands of the literature: Bank risk-talking, bank profitability, and the impact of conventional and unconventional monetary policy (mostly NIRP and QE) on both. In contrast to much of the existing literature examining large international banks, this paper focuses on exploiting the heterogeneity among different bank business models within a single major European economy. Also, focusing on just one country makes banks largely independent from varying business cycles in different countries, which is a usual concern with international bank data.

First of all, important contributions on how low interest rates affect bank risk-taking via the risk-taking channel have been made by Borio and Zhu (2012), Adrian and Shin (2010), and Dell'Ariccia et al. (2014). In addition to these theoretical work, many studies examine empirically how bank risk-taking is affected if conventional monetary policy keeps interest rates too low for too long, including Ioannidou et al. (2015), Maddaloni and Peydró (2011), Jiménez et al. (2014), and Dell'ariccia et al. (2017). Despite many studies find a negative relationship between the level of short-term interest rates and bank risk-taking, there is no clear consensus whether less capitalised banks are more or less prone to risk-taking. For example, Dell'ariccia et al. (2017) find that risk-taking is more pronounced for well capitalised banks due to risk shifting. On the other hand, Jiménez et al. (2014) argue that least capitalised banks react stronger to changes in monetary policy by taking more risk when monetary policy is eased. They find that in times of low interest rates, banks with less capital are those which are more prone to agency problems and, thus, grant more credit to ex ante risky firms.

The second important strand of the literature relates to bank income or bank profitability. Several authors have made important contributions to the topic of bank profitability both theoretically and empirically, see for instance English (2002) on bank interest rate risk and the NIM, English et al. (2014) showing that in the short run the capital gains channel outweighs changes in the net interest margin, Alessandri and Nelson (2015) indicating that large banks try to reduce yield curve risk by hedging against changes in income margins through interest rate derivatives, Bolt et al. (2012) on the impact of the business cycle on bank income, and Busch and Memmel (2015) who examine how the level of interest rates affects banks' net interest margin. In a related paper, Busch and Memmel (2016) decompose the different components of this margin.

While all these papers focus on normal times, this paper relates to several recent contributions on the impact of unconventional monetary policy on bank profitability and risk-taking[8]. Interesting theoretical models on the exact level of the lower bound come from Rognlie (2016) and Brunnermeier and Koby (2017) on the reversal interest rate. At some tipping point, lowering the short-term interest rate reduces banks' NIM and squeezes their profits. Since banks are equity constrained, a decline in profits might force banks to reduce their loan business which makes an expansionary monetary policy contractionary. Note that the level of the reversal interest rate does not necessarily have to be zero but rather can be higher or lower depending on various factors such as banks' balance sheet structure, their dividend policies, or the general economic environment.

[8]This third strand of the literature is growing fast, especially since the introduction of NIRP by the Danish Nationalbank (July 2012), the European Central Bank (June 2014), the Swiss National Bank (January 2015), the Swedish Riksbank (February 2015), and by the Bank of Japan (February 2016).

So far, most of the empirical studies examine the impact of low or negative interest rates on a more aggregate level, such as Jobst and Lin (2016) or on large international banks as in Altavilla, Boucinha, et al. (2014). Using the same data set on international banks, Borio, Gambacorta, and Hofmann (2017) focuses on the impact of low interest rates on bank profitability while Borio and Gambacorta (2017) is a similar study but focuses more on bank lending and risk-taking. Also, there exists a growing literature on the country specific experience with NIRP, see for instance Scheiber et al. (2016) for a study on Denmark and Sweden, Basten and Mariathasan (2018) for Switzerland, Kerbl and Sigmund (2017) for the Austrian banking sector, and Ahtik et al. (2016) for Slovenia. In addition to the effects of negative interest rates, other authors focus on the effects of large scale asset purchase programmes such as Lambert and Ueda (2014) and Demertzis and Wolff (2016) arguing that a QE policy boosts bank profits in short run, but the flattening of the yield curve may lead to a decline of bank income over the long-term.

Similar to this paper is the work of Borio, Gambacorta, and Hofmann (2017) who examined for a time period from 1995 to 2012 how certain profitability measures of banks (e.g. net interest income or other non-interest income) are explained by a monetary policy indicator and the slope of the yield curve. Their findings indicate that important non-linearities are present if interest rates are close to the ZLB. More precisely, the impact of monetary policy on bank income is particularly large when interest rates are unusually low and the yield curve is flat, leading to an erosion of bank profitability over time.

A second related paper from Demiralp et al. (2017) puts emphasis on bank balance sheet adjustments following the introduction of negative interest rates. Focusing on large Euro Area banks the authors distinguish between banks holding excess liquidity and those who do not. They find that treated banks tend to give more loans, purchase more non-domestic government bonds, and lower their levels of wholesale funding.

Another recent paper by Heider et al. (2017) focuses on bank risk-taking behaviour after the introduction of a NIRP. The authors argue that banks with large deposits are not able to pass negative interests on to their customers. Using a difference-in-difference approach their paper shows that banks with a higher share of deposit funding lend less and to riskier borrowers. This additional risk-taking would increase the moral hazard problem of managing loans and ultimately raise financial stability issues.

More generally, there is a lively discussion to which degree monetary policy decisions should take financial stability considerations into account which is, among others, largely influenced by the work of Svensson (2015) and Stein (2014).

3.3 The German Banking System and the Data Set

Before describing the data set in detail, this section discusses some specialities of the German banking sector in general. More importantly, the differences between the internationally known IFRS accounting standards and the German GAAP (Handelsgesetzbuch - HGB) are described. While economist often abstract from such technical details, a basic understanding of the rather conservative German accounting standards is key to the right interpretation of the results as the HGB largely influences the underlying data generating process[9].

[9]One might argue that looking at banks' balance sheets and P&L statement to identify banks profitability is potentially misleading from an economic perspective. In fact, following a rise in asset prices, the solvency of any bank improves from an

Several important aspects distinguish the German banking system from an Anglo-Saxon banking system. First of all, Germany has a universal banking system which is divided into the so-called three pillar system of private banks, cooperative banks, and public (savings) banks. Typically, private banks are found mostly in larger cities, have more wealthy private customers, and are more active in lending to larger firms, whereas cooperative and savings banks are dominant in the rural areas and in lending to private households and small companies. Moreover, all three pillars can be further split into subcategories. Most noteworthy are the four largest private banks (the so-called "Major banks") having branches all across the country. These are also the banks which are most active on the global markets. In contrast, the so-called "regional banks" are smaller private banks often focusing on some regional or topical niche market such as car financing. The second pillar of cooperative banks is mainly characterised by a special legal form and the cooperative principle. The largest subgroup in this pillar are the so-called "Volksbanken und Raiffeisenbanken". Finally, the distinguishing feature of the third pillar is that public banks are fully or partially owned by a public entity, which can be federal, regional, or county based. While most banks in this pillar are public saving banks, usually owned by a city or a municipality, the so-called "Landesbanken" (state banks) are owned by the German states.

A second important feature of the German banking system is the house bank principle which is widely spread, in particular among smaller banks[10]. Under the house bank principle, banks are also interested in the long-term success of their customers and might for instance be more willing to provide liquidity when needed. However, a house bank system has several merits and drawbacks. On the one hand, long standing credit relationships usually decrease information asymmetries between lender and borrower. This can overcome typical micro inefficiencies such as moral hazard or adverse selection problems, leading to lower screening costs for banks and, thus, can reduce credit rationing. Furthermore, long lasting credit relationships often make it easier for small and medium sized enterprises to raise cash when needed. On the other hand, the house bank principle also provides banks with some monopoly power which may result in inefficient lending conditions for firms and households. With respect to negative interest rates, this could in principle enable banks to more easily raise fees and commissions, effectively passing negative interest rates on to their clients.

Finally, as pointed out by Dombret et al. (2017), several studies have shown that the German banking system is, compared to its international peers, on average not as profitable. For instance, data by the OECD indicates that the average cost-to-income structure is significantly higher for many German institutions than for other international banks. As Dombret et al. (2017) argue, these high values result from lower revenue generation rather than higher costs. Moreover, German banks seem to have the highest dependency on interest rate income compared to banks in other OECD countries. A potential reason for this under average performance of German banks could be the relatively high share of savings

economic viewpoint irrespective whether a bank can capitalise these gains or not. However, this pure economic view could miss two important factors which are relevant in the real world. First of all, from an investors viewpoint it could make a difference if capital gains enter into profits or not. On the one hand, the investor receives a potentially larger dividend and, on the other hand, if banks seem financially more solid on their balance sheet, investors are more likely to provide fresh funding when banks face unexpected financial difficulties. Second, and more importantly, accounting standards can have a direct impact on banks' regulatory equity and therefore on the borrowing constraints banks face. For example, capital gains from asset holdings in the trading portfolio enter directly into the P&L statement. Hence, the available bank equity increases next period, and this bank is able to lend more to the real sector. See also Beatty and Liao (2014) for a recent survey on the effect of accounting standards at banks.

[10] See for instance Harhoff and Körting (1998) for an early study.

and cooperative banks in the German banking sector. In contrast to the monopoly argument made above, Dombret et al. (2017) argue that both kinds of banks rely heavily on deposit financing and, thus, might find it harder to pass additional costs associated with excess liquidity onto their customers. Also, as these smaller banks typically hold fewer assets being mark-to-market, their revenues could drop even further potentially making them strongly impaired by UMP measures in the Euro Area.

In general, fair value accounting is not as common under the German HGB as it is under the internationally relevant IFRS rules. In contrast, the principle of prudence is very dominant in German accounting. The basic idea of this principle is that a firm or bank should not gloss over its financial situation to provide protection to creditors. On the other hand, this often implies that the balance sheet representation is worse than the actual economic position. Two important concepts which materialise the principle of prudence are the so called realisation principle and the imparity principle. Under the realisation principle revenues can only be considered in the profit and loss statement if the cash flow has actually *realised*, which is in strong contrast to IFRS or US GAAP standards where revenues only have to be *realisable*. Moreover, this is complemented by the imparity principle treating profits and losses differently. On the liability side all foreseeable and *realisable* risks and losses have to be taken into account. This is put in more concrete terms by the so called lowest value principle for assets and highest value principle for liabilities. For example, the lowest value principle requires that assets must be impaired if the fair value is less than their carrying amount[11]. For long-term assets impairments can be revised if the reasons for the initial write down do not exist anymore.

However, since the implementation of the "Bilanzrechtsmodernisierungsgesetz" (Balance Sheet Modernisation Act) in 2010 fair value representation has been partially introduced in the German accounting standards. While the Balance Sheet Modernisation Act changed the accounting rules for several balance sheet positions such as defined benefit obligations, goodwill, or taxes, the most important two changes for this paper concern the treatment of financial derivatives and the introduction of a trading book which is held at fair value[12]. In fact, a mark-to-market trading book partially undermines both the realisation principle and the imparity principle as gains can now enter into the profit and loss statement without having actually realised.

While all these changes are very important for the German "Major banks" and the Landesbanken due to their more international business model and their larger trading portfolios, they are of second relevance for savings and cooperative banks. Capitalising financial derivatives in late 2010 effects both the size and the composition of the balance sheet of these international banks (see Figure B.1 for total assets, Figure B.3 for the asset composition, and Figure B.4 for liabilities in the Appendix). In contrast, smaller banks have typically have a more conservative business models, do not engage in hedging activities,

[11] Due to this property of the HGB rules, ever-greening of loans is not as common among German banks as in other jurisdictions. If loans are impaired they cannot be rolled over indefinitely to gloss banks' balance sheets but must be impaired instead.

[12] Under IFRS financial assets can be classified as either held-for-trading, held-for-sale, or held-to-maturity. While held-to-maturity assets are not mark-to-market, held-for-trading assets do enter the P&L statement directly via fair value changes. On the other hand, gains and losses from available-for-sale financial assets do not enter the P&L statement directly; instead they are a component of other comprehensive income. In contrast, under the new German HGB regulations assets can be categorised as either held-to-maturity or held-for-trading. The gains or losses from remeasurement of held-for-trading assets enter the P&L statement directly via the net trading income. Value changes in held-to-maturity assets are accounted for in the net income from the valuation of assets and provisions. These changes are according to the highest and lowest value principle. The categorisation has to be made upon purchase and may not be changed at a later point in time, which is again in contrast to the IFRS rules providing more flexibility with respect to reclassification.

Table 3.1: Profit and Loss Statement

(A)	+	Net interests received
(B)	+/−	Net commissions received
(C)	+/−	Net profit or net loss from the trading portfolio
(D)	+/−	Net income or net charges from the valuation of assets and provisions
(E)	−	Staff costs
(F)	−	Other administrative spending
(G)	+/−	Net other and extraordinary income or charges
	=	Profit before tax
(H)	−	Taxes
	=	Total profit/loss for the financial year

and often hold a very small trading book. Therefore, it is reasonable to assume that the positive effects of unconventional monetary policy measures via capital gains do not benefit smaller banks to a great extent. To get a better understanding of the relevant income components, Table 3.1 presents the income statements of German banks in a stylised form. Position A shows the net interest rates received which is simply the difference between all interest rates paid and all interest rates received. As a result of banks' role as financial intermediaries and their maturity transformation, this position is usually positive and the major source of income for all German banks. In contrast, the position B (net commissions received) can be either positive or negative since some banks rely heavily on brokers on the financial markets. This is similar for position D (net income or net charges from the valuation of assets) which can also be positive or negative. More precisely, it provides the net value adjustments with respect to loans and securities. Note that this position also captures the important provisions (or reversals of provisions) for loans. Other important cost components relate to staff costs and other administrative spending.

As the HGB is the relevant accounting principle in Germany, all data collected by the Bundesbank is under HGB regulations. The total data set used in this paper ranges from January 2003 to December 2016 and is constructed by merging two distinctive data sets: the monthly bank balance sheet statistics and the yearly profit and loss statements. Both of these data sets were provided by the Research Data and Service Centre of the Bundesbank. As all banks holding a banking licence in Germany are obliged to fill in these two statistics the response rate is close to 100% (only positions smaller than 1,000 EUR are not mandatory to report)[13]. As each bank reports at the individual bank level, no holdings are included.

After controlling for mergers by creating pro forma institutions[14], there are roughly 1600 banks left in the data set. More precisely, these banks can be subdivided into 20 building societies, 981 cooperative banks, 1 cooperative central bank, 10 Landesbanken, 4 Major banks, 156 regional banks, 12 private mortgage banks, 403 savings banks, and 19 special purpose banks such as the KfW (a state owned German development bank). For the regression analysis these banks will be regrouped and defined as follows: large banks (Major banks, Landesbanken, and cooperative central banks), small banks (savings banks and cooperative banks), regional banks, and all other banks[15]. To deal with outliers the relevant

[13] Also, more than 95% of all banks report over the whole observation period.

[14] A concern with this approach could be that mergers are endogenous. However, apart from a spike in late 2016 there does not seem to be a clear correlation between mergers and bank income. Moreover, the vast majority of mergers are horizontal mergers among savings or cooperative banks. As this group is by far the largest in the data set, only a small fraction of institutions is actually affected. Under the unlikely assumption that all 111 mergers since 2014 are a direct result of UMP, about 7% ($\approx \frac{111}{1600}$) of the banks in the data set would be affected. Running the regressions without pro forma institutions has no impact on the main results. For more details see Figure B.2 in the Appendix.

[15] While this categorisation may seem ad hoc it captures the factual banking structure reasonable well. While only the

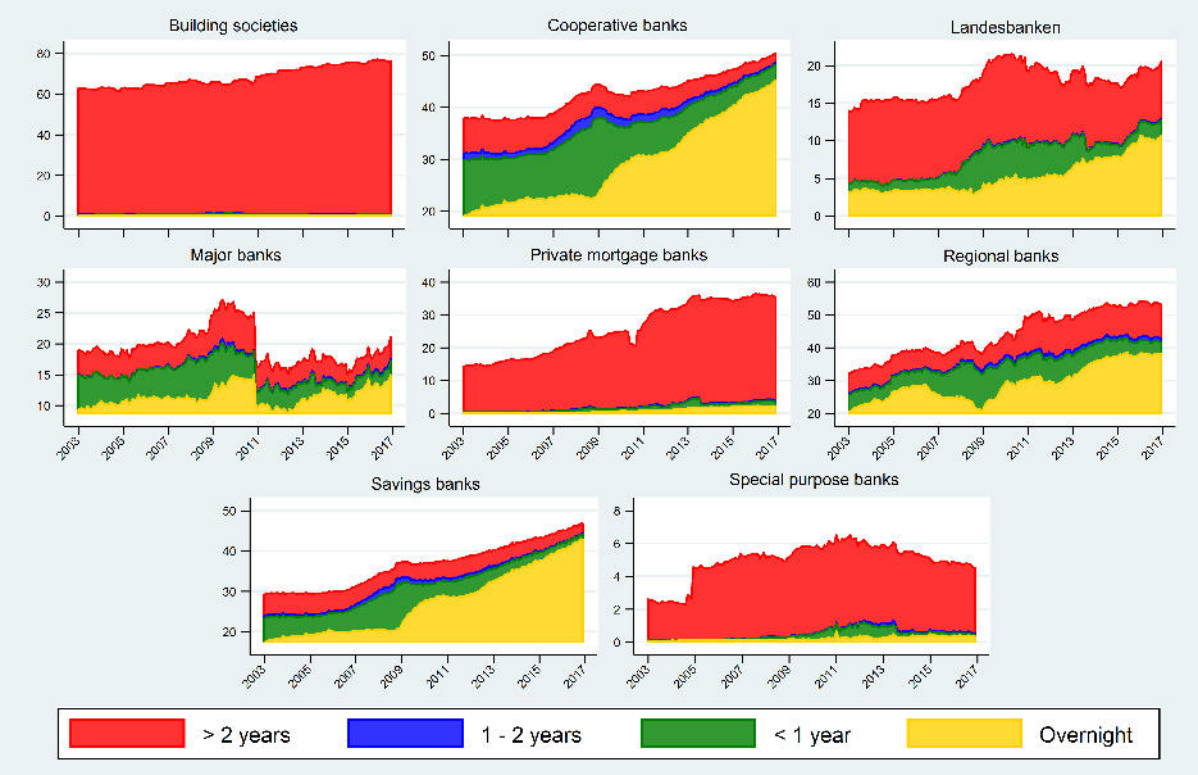
variables are winsorised at the 1st and 99th percentile by bank group and year.

Finally, the data set is merged with additional control variables which are taken from Datastream and the German Statistics Office. The macro control variables are the quarterly real GDP growth, and a monthly house price index. Moreover, the monetary and financial control variables are the 3 month interbank lending rate (EURIBOR), the log of the German stock index DAX, and the yield of a 10 year German government bond. As an indicator for the strength of UMP I use the ECB implied shadow rate as provided by Wu and Xia (2017). All financial variables are averaged over each year when working with yearly data. A full list of variables can be found in the Appendix in Table B.1.

3.4 Descriptive Analysis

It is not trivial to answer the question how banks have reacted to the unconventional policy measures by the ECB, which flooded the financial markets with liquidity and set the deposit rate below zero. Some authors, such as Jobst and Lin (2016), predicted that due to the downward stickiness of deposit rates below zero, banks were encouraged to substitute wholesale funding for deposits. Especially for larger banks, wholesale funding could provide a cheaper alternative relative to retail deposits via the issuance of unsecured or covered bonds. In addition, banks could also try to escape the liquidity overhang by

Figure 3.3: Average Borrowing from Households and Firms



Source: Bundesbank Balance Sheet Statistics. Own calculations. Borrowing relative to total assets by bank group. The averages are calculated as weighted averages of total assets.

three largest "small banks" overlap with the smallest "large bank", the residual group of "other bank" is admittedly more diverse. However, the alternative of grouping banks by total assets would come at the disadvantage of receiving more inconsistent groups with respect to banks' business model. Also, while the group of "other banks" varies strongly by size, the combining factor for these banks is a different liability structure. As Section **??** shows, all these banks have typically only long-term liabilities and very few overnight deposits.

pushing off some customers with large deposits. This way banks may try to lower the costs they pay to the central bank. In contrast, the evidence presented in Figure 3.3, showing the average borrowing from households and firms relative to total assets, suggests that short-term deposits have increased for almost all banks. This development started already during the financial crisis in 2009, then ceased around 2011, and resumed in 2012 when the deposit rate was set to zero. Striking is the increase for smaller cooperative and savings banks in overnight borrowing (i.e. money on current accounts) from households relative to longer maturities (such as savings accounts). However, the share of overnight deposits also increased for major banks, regional banks, and the Landesbanken in the recent years. In contrast, building societies, private mortgage banks, and special purpose banks usually borrow at longer maturities, i.e. they are not affected to the same extend.

However, this graph should be interpreted with caution. In fact, it does not tell anything about whether this development is driven by supply or demand effects. As this development started already before UMP measures, one can argue that it is simply driven by low opportunity costs of holding overnight deposits[16] and liquidity preferences by households and firms. A recent paper by Drechsler et al. (2017) supports this argument. Also, one may argue that due to the vast amount of liquidity provided by the ECB since the financial crisis, banks on average are simply unable to escape the excess liquidity in the system and, hence, are forced to absorb additional short-term funding[17]. In this respect, it is crucial to understand that banks cannot simply "transform" short-term funding into credits to the real sector. In fact, if a bank grants a new credit to a firm or a household new deposits are created by the bank. Put differently, the creation of a new long-term asset (a real sector credit) goes hand in hand with the creation of a new short-term liability (in form of deposits).

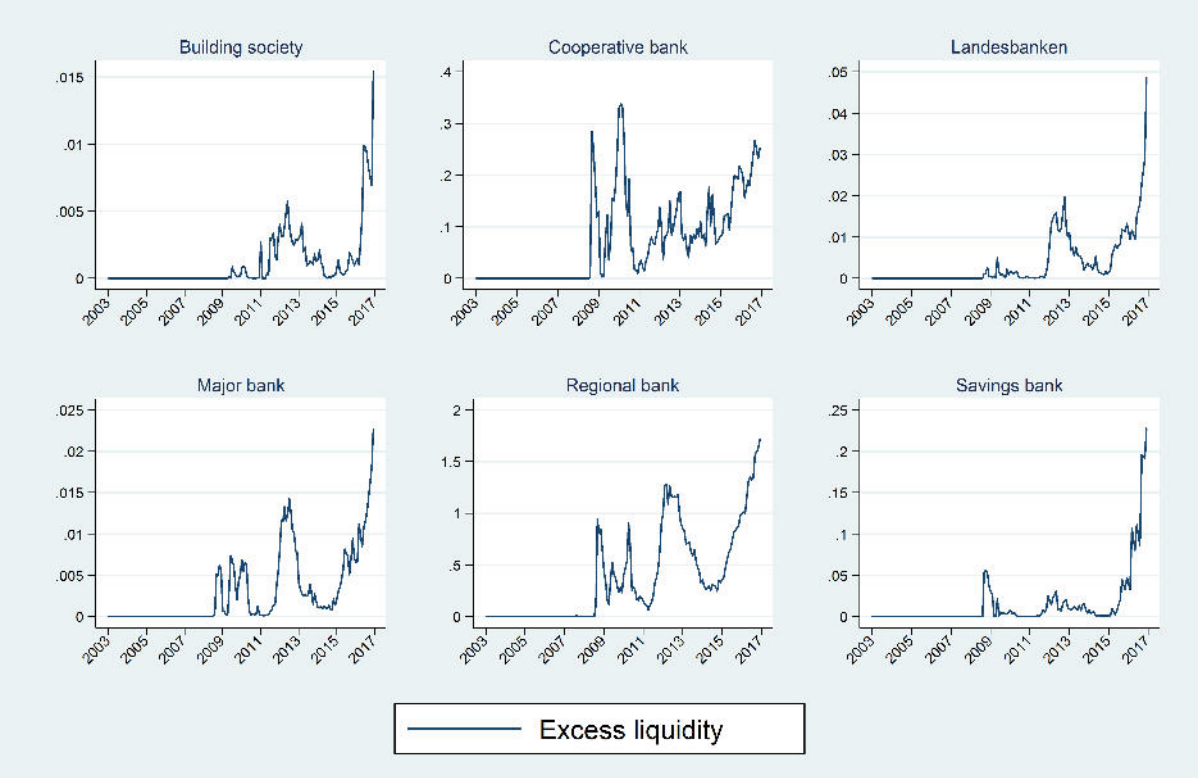
Moreover, even if banks would decline to sell government bonds to the ECB, in order to keep longer term assets, the additional liquidity will ultimately end up on their balance sheet as a short-term asset and a short-term liability. To illustrate this point, suppose a bank declines to sell a government bond to the ECB under its QE programme. Instead, the ECB purchases the bond from a private agent, such as a hedge fund or an insurance company. This transaction leads to long-for-short asset exchange on the balance sheet of the private agent. Assuming that an ordinary private agent has a bank account, this transaction increases the short-term deposit on the private agent's bank account. On the flip side, from the bank's perspective the transaction implies an increase in short-term liabilities *and* short-term assets since the private agent now has larger deposit claims (a liability) and the transaction will initially be booked on the current account of the bank at central bank (an asset). Put differently, even if all banks would collectively decide not to sell a single bond to the ECB to avoid excess liquidity, they will end up holding the excess amount of short-term liquidity and would have to store it at the ECB. This explains the logic that the ECB "forces" banks to hold excess liquidity in large amounts. While these amounts are still rather minor relative to total assets, they are strongly increasing across all banks[18]. Major banks especially hold a small amount of excess liquidity in relative terms whereas regional banks hold the largest

[16] In fact, some government bonds even have a negative yield providing even less incentive to invest.

[17] The recent widening of the TARGET imbalances suggests that much of this liquidity enters into the German financial system leaving German banks over-proportionally affected.

[18] Note that the data on excess liquidity holdings are not directly observable in the monthly balance sheet. In fact, the excess liquidity is calculated based on the daily in and outflow of payments on banks' current accounts at the central bank. Unfortunately, upon request the Bundesbank provided only aggregate data for some subsets of bank groups.

Figure 3.4: Average Excess Liquidity by Bank Group



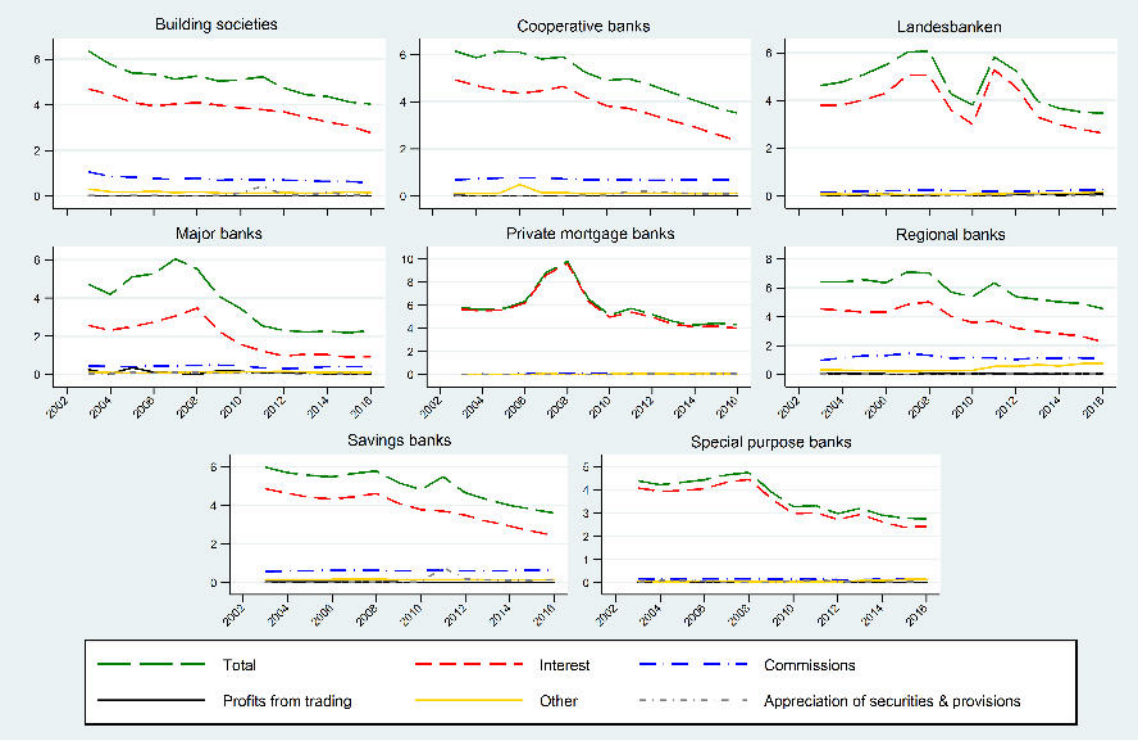
Source: Bundesbank. Own calculations. In percentage relative to total assets.

amount of excess liquidity on average as shown in Figure 3.4.

Therefore, the banking system as a whole is unable to escape the short-term liquidity overhang. As banks are unable to transform the short-term liquidity overhang into other long-term credits, this may lead to large extra costs for banks via the negative deposit rate. To evaluate this concern, this section first examines the development of the most important income and cost elements from the yearly profit and loss statements. In a second step, the current trends in some simple risk-taking measures are examined. I begin with the average bank income structure.

Arguably, one simple way for banks to counteract the costs related to negative interest rates charged by the ECB would be to simply increase their commission and fees. However, as Figure 3.5 indicates this has not been the case to a large extend until the end of 2016. While the average total commission income is usually the second most important income component it is still relatively small and remarkably stable across all banking groups. Even though it is true that many banks have raised their account administration charges or their fees for transferring money recently, this additional income does not play a major role relative to total income as it is not proportional to the deposits. Unfortunately, the position commission income in the P&L cannot be disentangled into it subcomponents of brokerage income or fees. In contrast, the income from interest rate payments is the most crucial income component of total income. The fluctuation in interest income largely determines the fluctuation of total income. On the other hand, income from the trading portfolio or the reversal of provisions are rather small for most bank groups, which is in contrast to the findings of Alessandri and Nelson (2015) who find larger trading income for UK banks. Even for the larger banks with sizeable trading portfolios the profits from trading

Figure 3.5: Average Income Structure



Source: Bundesbank P&L Statistics. Own calculations. Income components as percentage relative to total assets by bank group. The averages are calculated as weighted averages of total assets.

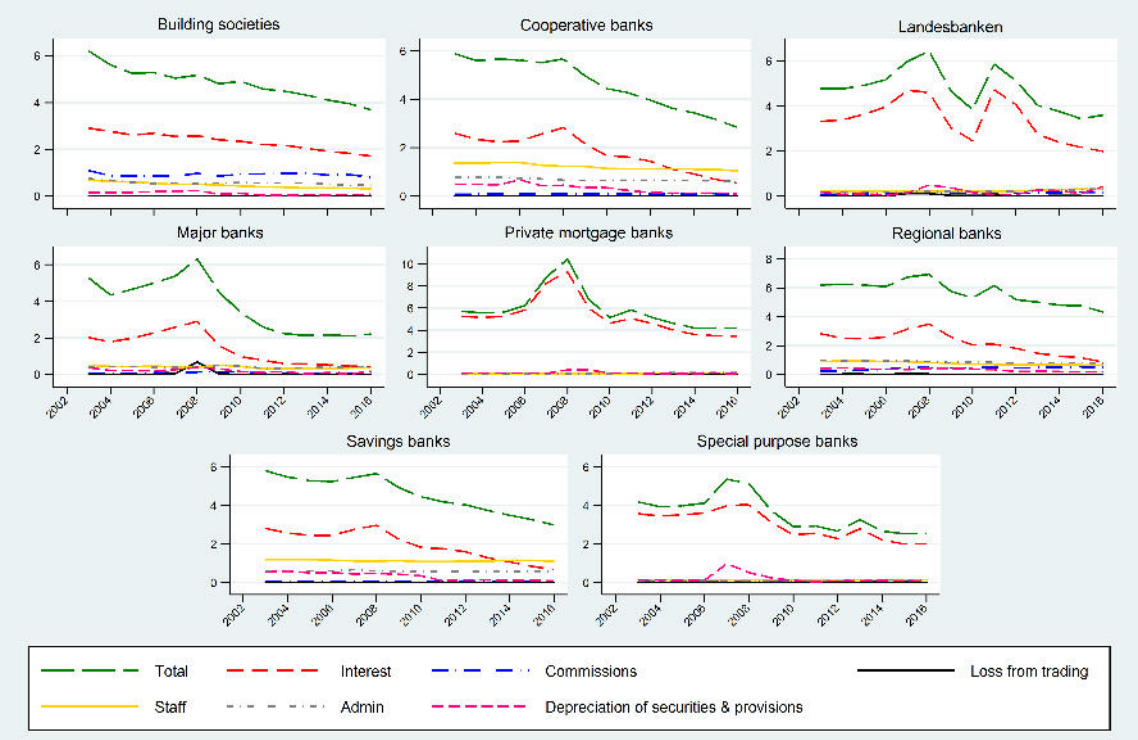
are on average lower than 1% relative to total assets. One reason for the low income from trading is the conservative German Commercial Code (HGB). However, also under the more market based IFRS accounting principle the income from trading is clearly outweighed by the income from interest[19].

The next natural question is how the different cost components have developed over time, which is shown in Figure 3.6. The widespread concern that negative interest rates pose a large cost burden for banks due to increasing interest rate costs does not seem to hold. Rather, banks have largely benefited from declining interest rates, which is consistent with the classical view that banks borrow short and lend long. Since the financial crisis in 2008 interest costs are characterised by a clear downward trend across all banking groups. Again, interest rates are the most sizeable element of the total costs. Only in recent years staff costs have been larger than interest costs for cooperative and savings banks, which typically hold a large network of branches in rural areas. In addition, another positive effect arising from low interest rates is the decline in write downs and provisions. Due to low interest rates and the positive economic outlook in Germany, the relevance of write downs and provisions as a cost factor has mostly declined. In addition, commission costs are an important cost component for some banks such as building societies, which rely heavily on brokers. This holds also for regional banks where these costs increased slightly in recent years, potentially due to a higher search-for-yield and the related higher brokerage cost. With respect to the losses from the trading portfolio it is notable that only major banks suffered mentionable losses during the global financial crisis. Otherwise these costs do not play an important role.

Combing the various cost and income elements into the total net development of the P&L statement shows that the net interest income, which is calculated by deducting the interest payments from the

[19] See Figure B.5 in the Appendix for a simple comparison.

Figure 3.6: Average Cost Structure



Source: Bundesbank P&L Statistics. Own calculations. Cost components as percentage relative to total assets by bank group. The averages are calculated as weighted averages of total assets.

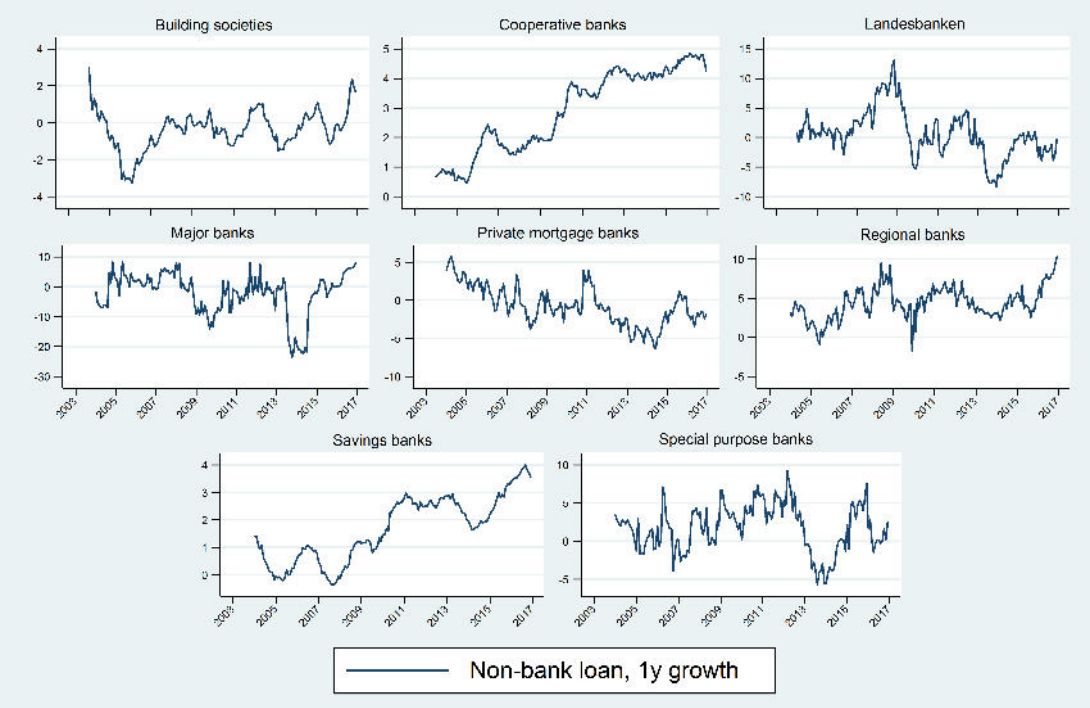
interest revenues, is remarkably constant over time. The net effect of income and cost components can be found in the Appendix in Figure B.6 together with the evolution of the return on equity before and after taxes, which is shown in Figure B.7.

With respect to bank risk-taking, Figure 3.7, 3.8, and 3.9 provide some primary evidence by illustrating the change over time in bank loan growth rates, the credit to GDP ratio, and the leverage ratio, respectively. In contrast, to what some have feared banks on average did not increase their risk-taking in these three dimensions after the introduction of NIRP or QE until the end of 2016.

Examining the growth rates of firm and household loans in more detail, Figure 3.7 illustrates that most bank groups have recently increased their loan rates. Interestingly, many German banks already extended their lending to firms and households *during* the financial crisis from 2008 till late 2009 and onwards. While the typical boom-and-bust credit cycles is found to be pro-cyclical to the GDP growth rates as illustrated in the case of the Landesbanken, many smaller German banks have extended their credit lines to their customers during the crisis. Most likely, this finding is, first, due to the house bank principle providing fresh funding in times of crisis and, second, due to firms and households making loan on overdrafts from their current account. However, given the visible volatility in loan growth rates, at which point can we think of loan growth rates and risk-taking as being *excessive* and when are they simply due to fundamentals of the economy?[20]

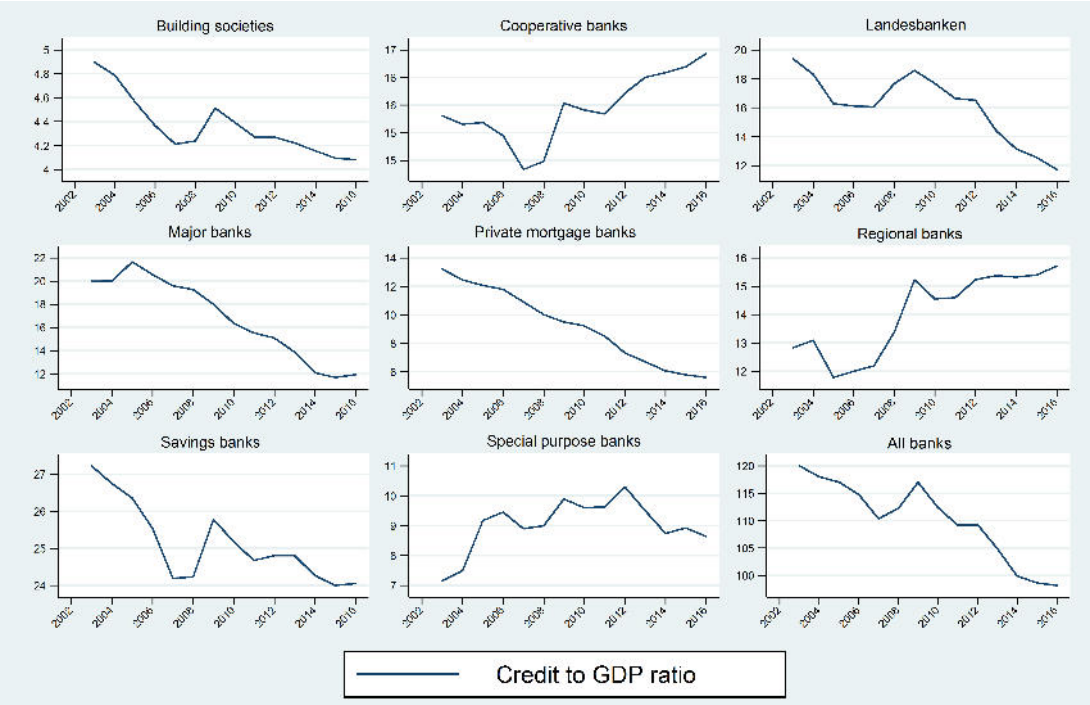
[20] As Cœuré (2016) argues, any risk-taking in terms of loan growth is "good" as long as it finances projects with a positive net present value. In contrast, risk-taking would only be "bad" if banks would finance projects with a negative net present value.

Figure 3.7: Average Loan Growth to Households and Firms



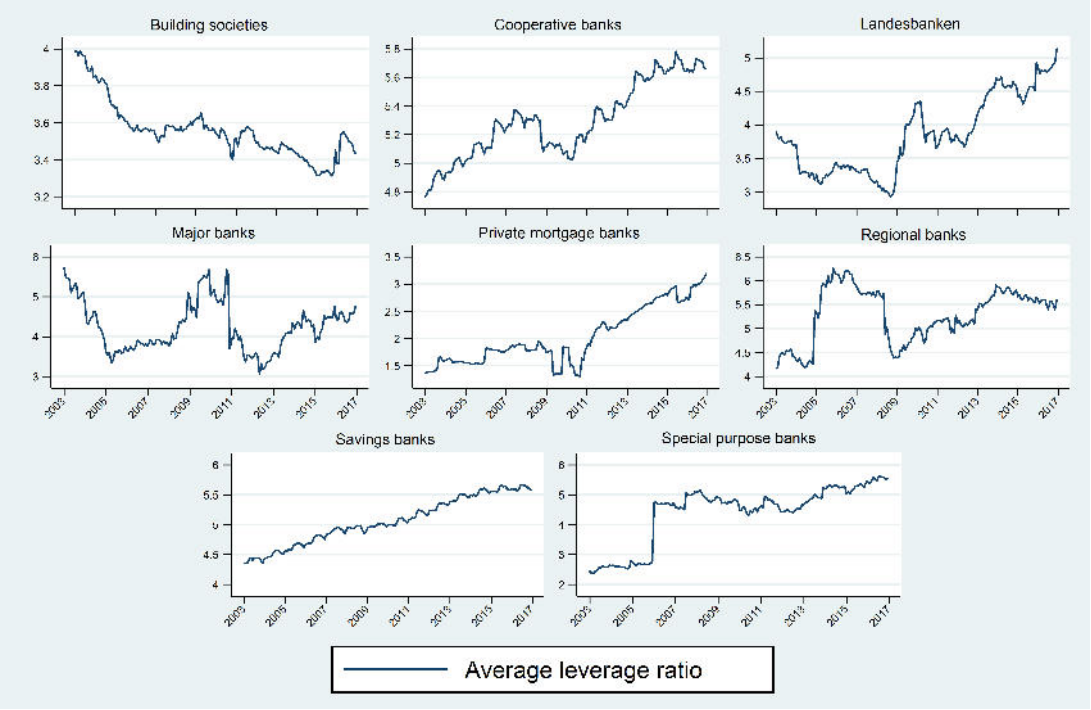
Source: Bundesbank Bank Balance Sheet Statistics. Own calculations. Growth calculated as year to year growth for each month. Averages are expressed as the median value of growth rates within each bank group.

Figure 3.8: Credit to GDP ratio



Source: Bundesbank Bank Balance Sheet Statistics. Own calculations. Growth calculated as year to year growth for each year.

Figure 3.9: Average Leverage



Source: Bundesbank Bank Balance Sheet Statistics. Own calculations. Leverage is defined as CET1 over total assets. The averages are calculated as weighted averages of total assets.

It is in general not easy to define which level of risk-taking can be considered as "excessive" or "normal". One guideline to this question is provided by the Basel III framework (The Basel Committee (2011)) which suggests considering the development of the credit to GDP ratio. Credit growth is considered to be excessive if the ratio deviates strongly upwards from its long-term trend. Figure 3.8 plots this ratio for all subgroups of German banks as well as the banking system as a whole. Only cooperative and regional banks exhibit a mild increase in the credit to GDP ratio in the recent years while the ratio is declining for all others banks as well as the total banking system. In other words, there is little indication that banks have taken an *excessive* amount of risk by issuing too much credit to risky firms or households since the start of NIRP and QE.

Another common measure to judge risk-taking is the leverage ratio, which is calculated by dividing a capital measure over a total exposure measure. Typically, this is done by taking core equity tier 1 (CET1) relative to total assets. In Germany, the core tier 1 capital largely consists of the paid-up capital and the reserves of an institution as defined in the Banking Act. Thus, the leverage ratio is calculated by the sum of subscribed capital and reserves divided by total assets[21]. As shown in Figure 3.9, most German banks have strengthened their leverage ratio over the last years. In this respect, the Basel III framework is already showing its bite even though the target rate of 3% is not yet fully phased-in.

Admittedly, examining banks' balance sheet statements to assess financial risk building up in the banking sector does not give a fully comprehensive picture. In fact, all measures presented until here are backward looking and can only help to answer the question if financial risk has already materialised

[21]Note that this definition of the leverage ratio is only an approximation for the reported leverage ratio in banking supervision. Due to difference in accounting standards large international banks often get acknowledged other instruments as CET1. Put differently, the leverage ratio calculated here is a fair proxy for small German banks whereas it is a conservative estimate for large banks.

in banks' balance sheets. However, they cannot serve as a forward looking predictor to detect future financial risk. To illustrate this point, one important caveat of Figure 3.7 is that it merely captures the *quantity* of loans but is ex ante silent on the *quality* of newly issued loans, which is only revealed at a future point in time. For example, if banks have lowered their lending standards and issued more risky credit, which would diminish the overall quality of their portfolio, they would be more vulnerable to negative shocks in the future. Therefore, in the remaining part of this section I present other aggregate statistics, which are not part of the data set I use, but can help to give a more comprehensive picture on bank risk-taking.

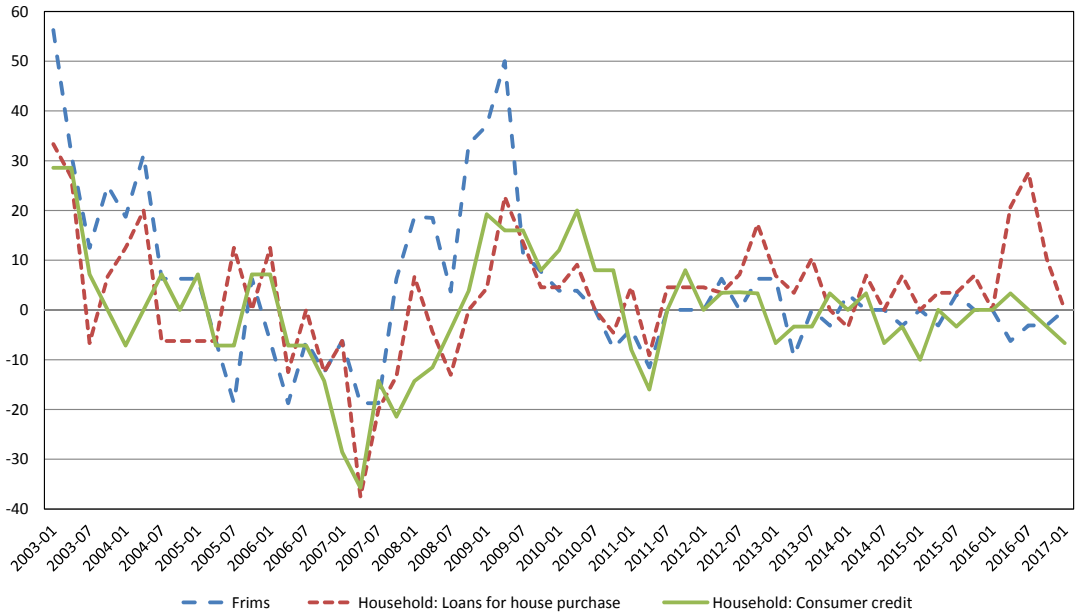
First of all, the empirical evidence provided by the bank lending survey[22] shown in Figure 3.10 does not indicate that banks lowered the overall quality of their loans. Since the end of the financial crisis, the net change in bank credit standards has mostly fluctuated around zero indicating constant lending standards. While recently many concerns have been raised that the large increase in real estate prices in Germany could lead to a bubble on the property market, the bank lending survey suggests that credit standards with respect to household loans for real estate purchases have tightened over the last quarters due to a change in the lending law. From this perspective, it is unlikely that the overall quality of bank credits has deteriorated.

While there is little sign of an increase in bank risk-taking in terms of loan volume and loan quantity, the recent financial stability report by the Deutsche Bundesbank (2016) highlights one important variable which could be helpful to detect the build-up in banks' overall risk position namely the average interest rate fixation period. Even though it is not clear when interest rates rise again, an increase in refinancing cost could lead to some serious problems in the future if rates will stay low for an extended period of time. Recall the two key variables to contemporaneous bank income: banks' asset legacy and the NIM between long-term assets and short-term liabilities.

As shown in Figure 3.11, banks have on average increased the interest rate fixation period for households mortgage lending, which can be interpreted as an additional dimension of risk-taking since the maturity mismatch between long run assets and short run liabilities widens. While the share of variable or 1-year fixed interest rate contracts has declined, the share of contracts with more than 10-years fixed interest rates has increased strongly since 2014 from roughly 30% to almost 45%. Recalling Figure 3.3, the increase in overnight deposits combined with the large share of long-term fix assets composes an interest rate risk which may only materialise in a few years.

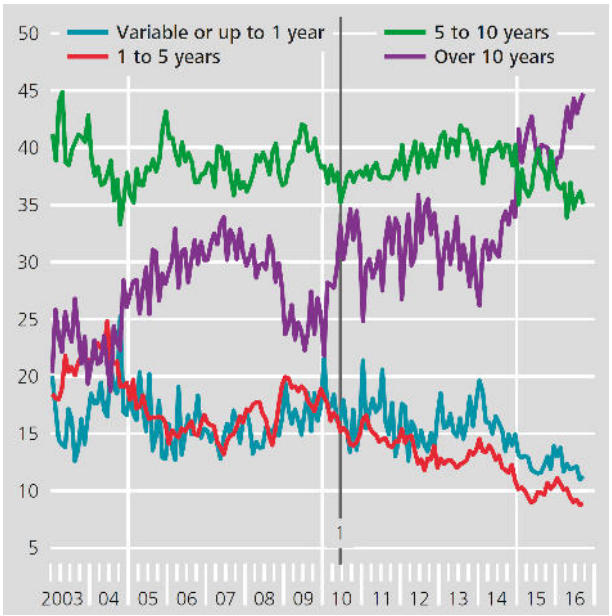
[22]The bank lending survey is a quarterly survey among a representative sample of Euro Area banks. The questionnaire comprises 23 qualitative questions on past and expected future lending policies and is conducted by each national central bank.

Figure 3.10: Overall Credit Standards of Loan Supply



Source: Bundesbank Bank Lending Survey. Changes in the last three months as net percentage (frequency of tightened minus that of eased or reverse). Positive values indicate tightening of credit standards, negative values indicate a relaxation.

Figure 3.11: Households Lending for House Purchase by Interest Rate Fixation Period



Source: Deutsche Bundesbank (2016) Financial Stability Report. As a percentage of new business, monthly. Within the Euro Area and including non-profit organisations serving households. Vertical line indicates change in the extrapolation since June 2010.

In other words, suppose a scenario where the ultra-low and negative interest rates prevail for a few more years, followed by a quick and unanticipated increase in short-term interest rates. If banks have mostly issued fix interest rate contracts during the years of the ultra-low period, their income in the following years is largely determined by these low interest contracts. In addition, a sudden and unexpected hike in short-term interests would lead to high refinancing costs and a large shrinkage in the NIM. Especially

cooperative and savings banks are subject to heightened interest rate risk. The reason for this high risk is that these banks have seen the strongest increase in the share of overnight deposits and – unlike large international banks – cooperative and saving banks are usually not active on the capital and wholesale markets and do not hedge their positions with interest rates swaps[23].

3.5 Regression Analysis

One essential advantage of micro level data is that it allows for a more detailed analysis beyond a simple average as, for example, some banks might have strongly reduced their credit growth rates while other could have strongly increased it leaving the average unaffected. This section first presents the baseline regression for the profit and loss statements with yearly observations using a fixed effect and System-GMM estimator. Second, a similar regression analysis measures the impact of unconventional monetary policy on bank leverage and loan growth rates again employing a FE and System-GMM estimator. As these two variables are based on monthly balance sheet data a slightly different specification can be used. Note the following for both cases: As the data set contains bank balance sheets, P&L statements, and takes macroeconomic conditions as given, the analysis is entirely backward looking and does not capture any feedback effects of unconventional monetary policy on bank profitability and risk-taking. Still, it provides important insights on how German banks have behaved during the first two and a half years of NIRP and QE policy measures.

A usual starting point for firm or bank level data is the fixed effects estimator in order to take the unobserved heterogeneity across entities into account. In the context of UMP measures, this would capture the unobserved time invariant characteristics of an individual bank. For example, this could be an individual bank's business model, which may be an important factor on how good or bad a bank can cope with negative interest rates and a flattening yield curve. However, in the case of yearly P&L statements the estimator operates in a large N, small T world where the FE estimator is subject to the Nickell-bias and the coefficients are downward biased relative to the true value. In contrast, the System-GMM estimator, which was developed by the work of Blundell and Bond (1998) and Arellano and Bover (1995), should provide unbiased and consistent estimates in this environment. Given the data at hand, these are desirable features as the data set includes balance sheet and macroeconomic variables of which several display autoregressive behaviour. Moreover, balance sheet data can be subject to simultaneity which, however, should be alleviated by lagging these positions and defining the variables as endogenous in the System-GMM estimator.

Another debatable issue arises with respect to endogeneity of monetary policy in the sense that the central bank's decision could be influenced by banks' profits or, more generally speaking, by financial stability considerations. However, this concern is somewhat eased by the fact that the data set is largely dominated by small German bank which individually are not key to the stability of the financial system. On the other hand, one German bank is listed among the globally systemic important financial institutions and does play a role for financial stability.

[23]Figure B.3 and B.4 show the average composition of the balance sheet of each bank group. Inter alia, the position "Other" includes financial derivatives. Following the Balance Sheet Modernisation Act in 2010, many large banks capitalised various financial derivatives while smaller banks typically do not hold such financial instruments.

A critical assumption of the System-GMM estimator is that there is no autocorrelation in the in the idiosyncratic errors. Yet, due to first differencing the *differenced* errors have first order auto correlation by construction. This can be tested with the Arellano-Bond test under the H_0 of no first/ second order serial correlation, i.e. we *do* want to reject the test for first and *do not* want to reject the test for second order auto correlation of the errors. In addition, as the System-GMM estimator can easily employ a long list of (potentially irrelevant) instruments, the Sargan test is often employed to test for overidentification, assuming at least one of them is valid. Under the H_0 that all instruments are valid the null should not be rejected. Unfortunately, the Sargan test depends on homoscedasticity and does not work with a two-step estimator used in this paper. Nonetheless, it is still possible to manually limit the number of instruments employed[24].

As the Sargan Test for the one-step estimator provided evidence that the instruments are valid[25], the System-GMM estimator is next specified as a two-step estimator, i.e. the inverse of the covariance matrix of the moment vector from the first-step estimation is used in a second step as the weighting matrix. Also, the standard errors are computed as robust standard errors using the estimator developed by Windmeijer (2005). In the case of the FE estimator, standard errors are clustered by bank entities allowing for intra-bank correlation. In order to assess the average impact of the interest rate level and the slope of the yield curve on different income components, the following baseline regression is run:

$$\begin{aligned} y_{i,t} = {} & \alpha\, y_{i,t-1} + \beta_1\, \texttt{level}_t + \beta_2\, \texttt{level}_t^2 + \beta_3\, \texttt{slope}_t \\ & + \phi\, \texttt{deposit ratio}_{i,t}\, \texttt{level}_t + \varphi\, \texttt{deposit ratio}_{i,t}\, \texttt{UMP}_t\, \texttt{level}_t \\ & + \gamma\, Z_{t-1} + \theta\, X_{i,t-1} + v_i + u_{i,t}, \end{aligned} \tag{3.1}$$

where $y_{i,t} = \frac{Y_{i,t}}{\texttt{Avg. TA}_t}$ denotes the dependent variables which are: net interest income, net income from commissions, and net income from the valuation of assets and provisions each calculated in basis points relative to total average asset in year t. Due to the introduction of fair value accounting in late 2010, a structural break strongly affects the net income from trading. Therefore, for this variable the data set is split accordingly (see below).

The most relevant explanatory variables are the $\texttt{level}_t$ of short-term interest rate (three month Euribor rate), the $\texttt{slope}_t$ of the yield curve (ten year German Bund − three month Euribor) and the interaction term. To capture potential non-linearities, the squared value of the $\texttt{level}_t$ of the interest rate is also taken into account. While both the level and the slope are affected by unconventional monetary policy in general, the former should mostly be influenced by the ECB's choice of setting the short-term refinancing and deposit rate (NIRP), whereas the latter is thought to be determined by the ECB's large scale asset purchase programme (QE). A second important aspect of this paper is the potential heterogeneity of banks in times of unconventional monetary policy. The interaction term $\texttt{deposit ratio}_{i,t} \cdot \texttt{level}_t$ is included to take this heterogeneity into account. The central idea behind this approach is that at negative levels of the short-term interest rate there could be a stronger relationship between the share of deposits and different income components. More precisely, breaking through the

[24] If not stated differently, the maximum number of lags used as instruments for the System-GMM estimator is capped at three in the following analysis.

[25] Results for the one step estimator are omitted here for brevity.

ZLB could make expansionary monetary policy contractionary in particular for those banks with higher deposit ratios as a source of funding. Thus, to differentiate between average times and unconventional monetary policy by the ECB, one interaction term is multiplied with the dummy $\texttt{UMP}_t$ (= 1 from 2014 to 2016)[26].

Furthermore, to account for bank specific effects $X_{i,t-1}$ denotes a set of bank explanatory variables. These variables are bank size (log of total assets), the leverage ratio (CET1 to total assets), bank efficiency (cost-to-income ratio), bank loan ratio (non-bank loans to total assets), and the deposit ratio (overnight deposits to total liabilities) each lagged by one period to mitigate concerns of endogeneity. Additionally, Z_{t-1} represents a set of macro explanatory variables which are the same to all banks i. These are the year on year German GDP growth rate, the log of the yearly average of the German DAX index, and a yearly house price index. Finally, v_i denotes the unobserved time invariant individual fixed effect and $u_{i,t}$ is the idiosyncratic error term. The same baseline specification is used for the System-GMM estimator.

Also, to differentiate between different bank groups, separate regressions for large banks (Major banks, Landesbanken, and cooperative central banks), small banks (cooperative and savings banks), and regional banks are run[27]. Note that for the group of small and regional banks the System-GMM estimator is employed. In contrast, for large banks the System-GMM estimator cannot be calculated as the N dimension is reduced to only 15 banks. Also, as argued in section **??** the group of large banks is subject to the structural break due to the Balance Sheet Modernisation Act in 2010. Thus, only a subset from 2010 onwards is taken into account for this group of banks. Unfortunately, since only six years are left this makes it harder to differentiate between average before and after UMP measures and the interaction term gets automatically omitted because of collinearity in the time dimension[28].

The results for the regressions on net interest income can be found in Table B.2. First of all, note that most coefficients have the anticipated sign. There is a positive and concave relationship between the level of short-term interest rates and bank income indicating that banks on average have higher net interest earnings when short-term interest rates are higher. However, this finding is only weakly significant. The only exception is the group of large banks which is arguably a special case due to few observations as outlined above. Regarding the slope of the yield curve, all estimators show the anticipated positive relation which is in line with the maturity transformation of banks. On the other hand, the mostly negative sign of the estimated coefficients for GDP growth and the house prices seems surprising. In the case of house prices, a possible explanation for this is the inverse relationship between interest rates and asset prices. If interest rates are low, usually house prices increase as currently observed in Germany. Also, a low interest rate correlates in general with lower net interest income as suggested by the level coefficient.

Turning to bank specific effects and the interaction term, while in general there is a positive relationship between the level of short-term interest rates and net interest income, the interaction term suggests

[26] The same results were obtained when directly differentiating between before and after going negative. In this case, the two interaction were specified as $\texttt{deposit ratio}_{i,t}\,\texttt{UMP}_t\,\texttt{level}_t$ and $\texttt{deposit ratio}_{i,t}\,(1-\texttt{UMP}_t)\,\texttt{level}_t$. These results are available upon request.

[27] The group of other banks was also tested. However, as this group of bank has predominately long-term obligations and the results were mostly insignificant, they are omitted here.

[28] Also, for the group of large banks the DAX explanatory variable is dropped automatically due to collinearity. The variation across bank entities is simply too small, which also makes time dummies superfluous as they are largely dropped automatically.

that during UMP banks with a higher share of deposits profit more when the interest rate level is higher. More intuitively, this positive relation implies that high deposit banks face lower net interest income when interest rates are lower. Importantly, this relationship becomes only relevant when breaking through the ZLB as the coefficient of the interaction term gets higher and significant for UMP but not for the total average interaction term. A stylised graphical interpretation of this result can be found in the Appendix in Figure B.8. Also note that this result seems to be driven by the smaller banks, which usually have a higher share of deposits and are more dependent on interest income. In addition, the coefficient of the deposit share is mostly negative, indicating that on average banks with more overnight deposits have fewer net interest income. However, the magnitude of this effect is still small. In other words, the results suggest that once setting the short-term interest rate to negative levels banks have slightly lower net interest income and this effect intensifies for banks with higher deposit ratios.

The results for net commissions are shown in Table B.3. It is important to note that this position in the P&L captures all fees and commissions paid or collected by the bank. Therefore, in addition to the previous estimation the log of the DAX index is included. The estimations yield a negative and significant relationship between the log of the DAX and net commission income. This could be driven by the fact that brokerage commissions have decreased over the last decade following increased competition and technological advancement, whereas the DAX has increased over the same period[29]. In contrast, there exists a positive relation between housing prices, which are typically a more local brokerage service, and commission income. However, the relationship regarding the interaction term is less clear. While it is positive and mostly significant during the years of negative interest rates it is not clear if banks with more or less deposit benefit as the deposit ratio coefficient is only negative and significant for the subset of small banks. This suggests that following negative interest rates small banks with larger deposits find it harder to raise commission income, which does not support the argument that banks could simply increase their fees to pass on negative interest rates.

The next variable of interest is the net income or the net charges from the valuation of assets, which primarily includes write downs/ups for assets, any loan loss provisions, and the reversals of loan loss provisions. The result can be found in Table B.4. The coefficient for the level of the interest rates indicates that at higher levels of interest rates more loan loss provisions are needed (a cost factor) since the interest burden is higher. Given the positive interaction term and the positive value of the deposit ratio, we can conclude that in this case it is actually more beneficial to have a higher share of deposits. However, the coefficient for the interest level is much higher compared to the interaction term, suggesting that it only plays a minor role. Moreover, in this regression the GDP growth rate has the anticipated sign that higher growth rates are correlated with fewer write down and more reversals of loan loss provisions.

As already noted above, the case of net trading income is special because fair value accounting was only introduced into German accounting law in late 2010. Therefore, for the regressions on net trading income the sample is split and starts only in 2010 which makes it harder to differentiate between before and after the introduction of negative interest rates. Thus, the baseline regression is changed to

[29]The alternative of taking DAX volatility does not change this result.

$$
\begin{aligned}
y_{i,t} = {} & \alpha\, y_{i,t-1} + \beta_1\, \texttt{level}_t + \beta_2\, \texttt{level}_t^2 + \beta_3\, \texttt{slope}_t \\
& + \phi\, \texttt{DAX}_t\, \texttt{trading book assets}_{i,t} + \varphi\, \texttt{DAX}_t\, \texttt{trading book liabilities}_{i,t} \\
& + \gamma\, Z_{t-1} + \theta\, X_{i,t-1} + v_i + u_{i,t},
\end{aligned} \tag{3.2}
$$

with additional bank specific control variable introduced, which are the share of the asset and the liability trading book. Also, two interaction terms between the size of the two trading books and the DAX are included. Table B.5 in the Appendix presents the outcome of this regression. Not surprisingly, as only a few German banks are active on the trading markets on a larger scale the bank specific explanatory variables are usually close to zero and insignificant. Not even the size of the trading book has a significant or sizeable impact on trading income. The only variables which seem to play a role are the macro explanatory variables, which all have the anticipated sign.

Admittedly, one potential concern with this approach is that the identification of UMP is to some degree ad hoc via a time dummy. Using a slightly different specification as in Equation (3.3), a similar regression is run which proxies the strength of UMP by specifying the interaction term as the deposit share multiplied with the difference between the level of the 3 month Euribor and the implied shadow rate.

$$
\begin{aligned}
y_{i,t} = {} & \alpha\, y_{i,t-1} + \beta_1\, \texttt{level}_t + \beta_2\, \texttt{level}_t^2 + \beta_3\, \texttt{slope}_t \\
& + \phi\, \texttt{deposit ratio}_{i,t} \cdot \texttt{UMP strength}_t + \gamma\, Z_{t-1} + \theta\, X_{i,t-1} + v_i + u_{i,t}.
\end{aligned} \tag{3.3}
$$

As pointed out by Wu and Xia (2017), the various unconventional actions taken by ECB lead to a much lower implicit policy rate, the so-called shadow rate. Therefore, taking the difference between these two should provide a crude estimate for the strength of UMP[30]. Notwithstanding, the unconventional policy actions by the ECB also push the Euribor downwards to the lower bound of the deposit facility. Hence, taking the difference between these two is a conservative estimate as the total strength of UMP is likely to be higher. Moreover, as the P&L variables are on a yearly basis, this difference is averaged across each year making it even cruder. Still, the results of this estimation, which can be found in the Appendix in Table B.6, B.7, and B.8, hint in the same direction as the regression based on a simple dummy identification. The stronger UMP measures the weaker average net interest income which intensifies for higher deposit ratios.

Having examined bank profitability in greater detail, the changes in bank risk-taking in terms of loan growth and leverage ratio are considered next. According to the risk-taking channel, banks could be induced to take more risk if interest rates are too low for too long. A potential reason for such behaviour could be limited liability considerations. However, as we have already seen in Section **??**, *on average* banks have only moderately increase loan growth rates and increased their leverage ratio due to the Basel III regulations[31].

[30] See Figure B.9 in the Appendix for a graphical illustration.

[31] In the current version of the paper, I do not explicitly control for the changes in the Basel III regulations. Despite the fact that the Basel III regulations undoubtedly have an effect on bank risk taking, it is not straight forward to control for these regulatory changes. A simple approach would be to introduce a dummy since the start of the Basel III regulations.

As the leverage and the loan growth rates are taken solely from bank balance sheet data, which are on a monthly basis, the Nickell bias decreases due to the higher T dimension and the fixed effects estimator should in principle provide unbiased estimates. Therefore, in the following all bank group regressions are based on the fixed effects estimator while the results for the System-GMM estimator are still included as a robustness check. Moreover, as the difference between the Euribor and the shadow rate can be calculated on a monthly basis this variable is taken as the main indicator for UMP. Note that the baseline regression with a dummy was also run leading to similar results[32]. All control variables are now based on monthly observations with the exception of the GDP growth rate which is quarterly.

The estimation results for the leverage ratio are summarised in Table B.9. The interaction term between the strength of UMP and the deposit ratio suggests a negative relationship between unconventional monetary policy measures and leverage ratio with a mostly positive coefficient for the deposit ratio. In other words, the stronger the unconventional monetary policy measures the lower leverage ratio especially for those banks with higher deposits. This does indeed indicate that high deposit banks have increased their risk-taking in terms by reducing their leverage ratio. However, note that the magnitude of the coefficient is quiet small and that most banks in total increase their leverage ratio due to the new Basel regulations as outlined before. Put differently, this can be interpreted that banks with high deposit ratios must have reduced their *voluntarily* capital holdings relative to the increased *required* capital holdings applying to all the banks.

Finally, considering the impact of unconventional monetary policy on year on year loan growth rates Table B.10 suggests that stronger unconventional monetary policy correlates with lower loan growth rates for banks with higher deposits. While it is true that *on average* the German banking sectors has experienced positive loan growth rates, this micro view indicates that there has been a reshuffling of loans from high deposit banks to low deposit banks. This is an important finding as it indicates that the monetary policy pass-through is potentially jeopardised for these banks at negative policy rates. Consistent with early findings, smaller banks which typically have a higher share of overnight deposits find it harder to pass on negative rates to their customers. As a consequence they reduce their loan rates and expansionary monetary policy becomes contractionary.

3.6 Robustness

As an additional robustness check, I follow the approach by Heider et al. (2017) and Eggertsson, Juelsrud, et al. (2017). Assuming that going negative is indeed a "game changer" employing a difference-in-difference estimator should provide a consistent and unbiased estimate given some underlying assumptions. The average change for banks with high deposit ratios (treatment group) could be different at negative rates relative to banks with low deposits (control group) as for these high deposit banks the

However, this approach would be flawed for two main reasons. First of all, Basel III is not a structural break in the classic sense. In the European Union, most regulatory changes were decided in 2013. However, while these changes came into force from 2014 onwards banks were given several years to adjust to the new requirements. Therefore, some banks might have adjusted early whereas other bank could have waited longer. Second, such a dummy would very much overlap with the time frame of UMP making it unclear which effects are actually captured. Currently, I am trying to acquire additional data from the Bundesbank to create a distance to Basel III variable. If one, for instance, would look at the actual risk weighted tier one core equity ratio relative to the ratio a bank should have under the Basel III rules, it might be possible to calculate the difference between these two and to interpret the gap as the regulatory adjustment pressure.

[32] They are omitted here for brevity but are available upon request.

monetary pass-through might break down at negative rates. Formally, the diff-in-diff reads as

$$y_{i,t} = \beta\,\texttt{UMP}_t + \gamma\,\texttt{Deposit ratio}_i + \delta\,(\texttt{UMP}_t \cdot \texttt{Deposit ratio}_i) + v_i + u_t + \epsilon_{i,t}. \tag{3.4}$$

To differentiate between the treated and the untreated banks, first note that the average overnight deposit ratio in the data set is at 35% (see also the histogram of overnight deposits in Figure B.10 in the Appendix). Therefore, high deposit banks are defined as banks with a deposit ratio of more than 35% (`Deposit ratio` = 1) whereas low deposit banks are defined as banks with a lower deposit ratio (`Deposit ratio` = 0). Alternative specifications of taking "other banks" (with primarily long-term deposits) as the control group, or of taking the upper 75 percentile vs. the lower 25 percentile of the average bank deposit ratio, yield the same qualitative result.

Following the literature, for monthly balance sheet data a time frame of 2013 to 2015 is chosen[33]. The time dummy is set to be equal to one starting from June 2014 when the deposit facility was first lowered to negative levels (`UMP` = 1). Hence, there are roughly one and a half years before and after the treatment. In contrast, when working with yearly P&L data, I allow for a longer time period from 2012 to 2016 giving two observations before the treatment and three afterwards for each bank. As an alternative starting point of negative rates (May) 2015 was chosen when the Euribor entered into negative territory which, however, leaves the main result unaffected. Also, in order to control for unobserved heterogeneity across banks entities or across time, bank fixed v_i and time fixed u_t effects are introduced in the estimations. All remaining influences are captured by the error term $\epsilon_{i,t}$.

The results for the two main variables of interest (net interest income and loan growth) are shown below in Table B.11 and B.12[34]. The results from these estimations hint in the very same direction as the results shown in the previous section. Once interest rates become negative banks with larger deposits have on average a lower net interest income. Also, banks with an above average deposit ratio have decreased their loan growth rates relative to low deposit banks.

3.7 Conclusion

Since the announcement of a negative interest rate policy and a quantitative easing programme by the ECB, the German banking sector exhibited a huge short-term over-funding. However, despite what many commentators have feared *the good news* from the evidence given in this paper suggests that the German banking sector performed reasonably well during the first years of unconventional monetary policy. Banks so far have not faced a huge cost burden from negative interest rates. Rather, banks have benefited from lower refinancing costs and shrinking loan loss provisions. In fact, profits across all banking groups have so far been only mildly affected by NIRP and the QE programme. Furthermore, there is only little evidence that German banks have engaged in *excessive* risk-taking by granting too much credit or by lowering their lending standards in response to interest rates being too low for too long.

On the other hand, *the bad news* is that the often mentioned capital gains from asset holdings play

[33] While there is no formal test for the diff-in-diff estimator I run out of sample tests from 2005 to 2007 for monthly and from 2003 to 2007 for yearly data to find insignificant results.

[34] Moreover, estimations on the other indicators discussed in this paper were also run but mostly yield insignificant results. They are available upon request.

little role for German banks, due to the conservative German accounting rules. Only some larger banks with a sizeable trading portfolio may have profited from this income source whereas it is practically irrelevant for all other banks. Also, the hypothesis that banks can increase their fees and commission to pass on negative interest rates to their customers does not hold. Even though several banks did increase their fees, this additional income is usually a flat rate and not proportional. Hence, it is merely a drop in the ocean relative to total assets. Moreover, banks on average were neither able to push off large amounts of excess funding nor to substitute deposit financing with wholesale funding. While a few banks might have found creative ways to escape increasing short-term liabilities, the banking system as a whole has no way to do so. In fact, the average share of overnight private deposits increased since 2013 from about 30% to 45% of total assets for smaller banks. Even major banks exhibited a mild increase from roughly 10% to 15% of total assets over the same period. In addition, especially high deposit banks have on average a lower net interest income and they slightly decreased their leverage ratio.

While the magnitude of these negative effects is still small, one should be careful in concluding that negative interest rate transmit just like positive rates do and that there are no risks associated to these UMP measures. In fact, *the ugly truth* is that if interest rates remain on their current level and the yield curve keeps on flattening, banks must be adversely affected at some tipping point due to their intrinsic business model and the expansionary monetary policy stance becomes contractionary eventually. A clear indicator for this is that banks with high deposit ratios have already decreased their lending.

Moreover, the financial stability report from the Deutsche Bundesbank (2016) highlights an import additional source of risk-taking which is currently under-explored in the literature. The more extensive bank maturity transformation together with rising deposit ratios exposes banks to an increasing interest rate risks especially under a scenario of a fast and unexpected rise in short-term interest rates. As savings and cooperative banks typically do not hold any derivatives to hedge their position, these banks are in particular subject to this interest rate risk. A thorough examination of this finding is left for future research.

Chapter 4

Minimum Wage, Monopsony, and Labour Supply Shocks[*†]

[*]This chapter is based on joint work with Nikolay Hristov

[†]Disclaimer: The views expressed in this chapter represent the authors' personal opinions and do not necessarily reflect the views of the Deutsche Bundesbank or its staff

4.1 Introduction

One of the oldest questions in the field of economics concerns the impact of a minimum wage. Despite this issue being discussed extensively for several decades in the academic world and among policy makers no final conclusion has been reached. On the one hand, the proponents of a minimum wage argue, for instance, that a minimum wage increases aggregate demand, *reduces* macro volatility[1], protects employees and, ultimately, increases social justice. On the other hand, opponents of a minimum wage stress that it leads to inefficient markets, job losses, *increases* macro volatility[2] and, furthermore, is a unnecessary intervention into free labour markets by the government.

One key reason for this unresolved dispute is that theoretical models examining the minimum wage crucially depend on the assumed labour market structure. While models with a competitive labour market such as the traditional approach by Stigler (1946) usually find negative effects from a minimum wage, monopsony[3] models or models of monopsonistic competition as proposed by Manning (2003), which assume some market power for the employer, tend to find positive effects from a moderate minimum wage as it reduces the deadweight loss. In addition, also the empirical literature provides mixed evidence on this topic. For example, one popular paper by Card and Krueger (1994) finds non-negative effects from an increase of a minimum wage, whereas another widely cited paper by Neumark and Wascher (1992) highlights the potential risk of job losses due to a minimum wage.

Our contribution to this ongoing discussion provides a DSGE model to quantify the dynamic macro effects in different scenarios comparing the results between a competitive and monopsonistic labour market. To our best knowledge, all existing papers on monopsony labour markets use static models which lack a solid micro foundation with changes of preferences over time, or are partial equilibrium models. In fact, many authors have examined minimum wages in a dynamic labour market with an upward sloping labour supply curve implicitly assuming some degree of monopsony by introducing frictions through e.g. a search-and-matching function, such as Moser and Stähler (2009), and Charpe and Kühn (2012). However, we propose a DSGE model directly building on the work of Manning (2003) to model a monopsonistic labour market explicitly.

A second contribution of this chapter is that we model the minimum wage as an occasionally binding constraint in a DSGE model. In most existing papers such as Porter, Nathan and Vitek (2008) and Heberer (2010) the minimum wage is binding at every point in time. However, being effectively an inequality constraint the minimum wage in reality is not binding if the market wage of a representative household is above the minimum wage. Put differently, if the exogenously set minimum wage is below the market wage rate it would not be of high relevance. Therefore, we model the minimum wage as an occasionally binding constraint using the toolkit provided by Guerrieri and Iacoviello (2015)[4]. In our model, the economy is populated by three types of households. While skilled and medium skilled households are optimising their consumption/saving decision by investing into risk-free bonds in order to

[1] Similar to an automatic stabiliser as in Charpe and Kühn (2012)

[2] See Porter, Nathan and Vitek (2008)

[3] The term monopsony can be tracked back at least until Robinson (1969) who proposed the notion of "monopsony" for a market with just one buyer but many sellers as the analogous notion to a monopoly market with just one supplier but many consumers.

[4] As many central banks have lowered their target rates to zero after the financial crisis of 2008-09 it has become popular in monetary economics to model the zero lower bound as an occasionally binding constraint. See for instance Guerrieri and Iacoviello (2015).

smooth their inter-temporal consumption, a third type of so called unskilled households are "rule-of-thumb consumers" without access to financial markets[5].

Regarding the minimum wage, Germany is a very interesting subject of study for two reasons: the newly introduced minimum wage in early 2015 and the large migration inflow of late 2015. Most existing studies on the effects of the minimum wage introduction in Germany are derived from "back of the envelope" calculations disregarding any long-term dynamic effects. In fact, examining the current low unemployment numbers in Germany suggests that the moderate German minimum wage did not lead to job destruction on a large scale.

In addition, no study has been made so far to systematically examine the effects of a positive labour supply shock following the large migration inflow into the German labour market. Integrating about one million refugees is a huge challenge for any society especially if refugees come from a different cultural and ethnical background. One possibility often proposed to promote quick integration into a society is integration via the labour market[6]. However, relatively little is known about the education and skills of incoming refugees. A first guess would be to look at the general educational statistics of source countries which indicate a large heterogeneity among different countries of origin[7]. Various studies on international migration, such as Mattoo et al. (2008), suggest that even highly skilled workers tend to work in low-skilled positions in the host country. This phenomenon of "brain waste" is often explained by language or legal barriers such as the recognition of foreign educational and labour degrees. This evidence indicates that in the short and medium run the vast majority of migrants will enter into the German low skilled labour market, creating downward pressure on wages potentially making the minimum wage binding to a larger degree.

Trying to shed light on this question, our model suggests that following the drop in wage rates from a positive unskilled labour supply shock, skilled and medium skilled workers are substituted with cheaper unskilled workers. However, due to the wage setting power of medium and skilled household their consumption still increases over time. Interestingly, using this set-up macro volatility is actually reduced under a binding minimum wage. While the increase in unskilled consumption is lower with a binding constraint the substitution effect of different workers is less strong mitigating overall output volatility. Regarding the introduction of firm monopsony power the model predicts a reduction in the steady state level of unskilled wages. Unfortunately, this does not change the dynamics of the model calling for additional frictions. This is left for future research.

The remainder of this chapter is organised as follows. Section 4.2 sketches the introduction of the minimum wage in Germany and its effects so far. Section 4.3 reviews the literature on minimum wages and monopsony models while Section 4.4 discusses the prediction of static models and provides some intuition on how we think of the minimum wage and the situation in Germany. Afterwards, our dynamic model is presented in Section 4.5 with the calibration of the model being discussed in Section 4.6. The results of our analysis are presented in Section 4.7. Finally, Section 4.8 concludes.

[5] A large body of literature exists on rule-of-thumb consumers, see for instance Gali et al. (2007).

[6] Yet, if potentially tight and burdensome regulations keep migrants from finding employment or being hired this process could be jeopardised. Accordingly, some policy makers have argued that refugees should be excluded from the binding minimum wage in order to encourage their employment highlighting the policy relevance of this chapter.

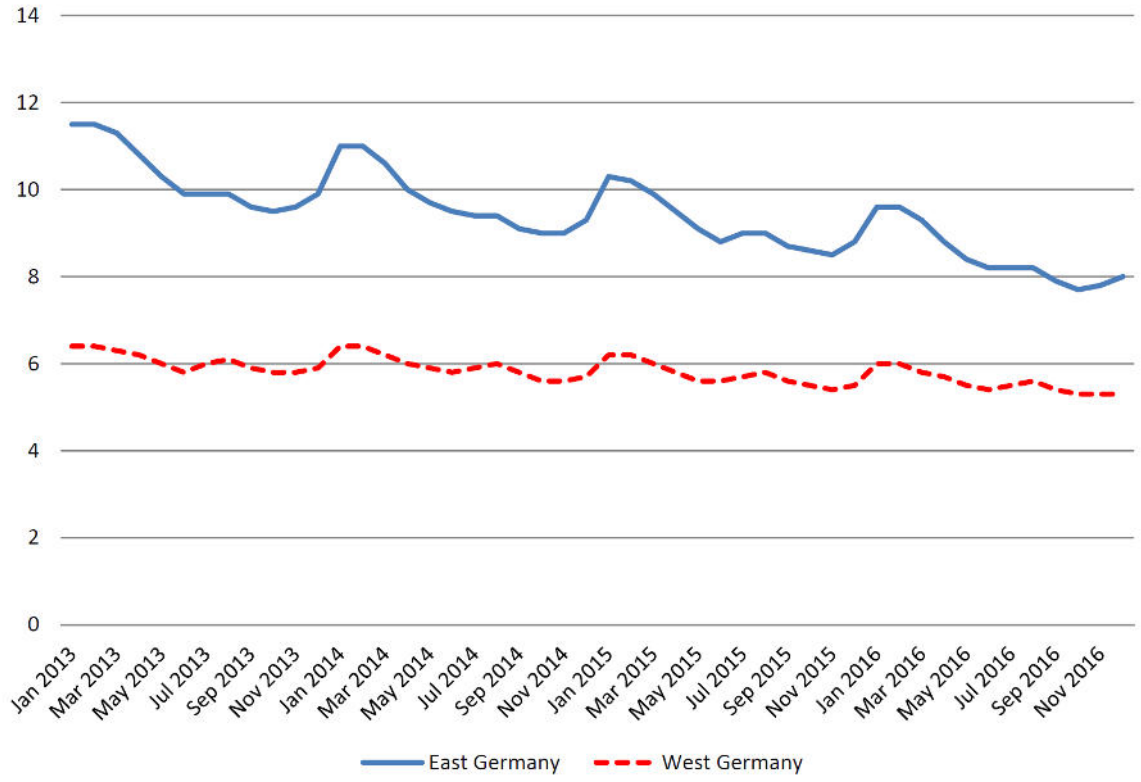
[7] For example Iran, one major source country of refugees, has a higher education rate similar to Germany of 13.1% while its neighbour country Afghanistan has a literacy rate of only 58%. More details are provided in the UNESCO Educational Data Centre available at http://data.uis.unesco.org/.

4.2 Minimum Wage in Germany

After a long debate among policy makers and academics in Germany, a binding minimum wage of 8.50 EUR was introduced by the Grand-Coalition on 1st of January 2015. Building on standard economic theory, some German economists predicted ex ante strong negative effects of up to 800.000 job losses especially in the low skilled sector[8]. In response to such adverse scenarios a comparably moderate minimum wage was designed with some exemptions and tools to keep the adjustment flexible[9]. For example, workers under 18, trainees and interns, or long-term unemployed are exempted from the minimum wage. Also, following the traditional collective bargaining procedure in Germany, some sectors such as the construction or cleaning sector have higher sector-specific minimum wages often regionally differentiated between East and West Germany. Similar to the model in the UK, a minimum wage commission has been implemented to decide about possible adjustments of the minimum wage in the future.

In order to fully judge the long-term effects of the minimum wage introduction on employment, one ideally needs a longer time series observing the participation rate for several years on a disaggregated sectoral level. Nonetheless, some preliminary conclusions have already been made by for example Amlinger et al. (2016). According to the German Federal Statistical Office it is estimated that about 10.7%

Figure 4.1: Monthly Unemployment Rate in Germany



Source: German Federal Statistical Office

[8]See for instance Arni et al. (2014) predicting 570.000 job losses, Peters (2015) forecasting 800.000 job losses over the mid-term, or Henzel, Engelhardt, et al. (2014) arguing that 56.000 to 470.000 full time and up to 306.000 part time jobs could be destroyed.

[9]For comparison, the minimum wage in 2016 was in France at 9.67 EUR, at 9.36 EUR in the Netherlands, and at 9.15 EUR in Ireland

of the German work force are paid the minimum wage[10], with small and medium enterprises being the predominant companies affected especially those located in East Germany. Moreover, the minimum wage affects the service sector stronger than the producing sector. Therefore, it seems surprising at first glance that e.g. the hotel and restaurant industry *increased* their workforce by 6.6% after the introduction. However, the reduction in so-called minor employment contracts by -4.0% suggests that the majority of these positions have been transformed to part-time jobs. But also on a more aggregate level, the evidence from monthly unemployment numbers in Germany illustrated in Figure 4.1 suggests no strong contraction in employment. Instead, there is a clear downward trend in unemployment numbers following the structural reforms in the early 2000s and the positive German GDP growth in 2014 and 2015.

However, drawing any conclusion about the effect from the minimum wage from simple correlations could be potentially misleading as employment numbers are driven by many other factors as well. In other words, employment numbers could increase despite the minimum wage resulting from an expansionary business cycle.

4.3 Literature Review

There exists a very large and continuously growing literature on the minimum wage. Despite this enormous body of literature, the impacts of the minimum wage on the economy are far from being genuinely well understood with many authors finding conflicting results. In fact, most academics and practitioners would agree that a very high minimum wage leads to adverse effects on the labour market whereas a minimum wage on a very low level is usually found to have no implications. Thus, the dispute rather concerns the question what can be regarded as "too high" or "too low".

From a theoretical point of view, a moderate minimum wage can be welfare increasing if we assume that labour markets are not neoclassical but are characterised by a monopsonistic labour market. In a monopsonistic market there is just one buyer but many sellers, which is the analogous notion to a monopoly market with just one supplier but many consumers. Due to the market power of this one buyer in such a market, the buyer is able to set prices similar as a monopolist does in a one seller market. However, one should not take notion of "monopsony" in the labour market literately. Monopsony should not be interpreted in the sense of just one employer, but rather in the sense that the supply of labour to an individual firm is less than infinitely elastic and firms face an upward sloping labour demand curve.[11].

Therefore, the common feature of all monopsony or monopsonistic competition models is that labour supply is not perfectly elastic to the firm as in the neoclassical case but to some degree upward-sloping instead. However, the reasons for this might differ. There are various sources for monopsony power proposed in the literature. First, monopsony power could result from various non-wage preferences of workers about employers, such as general working atmosphere, career opportunities, or distance to work leading to additional disutility for workers when commuting. These non-wage characteristics might lower workers' incentives to change jobs across different regions. Second, a firm could be a single large employer in a certain area, such as a large coal company in a rural area, providing the firm with some discretion

[10] See German Federal Statistical Office.
[11] See Manning (2003), ch. 1 for a discussion.

in its wage setting. Third, a somewhat more general argument of monopsony power accounts for any information or switching costs, be it pecuniary or non-pecuniary, resulting from a job change or the search for a new job[12]. In this respect, it has become popular to implicitly model monopsony in the market via search-and-matching costs, see for example Robin (2011)[13], Charpe and Kühn (2012)[14], Flinn (2006)[15], and Moser and Stähler (2009)[16]. However, note that some important distinctions exist. First of all, monopsony models assume that employers set wages whereas search-and-matching models often have some kind of wage bargaining between workers and firms. Second, while in many traditional matching models the wage bargaining process starts *after* the match, monopsony models have an ex ante wage posting.

In essence, search-and-matching models examine how matches between firms and workers are established and dissolved providing a theoretical framework to understand the effect of policy changes on these matches. A crucial part is the modelling of time varying outside options of firms and workers since separation is intended to occur endogenously. Roughly speaking, two broad approaches have emerged in the literature: the job ladder model[17] and the match quality model[18]. In the former, workers search both on and off the job. Hence, in the case of a better offer from another firm the worker is less likely to remain in his current job. On the contrary, in the match quality type of models the quality of a match is uncertain when the match is made. As more information about the quality of the match becomes available over time to both workers and the firm, each of them decides whether to remain or to separate and search for a better match. Regarding an increase of the minimum wage, ladder models suggest a reduction in job resignations since workers are less likely to find better paying jobs. In contrast, match quality models predict that more matches become unprofitable ex post for the firm, potentially increasing lay-offs. However, note that the benefits from the outside option have also increased suggesting an ambiguous effect of a higher minimum wage.

On the other hand, one should also note some of the empirical and theoretical problems associated to the theory of monopsony. For instance, a market with just one firm (or a few firms) hiring workers is per se not more realistic than the assumptions in the neoclassical labour market. Typically, low skilled labour markets are characterised by similar employers in close proximity to each other and a rather high worker turnover, suggesting a labour market of oligopsony[19] or of monopsonistic competition. Put differently, if other firms are present in the market competing for employees the reservation wage of workers is higher and, effectively, could be driven up to the competitive wage. Search-and-matching models such as Burdett and Mortensen (1998) offer an endogenous turnover while still allowing for the possibility of exploitation.

[12] An example for such switching costs are the so called non-compete clauses in the high-tech sector where highly skilled workers have to pay fines for changing to a firm's competitor.

[13] Proposing a dynamic search-and-matching model with cross sectional wage dispersion and heterogeneous abilities of workers. Robin (2011) generates endogenous job destruction and wage inequality across sectors.

[14] In a DSGE model proposed by Charpe and Kühn (2012) lower bargaining power of rule-of-thumb households is introduced via combining a search-and-matching model with Nash bargaining over income distribution. Downward wage rigidities such as a minimum wage are found to have stabilising effects on output and employment.

[15] In a continuous time model of search-and-matching with Nash bargaining, Flinn (2006) finds ambiguous effects of a minimum wage increase on unemployment with potential welfare improvements. In his model the bargaining parameter is most crucial in determining welfare implications of changes in the minimum wage.

[16] Moser and Stähler (2009) present a two sector search model with heterogeneous productivity levels. In their set up, a minimum wage leads to negative spill over effects from the unproductive sector to the productive. However, total welfare effects are ambiguous.

[17] Also referred to as on-the-job search models. See for instance Burdett and Mortensen (1998).

[18] As in Pissarides (2000).

[19] Similar to an oligopol firms could collude in order to keep wages low.

Ultimately, the question of market and bargain power in the labour market is an empirical one. In fact, in reality the elasticity of labour supply, one popular measure of market power in the empirical literature, may vary a lot across sectors, regions, skill levels, or preferences of employees. One obvious case of monopsony in reality is outlined in Naidu et al. (2014) examining the migrant labour market in the United Arab Emirates where under UAE's visa policy migrant workers were legally prohibited to change their employer. Such procedures are illegal in many other countries where estimated elasticities are higher but still far from infinity. For example, estimating labour supply elasticities for the grocery retail industry in the US Ransom and Oaxaca (2010) report elasticities raging between 1.4 to 3.0 with strong differences between men and women. In addition, Ransom and Sims (2010) find an elasticity of 3.7 for US school teachers, while Staiger et al. (2010) estimate a short run elasticity of only 0.1 in the nursing labour market with a natural experiment. In the case of Germany, Hirsch, Schank, et al. (2010) estimate the labour elasticity for the entire labour market. Using linked employer-employee data their paper estimates similarly small labour supply elasticities between 1.9 and 3.7. More recently, Bachmann and Frings (2017) provide estimates for the wage elasticities of various typical low skilled sectors. The authors find evidence that the retailing, hotel, and restaurant industry fit the description of a monopsonistic labour market whereas this is not the case for agriculture, mining, and public or private services. Moreover, evidence found by Hirsch and Jahn (2015) suggests that with a labour elasticity of only 1.64 - 2.6 migrants in Germany are in particular subject to uneven bargaining power. As migrants face a greater amount of information asymmetry and less collective bargaining power it is not surprising to find stronger monopsony in their case.

Moreover, empirical studies regarding the effects of a minimum wage are again often ambiguous. In a highly cited paper, Card and Krueger (1994) find no evidence that an increase in the minimum wage lowered employment. The authors use a diff-in-diff estimator to examine the impact of an increase in the minimum wage on employment in the fast-food industry in New Jersey and eastern Pennsylvania before and after an increase of the minimum wage. In contrast, more recently Clemens and Wither (2014) estimate a reduction in the national employment-to-population ratio by 0.7% due to the average minimum wage in the US being increased by 30% over the late 2000s. Other recent empirical papers examining the minimum wage for the US are for instance Dube et al. (2010); Dube et al. (2016); Neumark, Salas, et al. (2014); Neumark and Wascher (1992) which find both negative and non-negative effects. To summarise, these studies show the inconclusiveness of the empirical literature on the effects of the minimum wage. One explanation for these ambiguous empirical findings might be the level of aggregation or the structural variation both across regions and sectors, highlighting the importance to distinguish between subgroups of low-wage workers. In this respect, Giuliano (2013) compares the effects between overall employment for adult and teenage workers and finds an increase of teenage workers' labour supply in response to a rise of minimum wages, whereas adults showed a negative but insignificant response. In the case of Germany, Bachmann and Frings (2017) and Amlinger et al. (2016) provide some first insights about the response of the German labour market to the newly introduced minimum wage also on a disaggregate level.

Most existing studies on monopsony models are either static, partial equilibrium models, or both[20]. The traditional static literature on monopsony models with a minimum wage has largely been developed

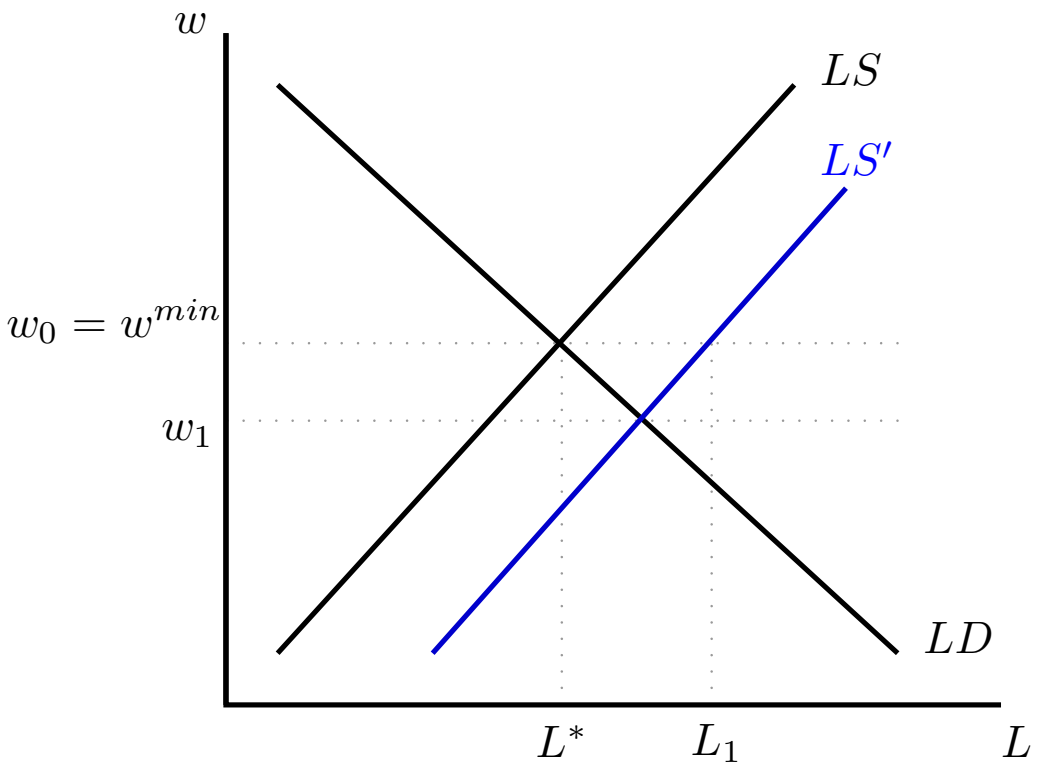
[20]For a literature overview see Ashenfelter et al. (2010).

by the work of Bhaskar and To (1999) whereas the work of Manning (2003); Manning (2006) and Boal and Ransom (1997) have provided dynamic versions of these partial equilibrium models. Our work is conceptually most closely related to Strobl and Walsh (2014) who examine the impact of a migration inflow in a static monopsony model with a minimum wage and methodologically to Heberer (2010) and Porter, Nathan and Vitek (2008) who proposes a DSGE model with a competitive labour market and a minimum wage. However, in contrast to Strobl and Walsh (2014) we use a dynamic general equilibrium model allowing for changes in agents' behaviour over time. Also, in contrast to Heberer (2010) proposing a very parsimonious model and in contrast to Porter, Nathan and Vitek (2008) focusing on the effects of minimum wage indexations and adjustment schemes, our three type labour model, first, compares the effects of a minimum wage between a competitive and monopsony model and, second, allows for the minimum wage to be only occasionally binding.

4.4 Static World

According to the standard textbook version of a neoclassical labour market a minimum wage leads to welfare losses unless the minimum wage is equal or below the competitive wage rate, which would render it redundant. This standard finding is illustrated in Figure 4.2. Suppose the government introduces a binding minimum wage and sets the exogenously defined minimum wage w^{min} equal to the competitive wage rate w_0, where the labour supply curve LS and the labour demand curve LD intersect leading to zero effects of the minimum wage initially. Next, consider the case of a shift in the labour supply curve due to an exogenous increase in the labour force, for example due to a large increase in migrants. Now,

Figure 4.2: Static Neoclassical Labour Market with a Minimum Wage



for a given wage rate households offer more labour shifting the labour supply curve rightwards to $LS^{'}$ with the new competitive wage w_1 being below the minimum wage w^{min}. Due to the binding minimum wage at w^{min} employers continue to hire L^* units of labour despite workers offering L^1 units of labour leaving the bulk of new workers unemployed.

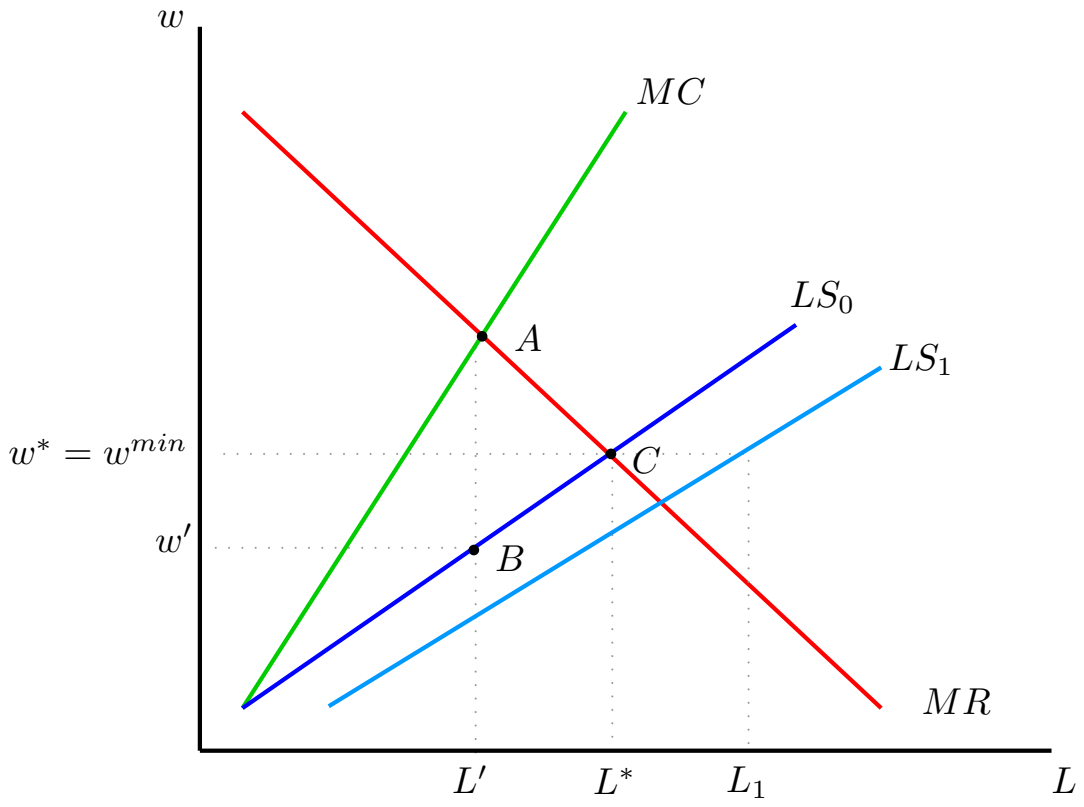
Consequently, the textbook version of the labour market predicts negative effects and an increase in unemployment among migrants and potentially also among domestic workers. Since it is likely that the vast majority of refugees enter into the low skilled sector, at least in the short run, the natural policy recommendation of this analysis would be to abolish the minimum wage or at least significantly reduce it for refugees in order to promote their integration into the labour market.

Despite being heavily criticised for unrealistic and overly simplistic assumptions, the neoclassical labour market is still frequently used in modern economics both in static and dynamic general equilibrium models. One particular crucial assumption concerns the market power of employers and its implication for policy recommendations about the minimum wage. Many have argued that especially in the low skilled sector firms often do possess a large degree of bargaining power since the market consists of a large number of unskilled workers whereas the number of companies is small. In order to incorporate this idea, the monopsonistic labour market assumes that there exists only one large firm demanding labour which, thus, has a large degree of market power facing many small workers competing among each other for employment.

Figure 4.3 shows the basic features of the monopsonistic labour market and its implication for the minimum wage. Suppose a market situation where just one employer demands labour offering the same wage rate to all workers prior to the introduction of the minimum wage. In contrast to the neoclassical model where labour supply is exogenous to the firm, a single employer now faces an upward sloping labour supply curve denoted by LS_0. Put differently, in the neoclassical model firms are price takers, i.e. for a single firm the labour supply curve is perfectly elastic, whereas from the perspective of a monopsonist wages are not exogenously given by the market but, instead, the wage is an increasing function of employment. In this case, the marginal cost function of the firm becomes $\text{MC} = w + \frac{\partial w}{\partial L} \cdot L$, where $\frac{\partial w}{\partial L}$ equals the slope of the labour supply curve. As long as the slope is positive the firm faces an upward sloping labour supply curve, whereas if $\frac{\partial w}{\partial L} = 0$ firms can demand any labour input for a given wage rate as in the neoclassical case. Under profit maximisation, the highest profits are reached if the marginal costs MC equal marginal revenues MR which is at point A. In the absence of a minimum wage, the firm offers the wage rate $w^{'}$ to workers leading to a labour supply of $L^{'}$ units of labour as in point B, which is the monopsony equilibrium. First of all, note that the equilibrium is supply side constrained as the firm would in principle employ a larger number of workers since the marginal revenue is higher. Second, the economic surplus is redistributed from the workers to the firm which is characterised by a welfare loss due to low employment levels given by the dead-weight loss from the triangle between the points $A - B - C$. In contrast, perfect competition would force the firm to offer higher wages as all workers would otherwise prefer to work for the competitor, thus, expanding their labour supply.

Again suppose that the government introduces a binding minimum wage forcing the firm to pay w^{min} to all workers which is set equal to the point where the labour supply curve intersects with the marginal revenue curve at w^*. As a result, employment is increased from $L^{'}$ to L^* as workers receive higher wages

Figure 4.3: Static Monopsonistic Labour Market with a Minimum Wage



encouraging them to increase their labour supply. Note that the firm pays the same wage rate to all workers. Thus, increasing the wage to w^{min} increases the wage for all workers leading to new total cost for the firm of $w^{min} \cdot L^*$ which reduces the firm's profits. Yet, an even higher minimum wage above w^* would not lead to more labour recruitment since then the total labour cost would be above the marginal revenue. Following this policy change, the dead-weight loss has been removed and rents are redistributed from the firm to the workers.

Still, if the economy is hit by large migration shock, shifting the labour supply curve rightwards to LS_1, workers now offer more labour for the same wage rate leading to a similar conclusion as in the neoclassical scenario. Workers would now offer L_1 units of labour supply while the firm only demands L^* units resulting in potential unemployment among workers. Note, however, that this is only the case if minimum wage is set equal to the intersection of marginal revenue and labour supply. If the minimum wage rate is below this point, i.e. $w^* > w^{min} > w^{'}$, employment can actually increase from the labour supply chock. In other words, the height of the minimum wage relative to the unobserved market wage rate and firm structure is most crucial to predict employment outcome.

In a nutshell, a moderate minimum wage in a monopsony labour market can increase welfare but market forces are not suspended. A shift in the labour supply curve, for instance due to a migration inflow, leads to a lower market wage rate which might be below the minimum wage depending on the relative strength of the shock. In this case, the same critique as in the neoclassical labour market applies calling for a lower minimum wage. But as this wage rate is unobserved in practice it remains unclear if this is actually the case leaving the effects ambiguous ex ante.

4.5 The Model

There is a continuum of infinitely lived private households of unit mass together with a continuum of firms producing differentiated intermediate goods. Also, the model contains a central bank which is in charge of monetary policy and a simple government with a closed budget. A fixed fraction λ of households, which are *rule-of-thumb* or *non-Ricardian* consumers, is of type U and supplies unskilled labour. On the labour market these household find either a perfectly competitive neoclassical labour market or are subject to monopsony firms. An additional fixed fraction κ of households of type M supplies medium skilled labour, while the remaining part $1-\lambda-\kappa$ is of type S and offers skilled labour. Skilled and medium skilled households are *optimising* or *Ricardian* and can trade securities on the financial markets to smooth their consumption. Additionally, it is assumed that there is just one sector in this closed economy model. When referring to all three types of households the subscript $\ell \in U, M, S$ is used.

4.5.1 Households

Motivated by the work of Gali et al. (2007) and the empirical findings of Campbell and Mankiw (1989), we model a fraction λ of the total households as rule-of-thumb consumers. This type of unskilled household can only consume their wage income and have no access to capital or financial markets. In other words, these consumers behave in a "hand to mouth" fashion, fully consuming their contemporaneous income in every period. This implies that these types of households are either unable or unwilling to smooth their consumption path over time when facing fluctuations in labour income. While we in principle do not take a stand about the source of this behaviour, possible explanations could be a combination of lack of access to financial markets, myopia, or potentially as in the case of migrants cultural, language, or institutional barriers. As the consumption level of these households is given by the budget constraint and not by intertemporal optimising behaviour they are sometimes also labelled as "non-Ricardian" households.

The remaining fraction of κ and $(1-\lambda-\kappa)$, i.e. medium and skilled households, do not show such behaviour. In contrast, they behave like standard optimising or Ricardian households and can trade a set of contingent securities to smooth their consumption when facing income fluctuations.

Optimising Skilled and Medium Skilled Households

To decrease computational burden, both types of medium and skilled households faces a standard and symmetric optimisation problem. Also, to save notation we merely discuss the case of skilled households. While the optimisation problem is the same for both of these types of households, their parametrisation differs slightly (see discussion below in Section 4.6). Both types of households maximise lifetime utility according to[21]

$$E_t \sum_{s=0}^{\infty} \beta^s \exp(e_{u,t+s}) \left(\frac{C_{S,j,t+s}^{1-\sigma}}{1-\sigma} - \exp(e_{S,t+s}) \frac{N_{S,j,t+s}^{1+\varphi}}{1+\varphi} \right), \tag{4.2}$$

[21] Note that the period utility function for unskilled households is in similar form of

$$U(C,N) = \exp(e_{u,}) \left(\frac{C_{U,j}^{1-\sigma}}{1-\sigma} - \exp(e_U) \frac{N_{U,j}^{1+\varphi}}{1+\varphi} \right). \tag{4.1}$$

where $j \in [0,1]$ is the household's index and $C_{\ell,j}$ and $N_{\ell,j}$ denote individual consumption and labour supply in working hours, respectively. β is the standard discount factor which is the same for medium and skilled households. With respect to consumption, $\sigma > 0$ determines the elasticity of intertemporal substitution. In the case of labour supply, φ denotes the inverse of the Frisch elasticity of labour supply η. Following a standard AR(1) process, $e_{\ell,t}$ and $e_{u,t}$ denote a household specific labour supply and a general preference shock, respectively. The maximisation problem is subject to a flow budget constraint stating that the sum of real expenditure on consumption and investment should be equal to the real income stream

$$b_{S,j,t} + C_{S,j,t} = w_{S,j,t} N_{S,j,t} + \frac{i_{t-1} b_{S,j,t-1} C^{\delta}_{S,t}}{\Pi_t} + \Gamma_{S,j,t} - T_{S,j,t} + \Upsilon_{\ell,j,t}, \tag{4.3}$$

where S and M types of household may invests in real risk free bonds to smooth their consumption $b_{S,j,t} = B_{S,j,t}/P_t$[22]. Households pay aggregate adjustment costs of $C^{\delta}_{S,t}$ when changing the level of bond holdings. The corresponding risk free interest rates is i_t. The skill specific real wage is denoted by $w_{\ell,j,t} = W_{\ell,j,t}/P_t$ and in the case of skilled and medium skilled households is set by household j. Therefore, we assume that medium and skilled households are able to set a mark-up over their wages. In addition, $\Gamma_{S,j,t}$ stands for dividends which S and M types of households receive from their ownership of firms. Finally, $T_{S,j,t}$ denotes tax payments P_t denotes the nominal consumer price level to be defined below.

As Section 4.5.3 outlines in more details, while households may differ in their actual wage income the presence of transfer payments $\Upsilon_{\ell,j,t}$, however, ensures that for any given price vector in the economy, each type of households are identical with regard to their consumption and investment plans. Accordingly, we can drop the household index and resort to the representative agent assumption within each of the labour types.

The first order conditions (FOC) to this problem are as follows

$$\frac{\partial \mathcal{L}}{\partial C_{S,t}} : \mu_{S,t} = \exp(e_{u,t}) C^{-\sigma}_{S,t}, \tag{4.4}$$

$$\frac{\partial \mathcal{L}}{\partial N_{S,t}} : N_{S,t} = \left(\frac{\mu_{S,t} w_{S,t}}{\exp(e_{u,t}) \exp(e_{S,t})} \right)^{\frac{1}{\varphi}}, \tag{4.5}$$

$$\frac{\partial \mathcal{L}}{\partial b_{S,j,t}} : \mu_{S,t} = \beta E_t \mu_{S,t+1} \frac{i_t C^{\delta}_{S,t}}{\Pi_{t+1}}, \tag{4.6}$$

where $\mu_{S,t}$ denotes the Lagrangian multiplier for the budget constraint of a household with a skill level S. Equation (4.5) yields the aggregate labour supply function for medium and skilled types, which can be restated as the marginal rate of substitution between consumption and working hours supplied by each type of household. This gives

$$mrs_{S,t} = \exp(e_{S,t}) \exp(e_{u,t}) \frac{N^{\varphi}_{S,t}}{\mu_{S,t}}. \tag{4.7}$$

[22] Accordingly, nominal risk free bonds are only traded among skilled and medium skilled households and are thus in zero net supply.

Rule-of-Thumb Consumers

As already described, we assume that only skilled and medium skilled households have access to capital markets while, in contrast, the representative unskilled worker does neither have access to capital markets nor does she have firm ownership. Thus, she can only consume her current income in each period and her consumption level is given by their budget constraint which reads as

$$C_{U,t} = w_{U,t} N_{U,t}. \tag{4.8}$$

For analytical convenience, as in Charpe and Kühn (2012) we assume that unskilled households do not pay any taxes.

As is standard in the literature, the labour supply of unskilled households in a competitive labour market must satisfy

$$w_{U,t} = \exp(e_{U,t}) N_{U,t}^{\varphi} C_{U,t}^{\sigma}. \tag{4.9}$$

This implies that unskilled households do not possess any market power on the labour market. In contrast, we also allow for monopsony power of firms with respect to unskilled labour input as discussed in the next section.

4.5.2 Firms

To focus on the labour market, we assume that firms only use labour and technology as input factors. More precisely, each firm i faces a standard production function using the three different types of labour as the main input factor. In particular, we have

$$Y_{i,t} = e^{A_t} \left[\lambda^{\frac{1}{\zeta}} \left(e^{A_{U,t}} N_{U,i,t}\right)^{\frac{\zeta-1}{\zeta}} + \kappa^{\frac{1}{\zeta}} \left(e^{A_{M,t}} N_{M,i,t}\right)^{\frac{\zeta-1}{\zeta}} + (1-\lambda-\kappa)^{\frac{1}{\zeta}} \left(e^{A_{S,t}} N_{S,i,t}\right)^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}}, \tag{4.10}$$

where $Y_{i,t}$ is firm's i production level at time t. e^{A_t} and $e^{A_{\ell,t}}$ represent the general and labour type specific technological levels, respectively, which evolve according to an AR(1) process with a stochastic component. The labour input from each household type is denoted by $N_{\ell,i,t}$ with ζ as the elasticity of substitution for different labour inputs.

In order to maximise profits, firms solve the following problem. Note also as discussed above, we assume that in equilibrium the minimum wage is not binding, i.e. the competitive wage is above the minimum wage.

$$\begin{aligned} \mathcal{L} = {} & P_{i,t} Y_{i,t} - \left(w_{S,t} N_{S,i,t} + w_{M,t} N_{M,i,t} + w_{U,t} N_{U,i,t}\right) \\ & + mc_{i,t} \left(Y_{i,t}(\cdot) - Y_{i,t}\right) + D_{i,t} \left(Y_{i,t} - \left(\frac{P_{i,t}}{P_t}\right)^{-\epsilon} Y_t \right), \end{aligned} \tag{4.11}$$

where $mc_{i,t}$ and $D_{i,t}$, are Lagrangian multipliers for the production and demand functions, respectively. Given the standard interpretation of these multipliers, $mc_{i,t}$ is equivalent to real marginal costs. Taking

the FOCs for price setting and production yields

$$\frac{\partial \mathcal{L}}{\partial P_{i,t}} : Y_{i,t} = D_{i,t}\epsilon \left(\frac{P_{i,t}}{P_t}\right)^{-\epsilon-1} \frac{1}{P_t} Y_t, \tag{4.12}$$

$$\frac{\partial \mathcal{L}}{\partial Y_{i,t}} : P_{i,t} - mc_{i,t} = D_{i,t}. \tag{4.13}$$

Rearranging (4.12) to $D_{i,t}$ and setting this equal with (4.13) yields the well-known expression for price setting

$$P_{i,t} = \frac{\epsilon}{\epsilon - 1} mc_{i,t}. \tag{4.14}$$

Labour Demand in the Neoclassical World

Assuming that firms do not have market power in the labour market yields the standard neoclassical case where firms' labour demand simply equals the marginal product of labour. In this standard case, the first order condition of skilled labour demand can be stated as

$$\frac{\partial \mathcal{L}}{\partial N_{S,i,t}} : w_{S,t} = mc_{i,t}(1-\lambda-\kappa)^{\frac{1}{\zeta}} (e^{A_t} e^{A_{S,t}})^{\frac{\zeta-1}{\zeta}} \left(\frac{Y_{i,t}}{N_{S,i,t}}\right)^{\frac{1}{\zeta}}. \tag{4.15}$$

Note that the neoclassical case is analogous for medium and unskilled labour demand, the only difference being the weighting parameter of λ or κ rather than $(1-\lambda-\kappa)$. As labour supply is infinitely elastic in the neoclassical world and firms are able to recruit at the market wage rate as much labour input as they wish to, and the wage equals the marginal product of labour.

Furthermore, the market clearing condition on the labour market requires that the sum of all labour supply functions from each type of household is equal to the aggregate labour demand $N_{\ell,t}$ defined as

$$N_{\ell,t} = \int_0^1 N_{\ell,t}(i) di. \tag{4.16}$$

Unskilled Labour Demand under Monopsony

After the neoclassical benchmark case, we introduce monopsony where firms are assumed to have market power but unskilled workers do not. In the case of unskilled households of type U the wages are determined as follows. Building on Manning (2003), monopsony is implemented in the most simple form, namely by a less then infinitely elastic labour supply curve.

Since a monopsonist is the only buyer of unskilled labour in a certain market, she is aware of the entire unskilled labour supply curve when making her optimal decisions. In such a world where a firm is a monopsonist, the more people it hires the higher the wage and the total labour costs. For simplicity, we assume a non-discriminating policy of the monopsonist which implies that hiring one additional worker means the firm has to pay all workers employed higher wages. Also note that in the case of monopsony, a firm i is the only demander of unskilled labour input. This could for instance be the case, if each firm i faces a regionally separated unskilled labour market while medium or skilled workers could migrate between different regions and could work for different firms i. Thus, the i sub-index for unskilled labour

demand can be dropped and the profit maximisation function can be restated as

$$\begin{aligned}\mathcal{L} &= P_{i,t}Y_{i,t} - (w_{S,t}N_{S,i,t} + w_{M,t}N_{M,i,t} + w_{U,t}N_{U,t}) \\ &+ mc_{i,t}\left(Y_{i,t}(\cdot) - Y_{i,t}\right) + D_{i,t}\left(Y_{i,t} - \left(\frac{P_{i,t}}{P_t}\right)^{-\epsilon} Y_t\right) + L_{i,t}\left[N_{U,t} - \left(\frac{w_{U,t}}{\exp(e_{U,t})C_{U,t}^{\sigma}}\right)^{\frac{1}{\varphi}}\right],\end{aligned} \tag{4.17}$$

where $L_{i,t}$ denotes the Lagrangian unskilled labour supply constraint for each firm i. This is motivated by the simple finding from the static monopsony case where the market outcome is also supply side constrained. Note that the monopsony and competitive market outcome are equal if the individual firm has zero monopsony power, i.e. the firm faces no additional unskilled labour supply constraint and $L_{i,t} = 0$.

Taking the FOC with respect to unskilled labour and unskilled wage in an equilibrium situation of monopsony (i.e. no binding minimum wage) yields

$$\frac{\partial \mathcal{L}}{\partial N_{U,t}} : \; w_{U,t} = mc_{i,t}\lambda^{\frac{1}{\zeta}}\left(e^{A_t}e^{A_{S,t}}\right)^{\frac{\zeta-1}{\zeta}}\left(\frac{Y_{i,t}}{N_{U,t}}\right)^{\frac{1}{\zeta}} + L_{i_t}. \tag{4.18}$$

Next, the FOC for unskilled wage is given by

$$\frac{\partial \mathcal{L}}{\partial w_{U,t}} : \; L_{i,t} = -\varphi w_{U,t}. \tag{4.19}$$

Inserting (4.19) back into (4.18) and rearranging for $w_{U,t}$ yields the final expression

$$w_{U,t} = \frac{mc_{i,t}\lambda^{\frac{1}{\zeta}}\left(e^{A_t}e^{A_{S,t}}\right)^{\frac{\zeta-1}{\zeta}}\left(\frac{Y_{i,t}}{N_{U,t}}\right)^{\frac{1}{\zeta}}}{(1+\varphi)}. \tag{4.20}$$

Hence, in the case of monopsony the firm offers a lower wage rate to the unskilled workers relative to the neoclassical case. In fact, the wage is reduced by a factor of $(1+\varphi)$ and this gap between the wage and the competitive wage is sometimes referred to as the rate of exploitation. Recall that $\varphi = \frac{1}{\eta}$ denotes the inverse of the Frisch labour elasticity η. Hence, as η approaches infinity we are back in the neoclassical world with a flat unskilled labour supply curve for each firm i. In contrast, for any smaller degree of labour elasticity we face a positive sloped labour supply curve, i.e. an increase in the market power of firms leading to a reduction in unskilled wages in steady state. Note that the same result can be obtained if $N_{U,t}$ in the optimisation problem is replaced with the labour supply curve and letting the firm choose the optimal $w_{U,t}$.

However, while this result seems appealing at first glance as it is very much in line with the basic prediction of the static monopsony model, note that Equation (4.20) is multiplicative. In fact, when taking the first-order Taylor approximation around the steady state, the factor $(1+\varphi)$ cancels out and the dynamics of the model are the same in both worlds.

4.5.3 Wage Setting

There are three different wage setting regimes with respect to the type of labour ℓ. Whereas labour types M and S are assumed to have some market power in their wage setting, unskilled households

face either a perfectly competitive or monopsonistic labour market as outlined above. Furthermore, the unskilled labour market is subject to an occasionally binding minimum wage.

To be more precise, medium skilled as well as skilled households are assumed to enjoy some degree of market power and set their nominal wage as a mark-up over the marginal rate of substitution between consumption and leisure. Furthermore, due to the assumption of a Calvo-type staggered wage setting, both types of households are heterogeneous regarding their individual nominal wages and thus, with respect to their labour supply within each type. The wage setting for skilled and medium skilled is in essence identical. Both are able to set a mark-up the only difference being that the medium skilled mark-up is lower. Once more, to save notation we only discuss the skilled case here, i.e. the medium skilled case works analogously. The aggregate nominal wage index for households of type S can be written as

$$\begin{aligned} W_{S,t} &= \left(\int_0^1 W_{S,j,t}^{1-\epsilon_S} dj \right)^{\frac{1}{1-\epsilon_S}} \\ &= \left[(1-\theta_{w,S}) \widetilde{W}_{S,t}^{1-\epsilon_S} + \theta_{w,S} (W_{S,t-1} \Pi_{t-1}^{\omega_S})^{1-\epsilon_S} \right]^{\frac{1}{1-\epsilon_S}}, \end{aligned} \tag{4.21}$$

where ϵ_S denotes the elasticity of substitution between different types of skilled labour, $\theta_{w,S}$ is the Calvo parameter, and ω_S denotes the degree of indexation to past inflation in case a skilled household is not able to adjust its nominal wage in a particular quarter.

Each skilled household faces the following labour demand function

$$N_{S,j,t} = \left(\frac{W_{S,j,t}}{W_{S,t}} \right)^{-\epsilon_S} N_{S,t}. \tag{4.22}$$

Assuming symmetry across households of type S, we can neglect the household specific index j. The nominal wage in period $t+k$ which was last adjusted in period t is given by

$$W_{S,t,t+k} = \widetilde{W}_{S,t} \prod_{i=0}^{k-1} \Pi_{t+i}^{\omega_S}, \tag{4.23}$$

where $\widetilde{W}_{S,t}$ is the nominal wage for skilled labour set in period t. Accordingly, a skilled household who has last adjusted her nominal wage in period t faces the following labour demand in period $t+k$

$$N_{S,t,t+k} = \left(\frac{W_{S,t,t+k}}{W_{S,t}} \right)^{-\epsilon_S} N_{S,t+k}. \tag{4.24}$$

Therefore, the typical household S solves

$$E_t \sum_{k=0}^{\infty} (\beta \theta_{w,S})^k \left[\exp(e_{u,t+k}) \left(\frac{C_{S,j,t+k}^{1-\sigma}}{1-\sigma} - \exp(e_{S,t+k}) \frac{N_{S,j,t+k}^{1+\varphi}}{1+\varphi} \right) \right], \tag{4.25}$$

subject to the budget constraint of household S (4.3) and the labour demand function (4.24).

The FOC with respect to the adjusted nominal wage, $\widetilde{W}_{S,t}$, can be written as

$$E_t \sum_{k=0}^{\infty} (\beta \theta_{w,S})^k N_{S,t,t+k} U_{C_{S,t+k}} \left(\frac{\widetilde{W}_{S,t} \prod_{i=0}^{k-1} \Pi_{t+i}^{\omega_S}}{P_{t+k}} - \frac{\epsilon_S}{\epsilon_S - 1} mrs_{S,t,t+k} \right) = 0, \tag{4.26}$$

where $mrs_{S,t,t+k} = -(U_{N_{S,t,t+k}}/U_{C_{S,t,t+k}})$ and assuming that $U_{C_{S,t,t+k}} = U_{C_{S,t+k}}$.

It can be shown that this expression for wage setting can be restated as

$$(1+\beta)\widehat{w}_{S,t} = \beta\widehat{w}_{S,t+1} + \widehat{w}_{S,t-1} + \beta\widehat{\Pi}_{t+1} - (1+\beta\omega_S)\widehat{\Pi}_t + \omega_S\widehat{\Pi}_{t-1} + \\ + \frac{(1-\beta\theta_{w,S})(1-\theta_{w,S})}{\theta_{w,S}(1+\epsilon_S\varphi)}\left(\widehat{mrs}_{S,t} - \widehat{w}_{S,t}\right). \tag{4.27}$$

For a more detailed derivation please see Section C.2 in the Appendix.

In contrast to skilled and medium skilled households, unskilled households do not have such wage setting power and are not able to add a mark-up. In a competitive market their wage is equal to the marginal rate of substitution between consumption and leisure. However, to mitigate social imbalances the government introduces a minimum wage $\underline{w}$ being equally paid to unskilled households if the market wage rate falls under the exogenously defined threshold. Put differently, we think of the minimum wage as a downward rigidity working effectively as an occasionally binding constraint with the steady state market rate being above minimum wage level[23]. Accordingly, we set up our model such that the minimum wage can only become binding in the market for unskilled labour if the market wage falls below the minimum wage. In particular, we assume that the government sets the real minimum wage at a fraction $\alpha \in (0,1)$ below the competitive market wage rate $w_{U,t}$. This implies that the government adjusts the real minimum wage in a way so that it is always a fraction of the steady state level of the real wage rate in the unskilled sector. Formally, this is defined as

$$\underline{w} = \alpha w_U. \tag{4.28}$$

The minimum wage becomes binding as soon as the real wage $w_{U,t}$ which unskilled households would like to set based on a standard optimality condition falls below the steady state value of the real wage associated with the minimum nominal wage $\underline{w}$. In other words,

$$w_{U,t} = w_{U,t} \qquad \text{for} \qquad w_{U,t} \geq \frac{\underline{w} - w_U}{w_U},$$

and

$$w_{U,t} = \underline{w} \qquad \text{for} \qquad w_{U,t} < \frac{\underline{w} - w_U}{w_U}.$$

4.5.4 Monetary and Fiscal Policy

Monetary policy is conducted via a policy function following a Taylor rule:

$$\hat{i}_t = \phi_i\hat{i}_{t-1} + (1-\phi_i)\left(\phi_y\hat{Y}_t + \phi_\Pi\hat{\Pi}_t\right) + v_t, \tag{4.29}$$

with ϕ_y and ϕ_π being weights on the output and inflation gap, respectively. In addition, ϕ_i denotes the weight of lagged interest rate deviations. In other words, the deviation of the short-term nominal

[23] More precisely, we use the OccBin toolkit provided by Guerrieri and Iacoviello (2015).

interest rate from its steady state value depends on its deviation in the last period and the sum of the contemporaneous deviations of output and inflation from the steady state values. Additionally, v_t denotes a monetary policy shock following a standard AR(1)-process

The government is assumed to run a balanced budget which is spent according to simple lump-sum taxes collected from medium and skilled households

$$G_t = T_t, \tag{4.30}$$

where $T_t = T_{M,t} + T_{S,t}$ denotes the total lump-sum taxes from M and S types of households. Public consumption G_t for goods is exogenous and in log-linear terms follows

$$\hat{G}_t = \rho_g \hat{G}_{t-1} + \epsilon_{g,t}.$$

4.5.5 Aggregation

The Consumption Index

Total consumption of a typical worker $C_{\ell,t}$ of type ℓ is defined as an aggregator over a continuum of a variety of goods. For example,

$$C_{\ell,t} = \left(\int_0^1 C_{\ell,j,t}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}, \qquad \epsilon > 1,$$

where ϵ denotes the elasticity of substitution. Government consumption is specified analogously and assumed to exhibit the same degree of substitutability between individual varieties.

The implied utility-based consumer price index reads

$$P_t = \left(\int_0^1 P_{i,t}^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}.$$

It can be shown easily that this definition implies that the sum of all good-specific expenditures equals the product of the price index P_t and the consumption index $C_{\ell,t}$

$$P_t C_{\ell,t} = \int_0^1 P_{i,t} C_{\ell,j,t} di.$$

Demand Functions and Derivation of the NKPC

The typical firm producing a good i faces the following downward sloping demand function

$$\begin{aligned} Y_{i,t} &= \left(\frac{P_{i,t}}{P_t} \right)^{-\epsilon} Y_t \\ &= \left(\frac{P_{i,t}}{P_t} \right)^{-\epsilon} (C_t + G_t) \\ &= \left(\frac{P_{i,t}}{P_t} \right)^{-\epsilon} (C_{U,t} + C_{M,t} + C_{S,t} + G_t). \end{aligned}$$

The goods market is monopolistically competitive. A typical firm sets its optimal nominal price such that it maximises the expected discounted present value of profits subject to the demand function and the production function. However, the price adjustment process is constrained by a Calvo-type friction. In each period a fraction $\theta \in (0,1)$, of randomly selected firms are not allowed to optimally change their prices. Instead, these firms partially index their prices to last period's inflation. In particular, the price charged by a typical "non-adjuster" in period t is given by

$$P_{i,t}^{non} = P_{i,t-1}\Pi_{t-1}^{\chi}, \qquad \chi \in (0,1),$$

where χ denotes the degree of indexation and Π_t is the gross inflation rate of producer prices. The remaining firms, constituting a fraction of $1-\theta$, optimally reset their prices. In particular, they solve the following problem

$$\max_{P_{i,t}} E_t \left(\sum_{q=0}^{\infty} \beta^q \theta^q \frac{\mu_{t+q}}{\mu_t} \frac{P_t}{P_{t+q}} \left(P_{i,t} \prod_{k=0}^{q-1} \Pi_{t+k}^{\chi} - P_{t+q} mc_{t+q} \right) \left(\frac{P_{i,t} \prod_{k=0}^{q-1} \Pi_{t+k}^{\chi}}{P_{t+q}} \right)^{-\epsilon} Y_{t+q} \right),$$

where the objective function is obtained after plugging the demand schedule into the profit function and observing that marginal costs are independent of the scale of production and identical across firms.

The first order condition to this problem can be represented recursively as

$$\frac{\tilde{P}_t}{P_t} = \frac{\epsilon}{\epsilon - 1} \frac{\Im_{1,t}}{\Im_{2,t}}, \tag{4.31}$$

where $\tilde{P}_t$ is the optimal reset price with

$$\Im_{1,t} = mc_t Y_t + \beta\theta \frac{\mu_{t+1}}{\mu_t} \left(\frac{\Pi_t^{\chi}}{\Pi_{t+1}} \right)^{-\epsilon} \Im_{1,t+1},$$

and

$$\Im_{2,t} = Y_t + \beta\theta \frac{\mu_{t+1}}{\mu_t} \left(\frac{\Pi_t^{\chi}}{\Pi_{t+1}} \right)^{1-\epsilon} \Im_{2,t+1}.$$

Note that each adjusting firm sets the same optimal price. The firm price index can be written as

$$1 = \left(\theta \left(\frac{\Pi_{t-1}^{\chi}}{\Pi_t} \right)^{1-\epsilon} + (1-\theta) \left(\frac{\tilde{P}_t}{P_t} \right)^{1-\epsilon} \right). \tag{4.32}$$

Combining (4.31) and (4.32) yields the hybrid New Keynesian Phillips Curve (NKPC) for goods prices.

$$\hat{\Pi}_t - \chi\hat{\Pi}_{t-1} = \frac{(1-\theta)(1-\theta\beta)}{\theta} \hat{mc}_t + \beta(1-\theta)(\hat{\Pi}_{t+1} - \chi\hat{\Pi}_t). \tag{4.33}$$

4.6 Calibration

The calibration of the model proceeds in a standard way by fixing the steady state values of important levels or ratios of endogenous variables as well as a series of deep parameters to their empirical counterparts. We start with a discussion of those ratios and parameters which are closely related to the skill structure of the labour market and the production technologies. Afterwards, we briefly explain our choice of the remaining parameters.

In the steady state, we set the overall fraction of time devoted to work $N = N_S + N_M + N_U$ to 1/3. To calibrate the share of skilled, medium skilled, and unskilled labour, N_S/N, N_M/N and N_U/N we resort to the qualification/skill-level definition proposed by the *International Standard Classification for Education (ISCED)*. Under this classification standards, workers with less than primary, primary and lower secondary education (ISCED levels 0-2) are termed low-skilled, workers with upper secondary and post-secondary non-tertiary education (ISCED levels 3 and 4) are labelled medium skilled, and workers with tertiary education (ISCED levels 5-8) are viewed as high-skilled. The latter group consists of persons with an university or a doctoral degree. According to this data, the share of high-skilled N_S/N is set to 24%, the medium skilled share N_M/N is set 56%, and the unskilled share N_U/N to 20%, which corresponds to the average values for Germany over the period from 2004 to 2014.[24].

The weight of labour input for firms is fixed to the historic averages of employment. According to the ILO statistics, the average employment of unskilled and medium skilled labour in Germany between 2004 and 2016 was about 14% and 59%, respectively[25]. Thus, we calibrate λ to 0.14 and κ to 0.59 implying a share of skilled labour input of 0.27. The elasticity of substitution between differentiated labour varieties follows the empirical estimations in Krusell et al. (2000) and we set $\zeta = 1.67$[26].

As outlined above, skilled and medium skilled households are assumed to set a mark-up above their wages. To calibrate these mark-ups, we rely on the Income and Labour Costs[27] report from 2015.Q4 published by the German Federal Statistical Office. In this report, households are grouped into 5 income categories from "managing position" to "unskilled workers". To calculate the mark-ups the average income from group 1 and 2 (high skilled) and group 3 (medium skilled) is set relative to group 4 and 5 (unskilled), to find mark-ups of 2.46 and 1.37, respectively[28]. We assume that consumer price inflation as well as the skill specific wage inflation is zero in the stationary equilibrium, i.e. $\Pi = \Pi_{W,S} = \Pi_{W,M} = \Pi_{W,U} = 1$ and $\pi = \pi_{W,S} = \pi_{W,M} = \pi_{W,U} = 0$. The Calvo parameters and the degree of indexation for household wage (as well as firms' price) setting are calibrated as in Smets and Wouters (2003).

Unlike medium and skilled households, unskilled households do not set a mark-up. Instead, they can be subject to an exogenously defined minimum wage if the competitive wage rate falls under a certain threshold. To calibrate this threshold in steady state, we rely on the income publications by the German Federal Statistical Office[29]. According to this data, the average wage rate for unskilled labour input per hour in Germany was 11.82 EUR in 2014. Under a minimum wage of 8.50 EUR in 2015 this make a

[24] See OECD as well EUROSTAT, labour force indicators, employment by educational attainment level.

[25] For details see ILOSTAT, employment by education.

[26] Note that if $\zeta \to 0$ different kind of workers are Leontief and output can only be produced using fix proportions, which is the case of perfect complements. In contrast, if $\zeta \to 1$ the production function is a Cobb Douglas production function. As $\zeta \to \infty$ different kind of workers become perfect substitutes.

[27] See "Verdienste und Arbeitskosten" by the German Federal Statistical Office, website accessed on the 03.01.2018.

[28] This implies an elasticity of substitution of different skilled and medium skilled workers of $\epsilon_S = 1.68$ and $\epsilon_M = 3.70$.

[29] See "Verdienste auf einen Blick 2017" by the German Federal Statistical Office, website accessed on the 03.01.2018.

Table 4.1: Calibration of Parameters

Parameters	**Symbol**	**Value**	**Source**
Households:			
Average total working hours	N	1/3	DSGE literature
Share of skilled labour	N_S	0.24	Eurostat (ISCED Education level)
Share of medium skilled labour	N_M	0.56	Eurostat (ISCED Education level)
Share of unskilled labour	N_U	0.20	Eurostat (ISCED Education level)
Discount factor	β	0.998	DSGE literature
Elasticity of intertemporal consumption	σ	1.2	DSGE literature
Inv. Frisch labour elasticity	φ	0.36	Hirsch, Schank, et al. (2010)
Bond adjustment costs	δ	0.0015	DSGE literature
Firms:			
Share of skilled labour input	$(1-\lambda-\kappa)$	0.14	ILOSTAT, employment by education
Share of medium skilled labour input	κ	0.59	ILOSTAT, employment by education
Share of unskilled labour input	λ	0.27	ILOSTAT, employment by education
Labour substitution elasticity	ζ	1.67	Krusell et al. (2000)
Marginal cost (=P/mark-up)	mc	1/1.33	Christopoulou and Vermeulen (2012)
Calvo parameter	θ	0.75	Smets and Wouters (2003)
Degree of inflation indexation	χ	0.75	Smets and Wouters (2003)
Wage setting and monopsony			
Skilled elasticity of substitution	ϵ_S	1.68	German Federal Statistics Office
Calvo skilled	$\theta_{w,S}$	0.75	Smets and Wouters (2003)
Skilled indexation (wage)	ω_S	0.75	Smets and Wouters (2003)
Medium elasticity of substitution	ϵ_M	3.70	German Federal Statistics Office
Calvo medium skilled	$\theta_{w,M}$	0.75	Smets and Wouters (2003)
Medium skilled indexation (wage)	ω_M	0.75	Smets and Wouters (2003)
Level of minimum wage	α	0.72	German Federal Statistics Office
Central bank and government			
Weight of lagged interest deviation	ϕ_i	0.9	DSGE literature
Inflation weight	ϕ_π	1.5	DSGE literature
Output weight	ϕ_y	0.5	DSGE literature
Share of government consumption	g_Y	0.187	World Bank

threshold of roughly 0.72 ($= \frac{8.50}{11.82}$), to make the minimum wage binding. Moreover, the value of the labour supply elasticity, which is important for monopsony, is taken as 2.8 which determines φ as 0.36. This value is taken as the simple median from Hirsch, Schank, et al. (2010) who estimate labour elasticities for different sectors in Germany ranging from 1.9 to 3.7.

The remaining parameters are set to the values used in the bulk of the DSGE literature. These are the subjective discount factor β and the inverse of the intertemporal elasticity with respect to consumption σ (see Table 4.1). The shares of government consumption $\frac{G}{Y} = g$ is set in accordance with historical averages for Germany[30]. Finally, the average marginal costs $mc = P/\text{mark-up}$, are set in accordance with the

[30]See OECD and World Bank general government consumption statistic from 2004 to 2016.

estimates for the average mark-ups in Germany provided by Christopoulou and Vermeulen (2012). In particular, we chose the mark-up as 1.33.

4.7 Results

In the present section, we analyse the effects of shocks to unskilled labour supply and a shock to the exogenously set minimum wage in the model economy described above. In particular, we focus on how the output, consumption, working hours, and the wage level of different agents are affected from these shocks. In doing so, we distinguish between the neoclassical benchmark case where neither unskilled households nor firms have market power and the monopsony case where each firm demands labour in, for instance, regionally separated unskilled labour markets providing them with market power. We start with the neoclassical benchmark.

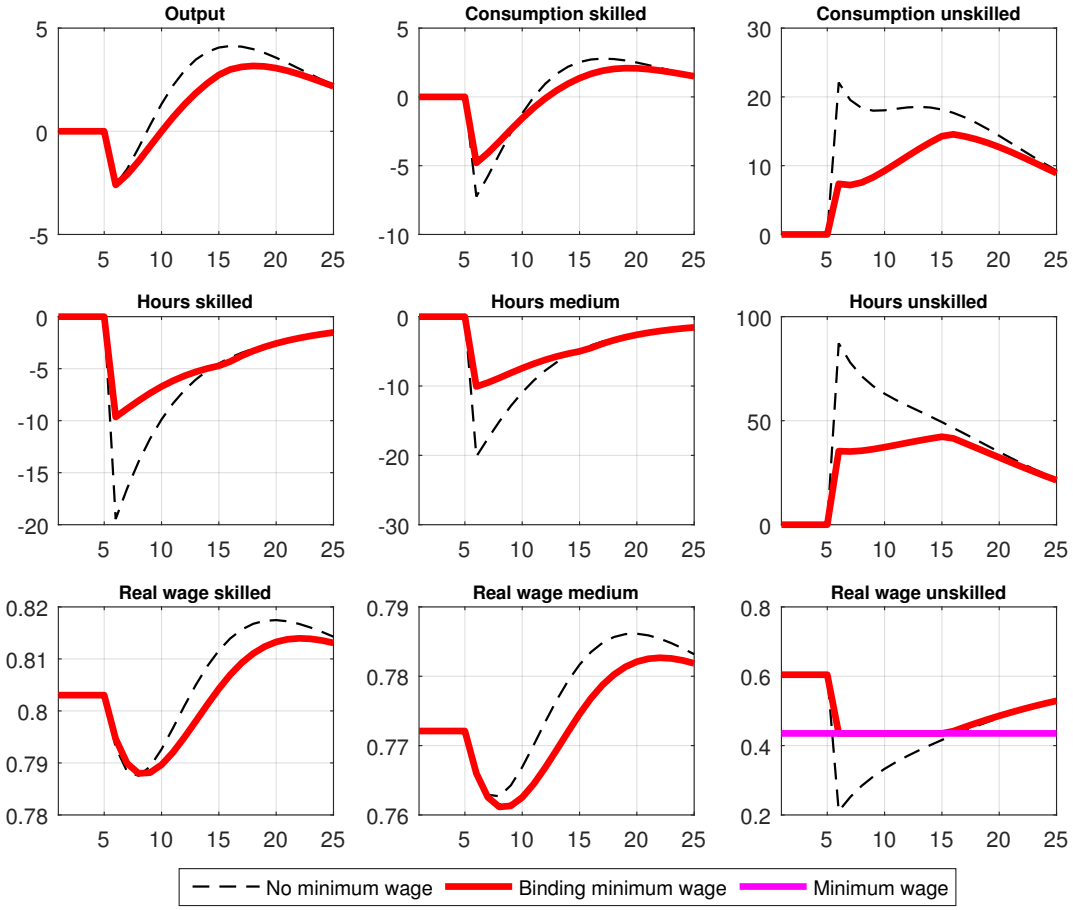
Neoclassical Benchmark

The results for the model under a neoclassical labour market are shown in Figures 4.4 and 4.5. Under a positive unskilled labour supply shock, unskilled agents increase their labour supply leading to a rise in the number of hours worked and a reduction in unskilled wages. As the increase in labour is higher than the reduction in wage, the contemporaneous income for rule-of-thumb consumers increases. Also, after a initial minor reduction, the output production of this model economy increases. Since the wage for unskilled labour drops, firms substitute relatively cheaper unskilled workers for relatively more expensive medium and skilled labour input. As a result, the number of hours worked from the other two agents declines. However, due to the wage setting power of skilled and medium skilled households, the wage only fluctuates slightly around the initial steady state value of the respective wage level and actually increases after a few periods. Following the reduction in labour income, consumption for skilled households is reduced initially but increases over time as the wage increases[31]. Note that due to optimising skilled household behaviour and the access to bond investments, skilled households can smooth their consumption which, thus, is less volatile compared to the stark reaction in unskilled consumption.

Comparing the non-binding regime to the binding minimum wage regime, first of all note that in our model the occasionally binding minimum wage actually *reduces* macro volatility. While the general direction of both regimes is the same, the up or down swings for each variable are not as intense under a binding minimum wage. However, while the typical channel of macro volatility reduction comes via the protection of unskilled labour in bad times, our model allows for an additional channel reducing macro volatility. Once the downward moving unskilled wage hits the lower bound of the minimum wage, firms are forced to pay the exogenously set minimum wage. On the one hand, although this implies that the increase in labour income and consumption of unskilled households is not as strong, on the other hand, it also implies that firms' incentives to substitute cheaper unskilled labour with more expansive other labour input types are reduced. Thus, the reduction in skilled and medium skilled working hours is less pronounced as is the wage volatility of these two household types leading to an overall reduction in output

[31] The results for consumption of medium and skilled households are equivalent.

Figure 4.4: Shock to Unskilled Labour Supply in a Neoclassical Market

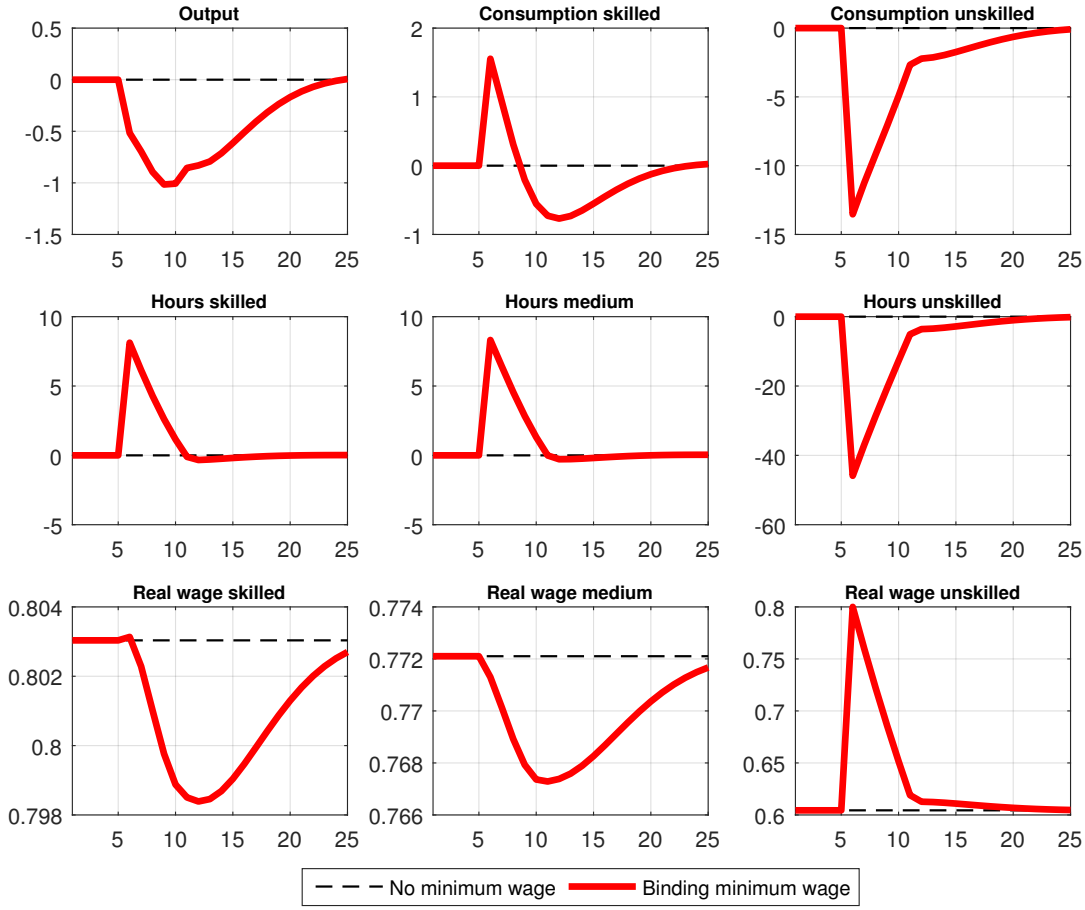


Notes: Estimated impulse responses to a positive unskilled labour supply shock. The Y-axis denotes periods after the shock at $t = 5$. The first six panels show the deviation from steady state. In contrast, the lower three panels on the wage development show the level and fluctuation around the steady state with a minimum wage for unskilled labour which is set at $\underline{w} = \alpha w_U$ (with $\alpha < 1$). The dashed black line plots the model of a non-existing minimum wage whereas the red solid line plots the model with an occasionally binding minimum wage.

volatility.

Concerning the impact of an exogenous positive minimum wage shock in Figure 4.5, our model is able to reproduce the standard findings from the static neoclassical model. First of all, note two presumably trivial findings that a) in a model with no binding minimum wage no impulse response functions are produced and b) in the model with a binding minimum wage one needs a rather strong minimum wage shock to make it binding initially. Put differently, an increase of the minimum wage which is still below the competitive market wage rate does not induce any reaction in the model. In contrast, implementing a positive minimum wage shock, where now α is > 1, leads to a reduction in unskilled working hours. As unskilled workers become too expensive, firms increase their demand for skilled and medium skilled households, who smooth their consumption intertemporally. However, due to the reduction in current income for unskilled households their consumption is lowered decreasing the overall output of the economy.

Figure 4.5: Shock to the Minimum Wage in a Neoclassic Market



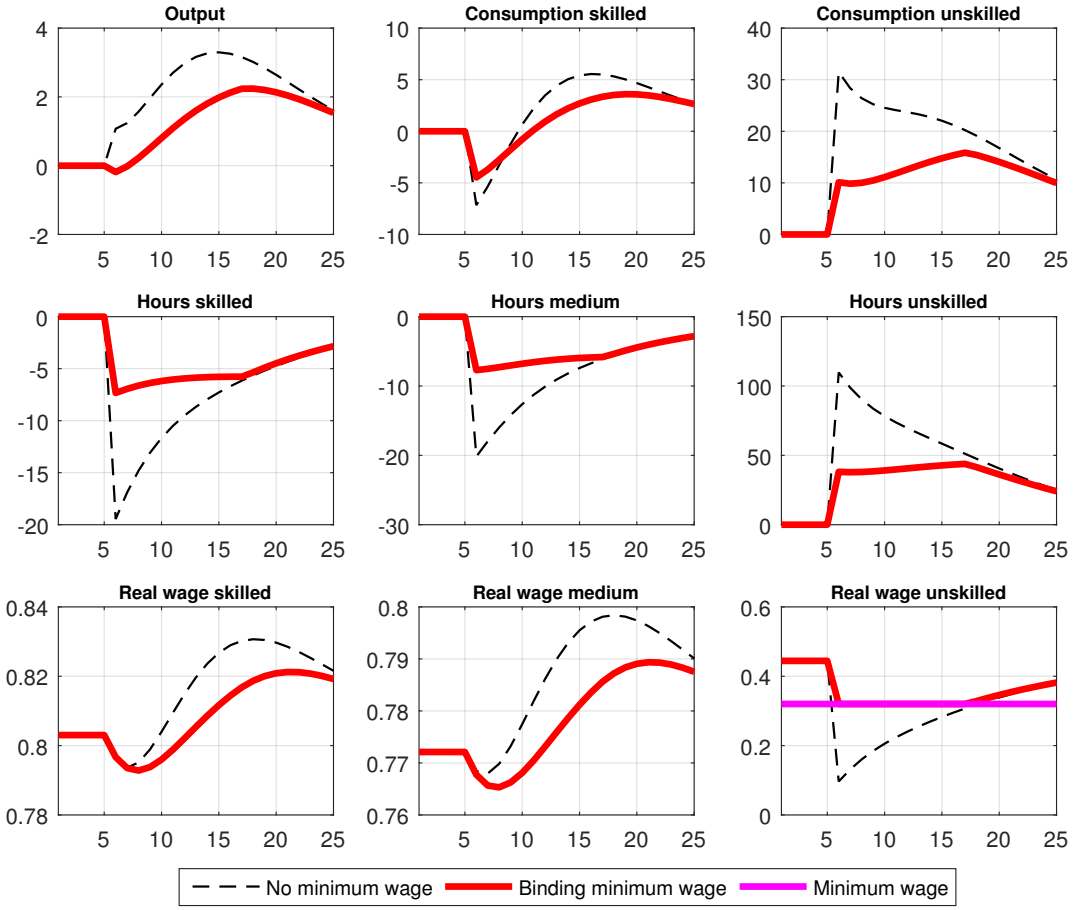
Notes: Estimated impulse responses to a positive minimum wage shock. The Y-axis denotes periods after the shock at $t = 5$. The first six panels show the deviation from steady state. In contrast, the lower three panels on the wage development show the level and fluctuation around the steady state. The dashed black line plots the model of a non-existing minimum wage whereas the red solid line plots the model with a binding minimum wage which is shocked to a higher level than the steady state value of the competitive unskilled wage.

Monopsony

In addition to the neoclassic benchmark model, we also examine the case of direct monopsony. The results are illustrated in Figures 4.6 and 4.7. As already indicated in Section 4.5.2, the direct modelling of monopsony leads to a lower unskilled wage in the steady state with unchanged dynamics of the model, however. Therefore, the only difference between Figure 4.6 and Figure 4.4 is the level of the unskilled real wage, which is reduced by the rate of exploitation $(1 + \varphi)$.

Unfortunately, the direct implementation of monopsony in a dynamic model does not replicate the findings from the static model with respect to the impact of the minimum wage. Even a moderate minimum wage above the wage rate that the monopsonist offers, leads to a reduction in number of hours of worked. While the firm now has to pay a higher wage, it does not employ more workers, but instead reduces output.

Figure 4.6: Shock to Unskilled Labour Supply in a Monopsonistic Market

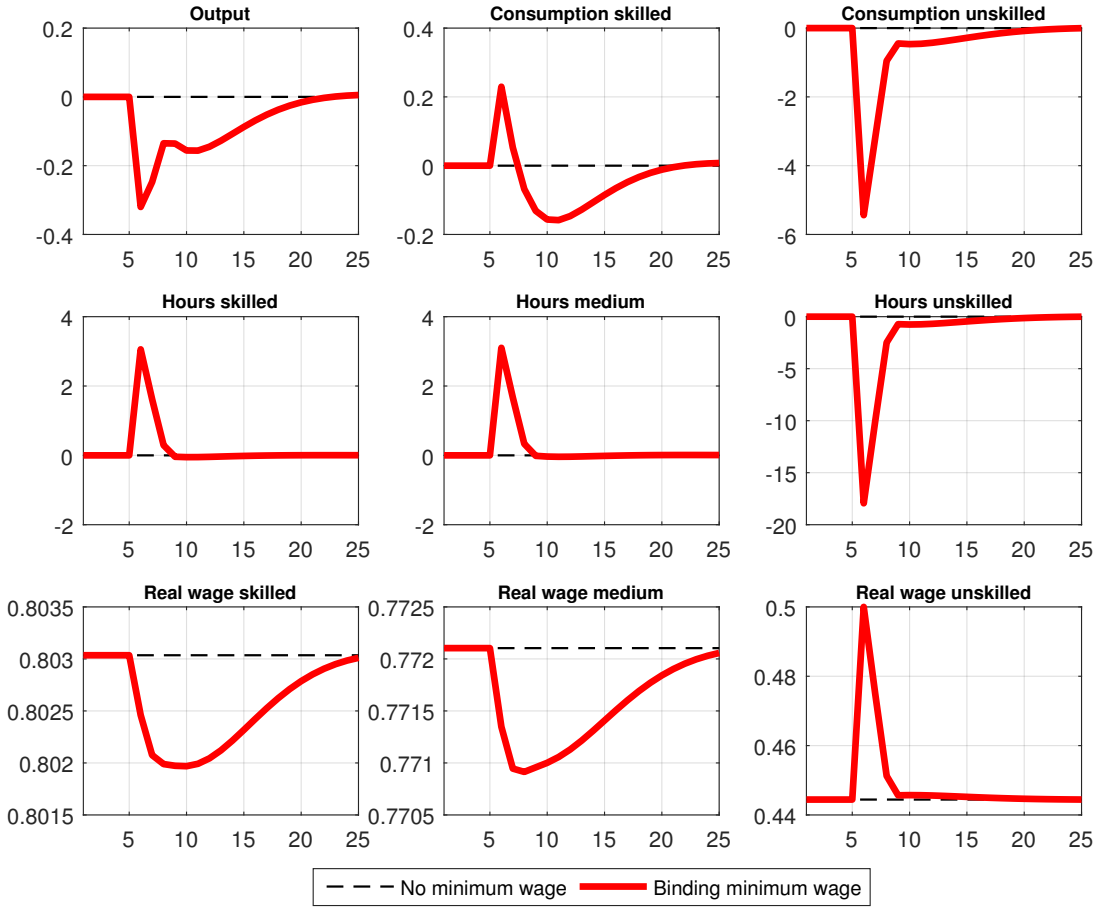


Notes: Estimated impulse responses to a positive unskilled labour supply shock. The Y-axis denotes periods after the shock at $t = 5$. The first six panels show the deviation from steady state. In contrast, the lower three panels on the wage development show the level and fluctuation around the steady state, with a minimum wage for unskilled labour which is set at $\underline{w} = \alpha w_U$. The dashed black line plots the model of a non-existing minimum wage whereas the red solid line plots the model with an occasionally binding minimum wage.

Note that this finding does not depend on the fact that the firm can substitute more expensive unskilled labour with relatively cheaper medium and skilled workers. The same finding would occur if our model would encompass just one type of household. In other words, to force the firm to employ more workers when the minimum wage is moderately increased one needs to implement additional labour market frictions. Most importantly, such a model needs a law of motion of labour as in the search-and-matching literature[32].

[32]Unfortunately, due to the upcoming deadline it was not possible to implement the huge search-and-matching literature in this thesis. However, this is left for future research.

Figure 4.7: Shock to the Minimum Wage in a Monopsonistic Market



Notes: Estimated impulse responses to a positive minimum wage shock. The Y-axis denotes periods after the shock at $t = 5$. The first six panels show the deviation from steady state. In contrast, the lower three panels on the wage development show the level and fluctuation around the steady state. The dashed black line plots the model of a non-existing minimum wage whereas the red solid line plots the model with a binding minimum wage which is shocked to a higher level than the steady state value of the competitive unskilled wage.

4.8 Conclusion

The introduction of a minimum wage in Germany has not led to enormous job destruction so far. In contrast, there is a clear downward trend in unemployment numbers in Germany following the positive GDP growth rates and the labour market reforms in the early 2000s. A likely explanation for this is that the German minimum wage is actually too low in the sense that for many sub sectors and jobs the market wage rate is higher leading to a non-binding minimum wage. However, there has been some concern that the large migration inflow in Germany in late 2015 could lead to wage reductions for many low skilled jobs making the minimum wage binding to a larger degree.

This chapter has presented a one sector closed economy model which is populated by unskilled rule-of-thumb consumers facing either a competitive neoclassical or monopsonistic labour market and Ricardian skilled and medium skilled households, which are able to smooth their consumption intertemporally and can set a mark-up over their wages. The minimum wage has been modelled as an occasionally binding

constraint in which the minimum wage is only binding if the market wage rate falls below an exogenously defined threshold.

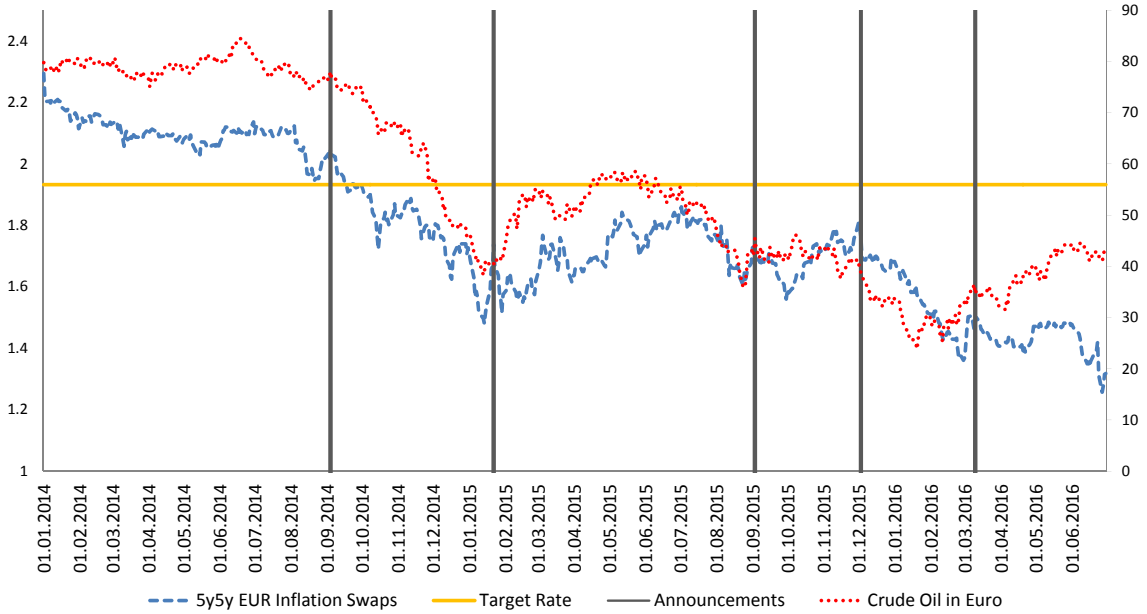
Our model provides a first step to a more structured discussion. However, more research needs to be done and the model could benefit from extensions along several dimensions. First of all, building on the same modelling approach as in the static monopsony world does not lead to different policy conclusions from the neoclassic case. In fact, while unskilled workers do get exploited in our model a minimum wage nonetheless reduces output. Hence, additional frictions in the labour market such as in a search-and-matching model are needed to better account for monopsony power of firms. Second, a more detailed government sector with, for instance, unemployment benefits would be a reasonable extension to examine how the introduction of an outside option would change our results. Third, as we currently have a closed economy model, the notion of migration is somewhat misleading. While migration was the motivation for this chapter it is actually not explicitly embodied in the current version of the model. In contrast, we were bypassing an open economy version by simulating migration inflows as a positive labour supply shock. All these extensions to our parsimonious model are left for future research.

Appendix A

Appendix to Chapter 2

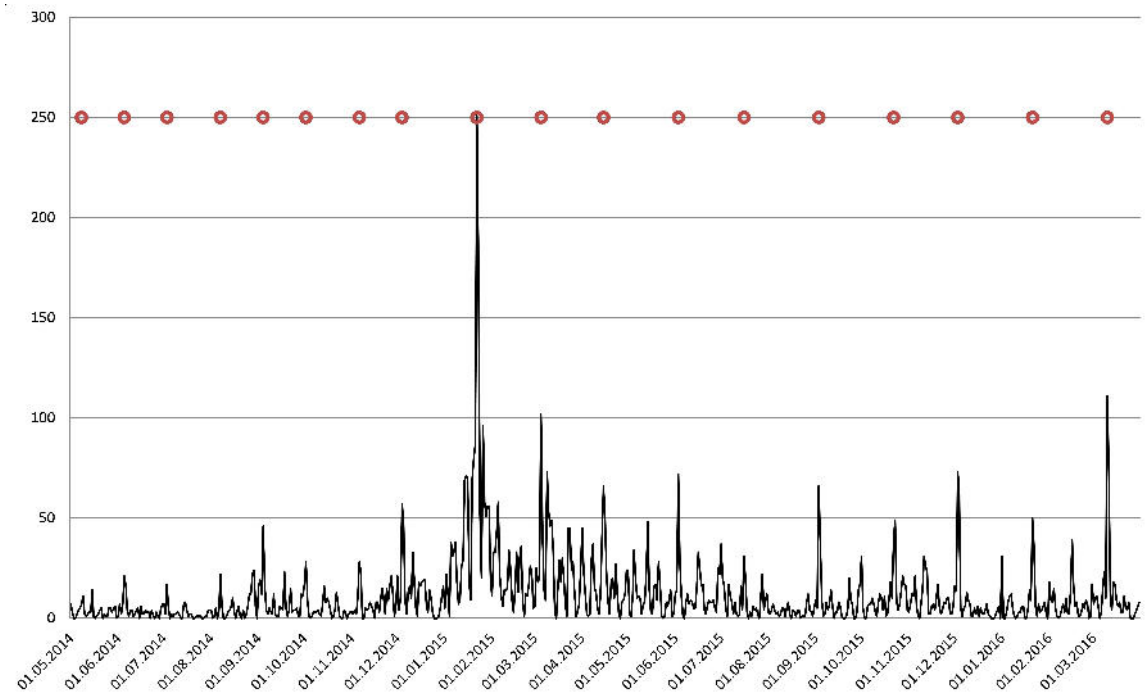
A.1 Appendix Chapter 2

Figure A.1: Alternative Event Day Specification: 5y5y Inflation Swaps



Source: Datastream. 5y5y Euro inflation swaps on the left y-axis. Price of crude oil (North Sea Brent) denominated in Euro on the right y-axis.

Figure A.2: Alternative Event Day Specification: Events from Lexis-Nexis



Source: Lexis-Nexis; red circles: ECB Governing Council meetings; search query: "Quantitative Easing <or> QE <or> Asset Purchase Programme <and> Draghi <or> ECB <or> European Central Bank <NOT> Fed, Federal Reserve, Bank of England, Bank of Japan, BoJ, BoE, U.S., Japan, England, US"

Table A.1: Event Days – Details

Date	Kind	Summary
05.06.2014	ECB monetary policy decisions	The Governing Council decided on a combination of measures • Lower the main refinancing operations by 10 basis points to 0.15% • Lower the marginal lending facility by 35 basis points to 0.40% • Lower the deposit facility by 10 basis points to -0.10% • Conduct a series of targeted longer-term refinancing operations (TLTROs) • Announced Purchases in the ABS market • Continue to conduct the MROs as fixed rate tender procedures with full allotment for as long as necessary
06.06.2014	Financial Times, P.1	Mario Draghi became the first major central banker to cut a key interest rate below zero as he unveiled a series of radical measures to stave off a crippling bout of deflation, and signalled his willingness to take further action. (…) Mr Draghi indicated that policy makers were still *willing to embark on some kind of quantitative easing* if ultra-low inflation persists.
04.09.2014	**ECB monetary policy decisions**	The Governing Council decided today to • Lower the main refinancing operations by 10 basis points to 0.05% • Lower the marginal lending facility by 10 basis points to 0.30% • Lower the deposit facility by 10 basis points to -0.20% • Start purchasing non-financial private sector assets under an ABS Purchase Programme (ABSPP) • Start purchases under the Covered Bond Purchase Programme (CBPP3)
05.09.2014	**Financial Times, P.1**	Mario Draghi startled markets yesterday, cutting interest rates to a record low and pledging to buy hundreds of billions of Euros of private sector bonds in a dramatic move to save the Euro-zone from economic stagnation. The Euro fell to its lowest level in more than a year (…) after what amounts to the ECB's *last gambit short of full-scale quantitative easing.*
14.01.2015	ECB press release	We take note of the *European Court of Justice Advocate General's legal opinion* in the Outright Monetary Transactions (OMTs) case. This is an important milestone in the request for a preliminary ruling, which will only be concluded with the judgement of the Court
15.01.2015	Financial Times, P.3	The *removal of a big legal hurdle* to government bond buying by the European Central Bank pushed the Euro to a nine-year low yesterday and paved the way for policy makers to press ahead with quantitative easing next week. A top adviser to the European Court of Justice *bolstered the case for aggressive action by the ECB* next Thursday, after he said an earlier, more controversial sovereign debt-buying plan lay within the ECB's mandate. The final decision on the Outright Monetary Transactions programme, expected in four to six months, is likely to follow the advocate-general's opinion.
16.01.2015	Financial Times, P.1	"Franken-Shock": The European Central Bank is next week *expected to embark on a sovereign bond buying programme* aimed at reviving growth and saving the Euro-zone from the ravages of deflation. A launch of full-blown quantitative easing would precipitate massive demand for the Swiss franc, widely seen as one of global markets' stronger havens — and would have made it increasingly difficult for the SNB to defend its currency ceiling.

Date	Kind	Summary
22.01.2015	**ECB monetary policy decisions**	ECB announces expanded APP • PSPP: ECB purchases bonds issued by Euro Area central governments, agencies and European institutions • Combined monthly asset purchases of €60 billion • Purchases at least until September 2016 • Hypothetical losses of ECB purchases will be subject to loss sharing. The rest of the NCBs' additional asset purchases will not be subject to loss sharing
23.01.2015	**Financial Times, P.1**	The European Central Bank launched a €60bn-a-month bond-buying programme that was *far bigger than investors had expected*, in its long-awaited bid to revitalise the Euro-zone economy and counter deflation. (…) "Expectations work only if there is a certain credibility," he said at the bank's Frankfurt headquarters. "Today we are showing that that credibility is deserved."
03.09.2015	**ECB monetary policy decisions**	The Governing Council decided to keep the key ECB interest rates unchanged. • Increase the issue share limit from the initial limit of 25% to 33%, subject to a case-by-case verification
04.09.2015	**Financial Times, P.1**	Mario Draghi buoyed investors yesterday as *he opened the door for further quantitative easing* should global market tremors and the emerging markets slowdown threaten Euro-zone recovery. The Euro and Euro-zone government bond yields plunged after the ECB president *indicated it stood ready to extend the "size, composition and duration"* of its €1.1tn bond-buying programme. (…) In a *sign of policymakers' willingness to reinforce* their QE package, the ECB raised the purchase limit of a single country's debt stock from 25 per cent to 33 per cent.
22.10.2015	ECB monetary policy decisions	The Governing Council decided to keep the key ECB interest rates unchanged.
23.10.2015	Financial Times, P.1	The *ECB signalled it would expand* its €1.1tn quantitative easing programme in December and cut its deposit rate (…) Mario Draghi said policymakers' measures would need to be "re-examined" at its December 3 vote. He said the central bank stood ready to *adjust the "size, composition and duration" of its QE programme*.

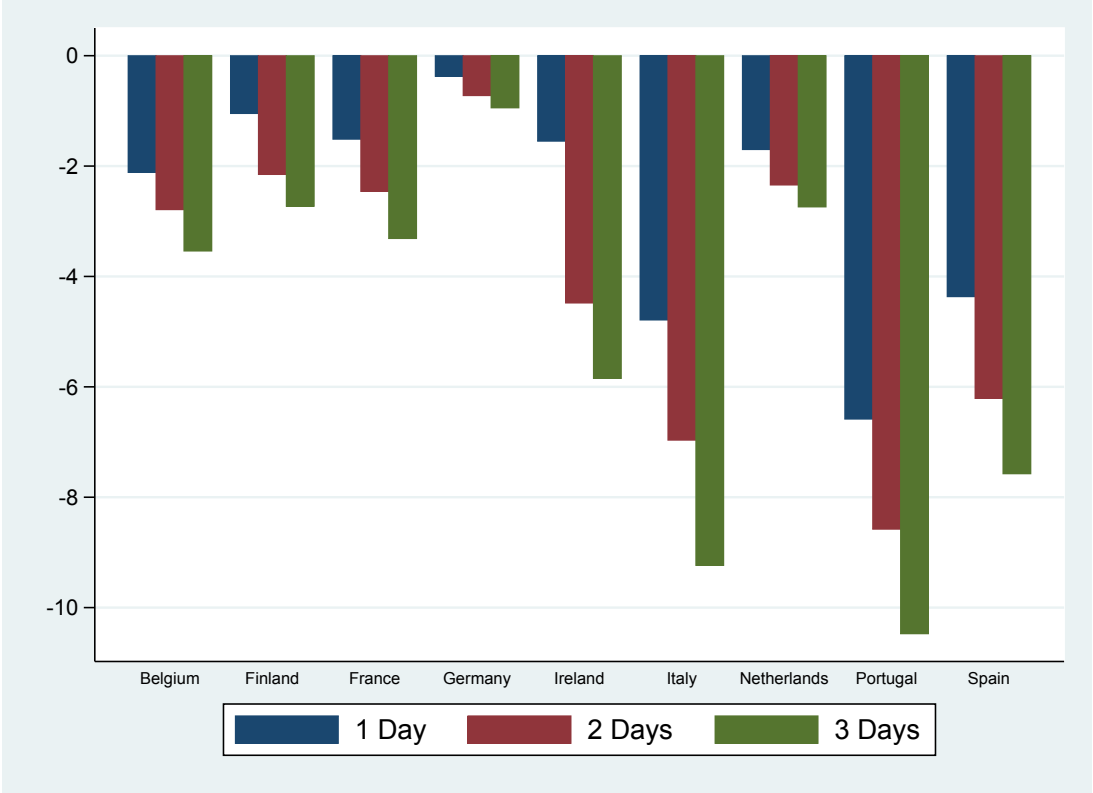
Green: announcement effects (new QE announcement and Financial Times P.1-3).
Yellow: speculation effects (no new QE announcement, but Financial Times P.1-3).

Table A.2: Event Days – Details (cont'd)

Date	Kind	Summary
03.12.2015	**ECB monetary policy decisions**	The Governing Council decided to • Lower the deposit facility by 10 basis points to -0.30% • The main refinancing operations and marginal lending facility remain unchanged • Extend the APP until the end of March 2017, or beyond • Include regional and local governments in the PSPP
04.12.2015	**Financial Times, P.1**	But these measures (…) *disappointed investors* who had hoped for deeper rate cuts and more monthly bond purchases. (…) More aggressive stimulus would probably have run into stiff German-led opposition (…). While support for the package was not unanimous, Mr Draghi said a "very large majority" were in favour of the measures.
21.01.2016	ECB monetary policy decisions	The Governing Council decided to keep the key ECB interest rates unchanged.
22.01.2016	Financial Times, P.1	Mario Draghi signalled that the European Central Bank was prepared to launch a fresh round of monetary stimulus as soon as March (…). The ECB has "the power, the willingness, the determination to act" and "*there are no limits to our action*" to bring inflation up to its target of just below 2 per cent, he said.
18.02.2016	ECB press release	The minutes show the governing council was *unanimous* in concluding that its current policy stance "*needed to be reviewed and possibly reconsidered*"**.**
19.02.2016	Financial Times, P.1	Mario Draghi, the ECB president, has won *wide support for further policy action* next month (…). Markets are expecting the ECB's deposit rate to be cut another 10 basis points to minus 0.4 per cent next month, while the €60bn quantitative easing programme launched a year ago is likely to be increased in scope.
10.03.2016	**ECB monetary policy decisions**	The Governing Council decided to • Lower main refinancing operations by 5 basis points to 0.00% • Lower marginal lending facility by 5 basis points to 0.25% • Lower deposit facility by 10 basis points to -0.40% • Expand the monthly purchases of APP from €60 billion at present to €80 billion. They are intended to run until the end of March 2017, or beyond, if necessary • The issuer and issue share limits for securities issued by eligible international organisations and multilateral development banks will be increased to 50% • Include investment-grade Euro-denominated bonds issued by non-bank corporations in the list of assets (CSPP) • Launch a new series of TLTRO II
11.03.2016	**Financial Times, P.1**	The European Central Bank has *unleashed a bigger-than-expected package* of measures to stimulate the Euro-zone economy, with expanded quantitative easing, incentives to banks to increase lending and further interest rate cuts.

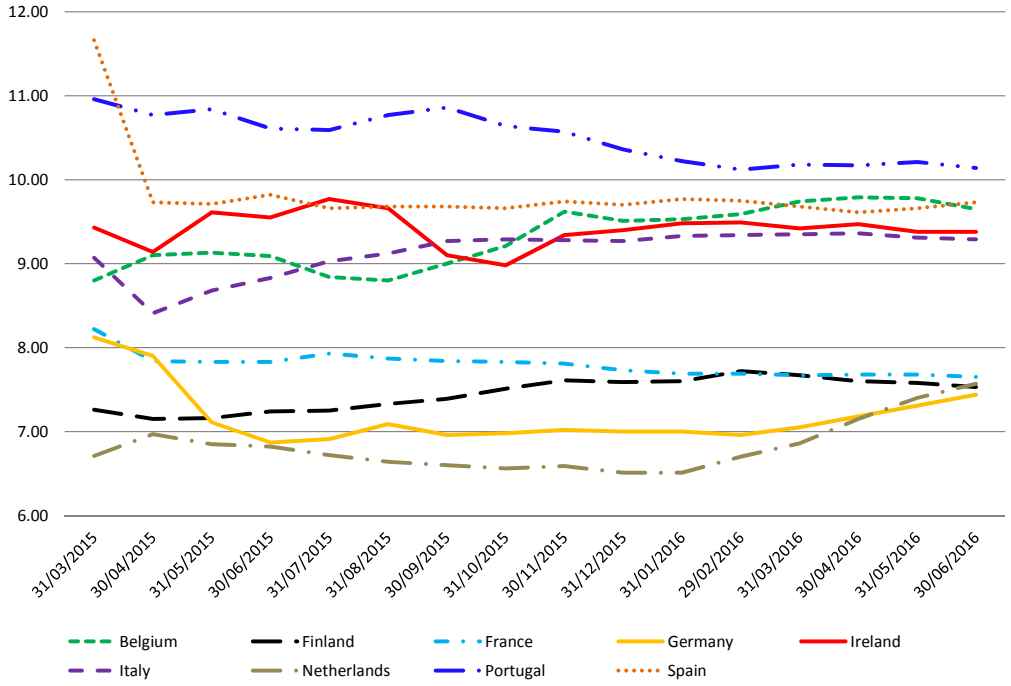
Green: announcement effects (new QE announcement and Financial Times P.1-3).
Yellow: speculation effects (no new QE announcement, but Financial Times P.1-3).

Figure A.3: Average Impact of QE Announcement Across Maturities and Sensitivity to Window Size



Source: Datastream. Y-Axis shows reduction in BPS for each window size. The average is calculated on the average reduction per event across maturities for each country.

Figure A.4: Weighted Average Maturity in Years of PSPP Portfolio Holdings



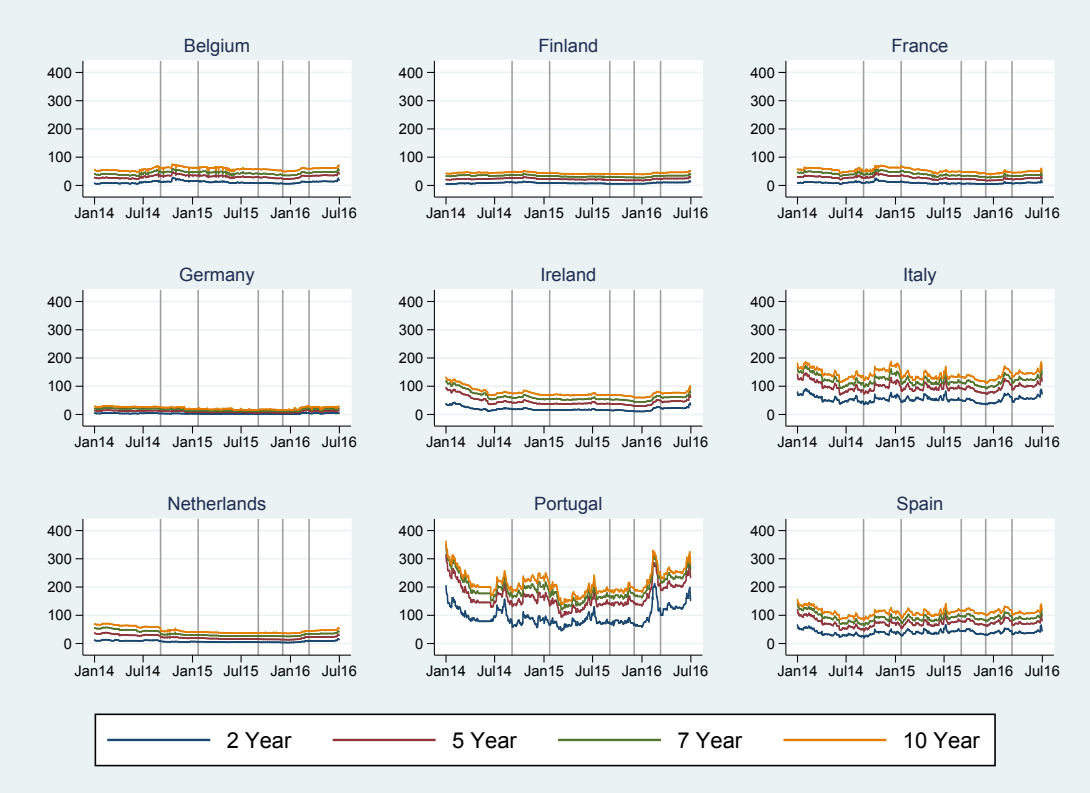
Source: ECB.

Table A.3: Overview Control Variables

Variable	Belgium	Finland	France	Germany	Ireland	Italy	Netherlands	Portugal	Spain	Euro Area
Business Confidence	X	X	X	X		X	X	X	X	X
Consumer Confidence	X	X	X	X	X	X	X	X	X	X
GDP QoQ final	X	X	X	X	X	X	X	X	X	X
GDP QoQ flash	X	X	X	X		X	X	X	X	X
GDP YoY final	X	X	X	X	X	X	X	X	X	X
GDP YoY flash	X	X	X	X		X	X	X	X	X
Industrial Production YoY	X	X	X	X	X	X	X	X	X	X
Inflation MoM	X	X	X	X	X	X		X	X	X
Inflation YoY	X	X	X	X	X	X	X	X	X	X
Manufacturing PMI			X	X	X	X	X		X	X
Retail Sales MoM	X	X	X	X	X	X	X	X	X	X
Retail Sales YoY	X		X	X	X	X	X	X	X	X
Unemployment Rate	X	X	X	X	X	X	X	X	X	X
ZEW Economic Sentiment										X
Bid-Ask Spread	X	X	X	X	X	X	X	X	X	
CDS Premia	X	X	X	X	X	X	X	X	X	
VSTOXX Index	X	X	X	X	X	X	X	X	X	
US 10 Year Benchmark	X	X	X	X	X	X	X	X	X	

Source: News data is taken from the calendar function of the publicly available website tradingeconomics.com. Surprise components of news announcements are calculated as actual value − forecast value on the day of each announcement. All non-announcement days are zero. To make different national business confidence and consumer confidence indices more comparable, the surprise component is calculated as percentage deviation from forecast value. Euro Area news apply for all nine countries. Bid-ask spreads are calculated as the daily average bid-ask spreads for a large subset of national bonds.

Figure A.5: CDS Benchmarks per Country



Source: Datastream. Vertical lines indicate announcement dates. Y-axis shows CDS premia.

Table A.4: Total Purchases to Total Debt Outstanding

	Jan 2015	Dec 2015	Mar 2016
Belgium	7.3389%	2.2699%	1.5099%
Germany	12.5376%	3.9621%	2.6522%
Finland	13.3378%	4.1292%	2.6328%
France	9.2687%	2.8376%	1.8614%
Ireland	8.9557%	2.9897%	1.8554%
Italy	7.4892%	2.3277%	1.5318%
Netherlands	12.1816%	3.6562%	2.6104%
Portugal	15.3784%	4.3524%	2.7553%
Spain	11.7811%	3.4739%	2.2674%

Source: County debt data is taken from Datastream. Total debt outstanding is defined as non-short term Euro denominated debt only at the time of the announcement. Total PSPP purchases are calculated as monthly APP purchases times the share of the PSPP times the number of month announced. In a second step, the country specific purchases are obtained by multiplying the total PSPP purchases with each capital key. Note that for the announcements in December 2015 and March 2016 only the *additional* amount of purchases is taken into account.

Appendix B

Appendix to Chapter 3

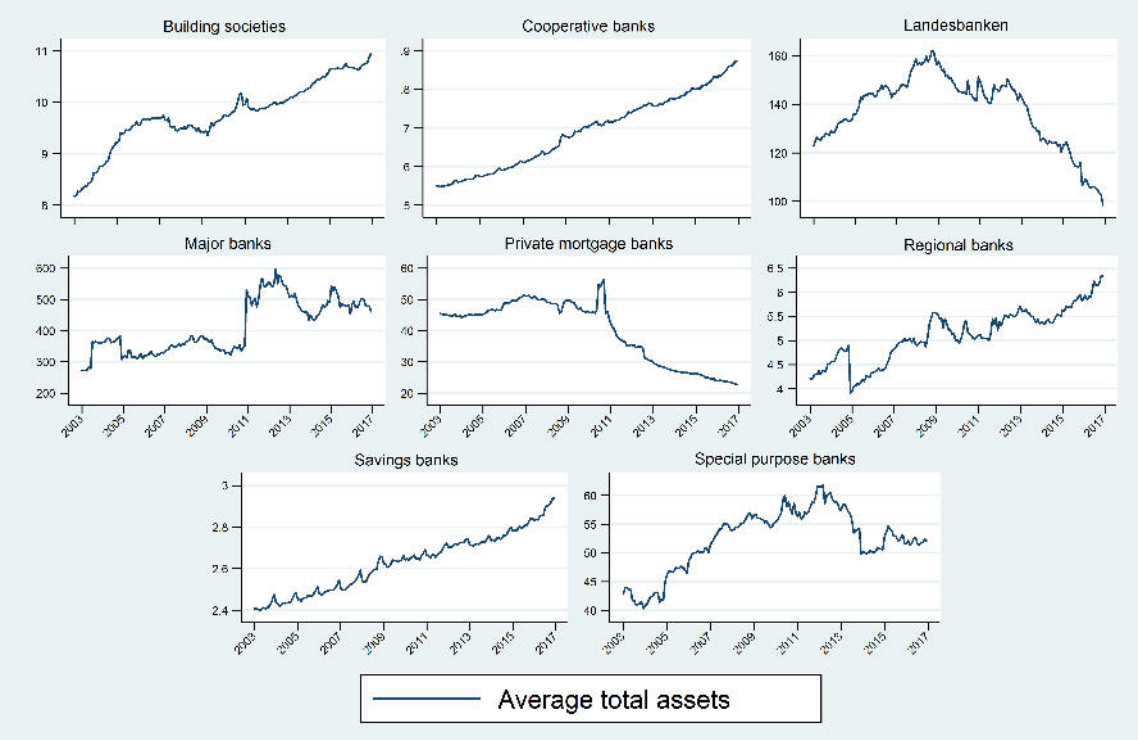
B.1 Appendix Chapter 3

Table B.1: List of Variables

Monthly balance sheet statistics	**Source:**
Total assets	Bundesbank
Cash in hand	Bundesbank
Balances with central banks	Bundesbank
T-bills and similar debt instruments	Bundesbank
Loans to banks	Bundesbank
Loans to non-banks	Bundesbank
Loans to households	Bundesbank
Loans to firms	Bundesbank
Loans to government	Bundesbank
Debt instruments	Bundesbank
Bonds and notes	Bundesbank
Shares and other variable-yield securities	Bundesbank
Trading portfolio (assets)	Bundesbank
Total liabilities	Bundesbank
Capital	Bundesbank
Liabilities to banks	Bundesbank
Liabilities to non-banks	Bundesbank
Securitised liabilities	Bundesbank
Fiduciary liabilities	Bundesbank
Provisions for liabilities and charges	Bundesbank
Trading portfolio (liabilities)	Bundesbank
Yearly banks' profit and loss statements	**Source:**
Net interest received/ paid	Bundesbank
Net commissions received/ paid	Bundesbank
Staff costs	Bundesbank
Total administrative spending	Bundesbank
Net profit/ loss from trading portfolio	Bundesbank
Net income/ charges from valuation of assets	Bundesbank
Other and extraordinary income	Bundesbank
Gross earnings	Bundesbank
Operating profit	Bundesbank
Profit before tax	Bundesbank
Taxes paid	Bundesbank
Profit after tax	Bundesbank
Additional control variables	**Source:**
Real German GDP growth	German Federal Statistic Office
EURIBOR, 3m	Datastream
German Bund, 10 y	Datastream
Stock market: DAX, log	Datastream
House price index	German Federal Statistic Office
ECB shadow rate	Wu and Xia (2017)

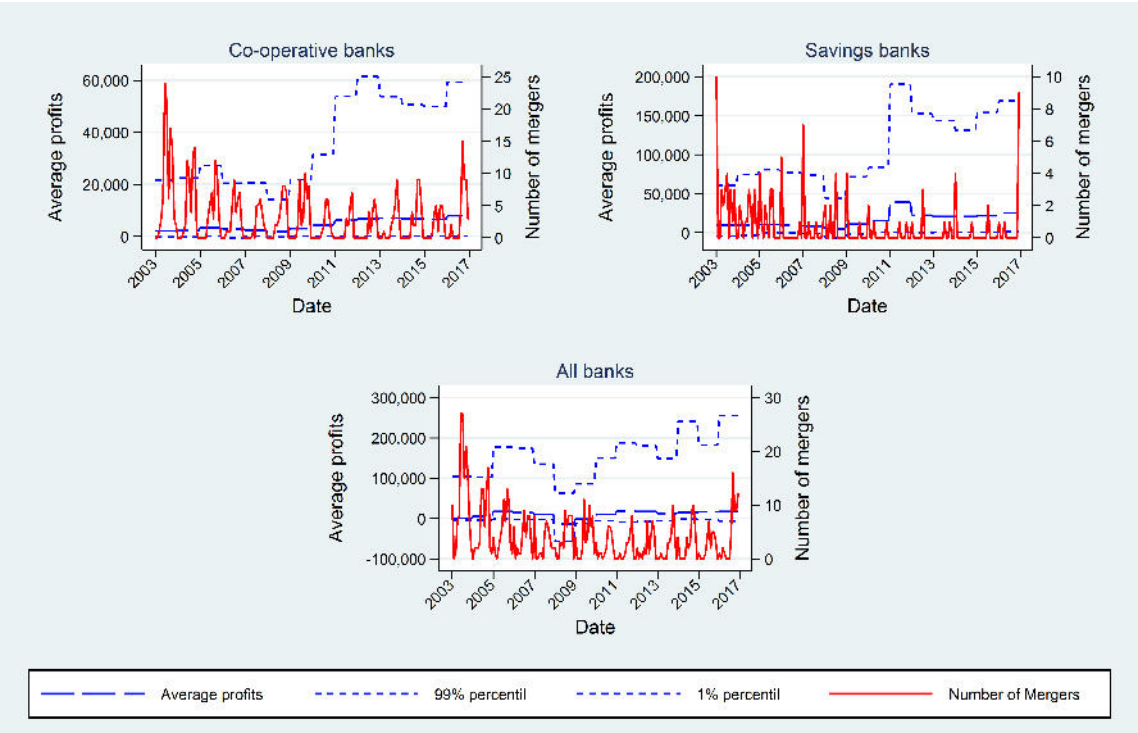
Note: Several of the balance sheet variables are also available at sub aggregates, which are e.g. divided into regions (domestic, Euro Area, non-Euro Area) or maturity (overnight, up to 1 year, 2 to 5 years, etc.). For more details about the balance sheet statistic or the P&L statements please see the Bundesbank website.

Figure B.1: Average Total Assets Over Time



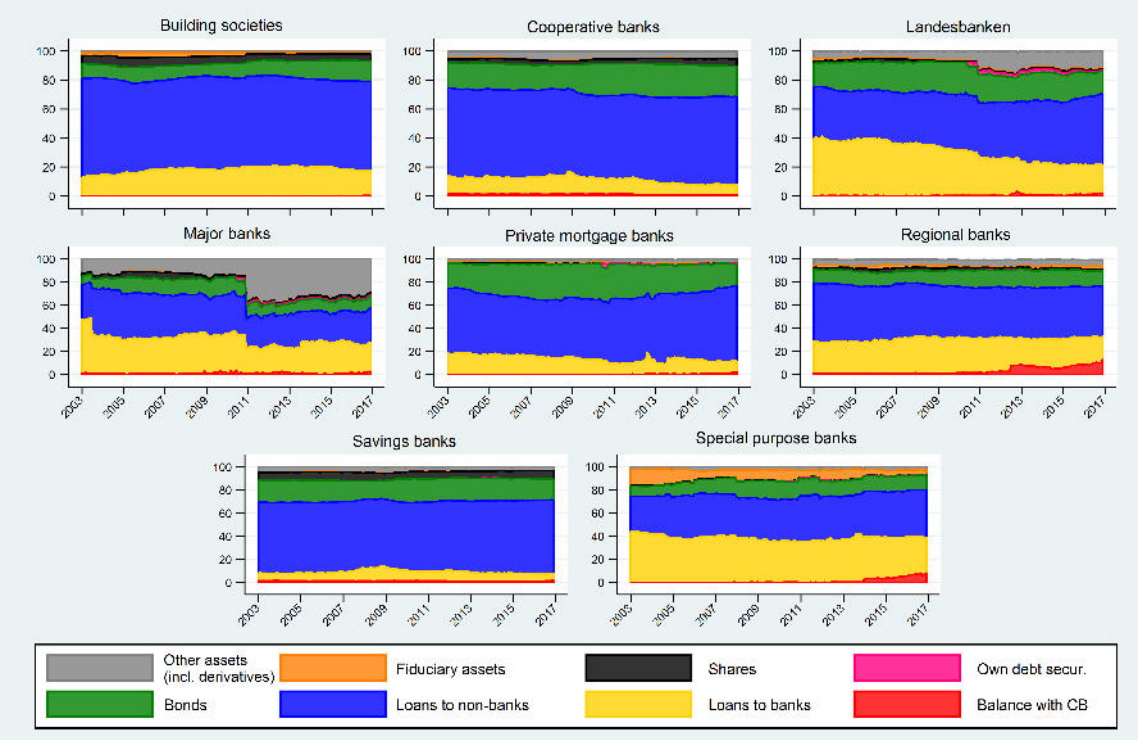
Source: Bundesbank balance sheet statistics. In billion EUR.

Figure B.2: Number of Mergers and Average Bank Income



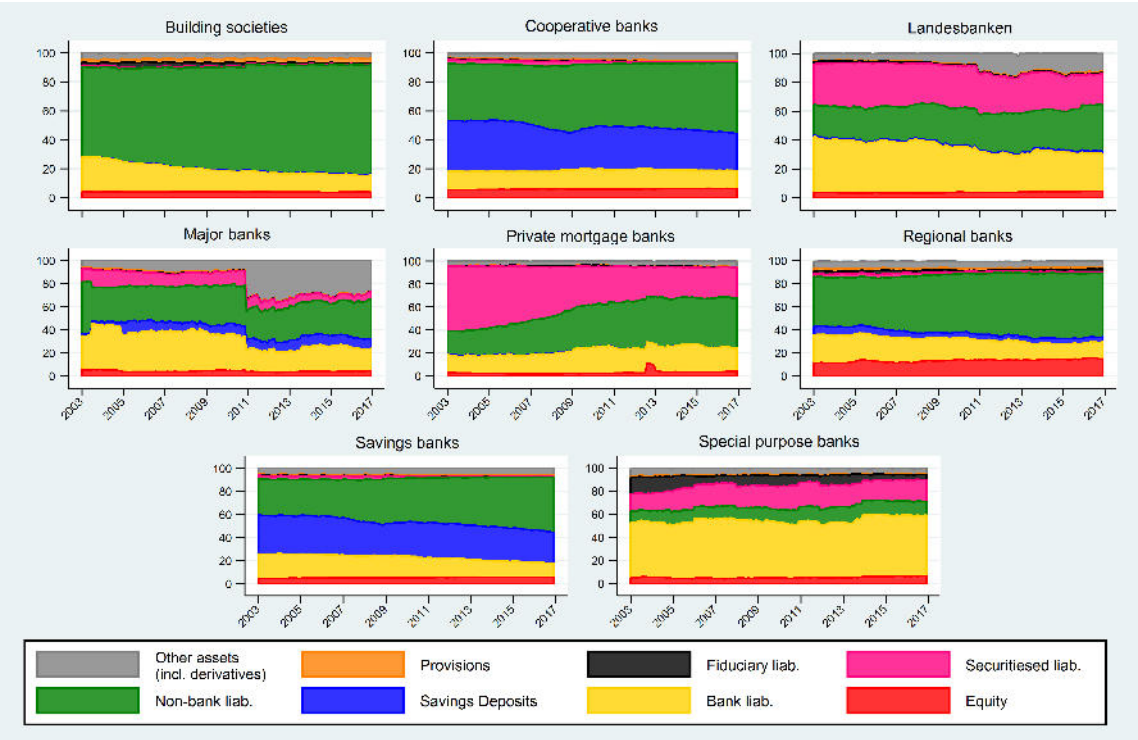
Source: Bundesbank. Own calculations. Number of mergers is summed over each month.

Figure B.3: Average Composition of Total Assets Over Time



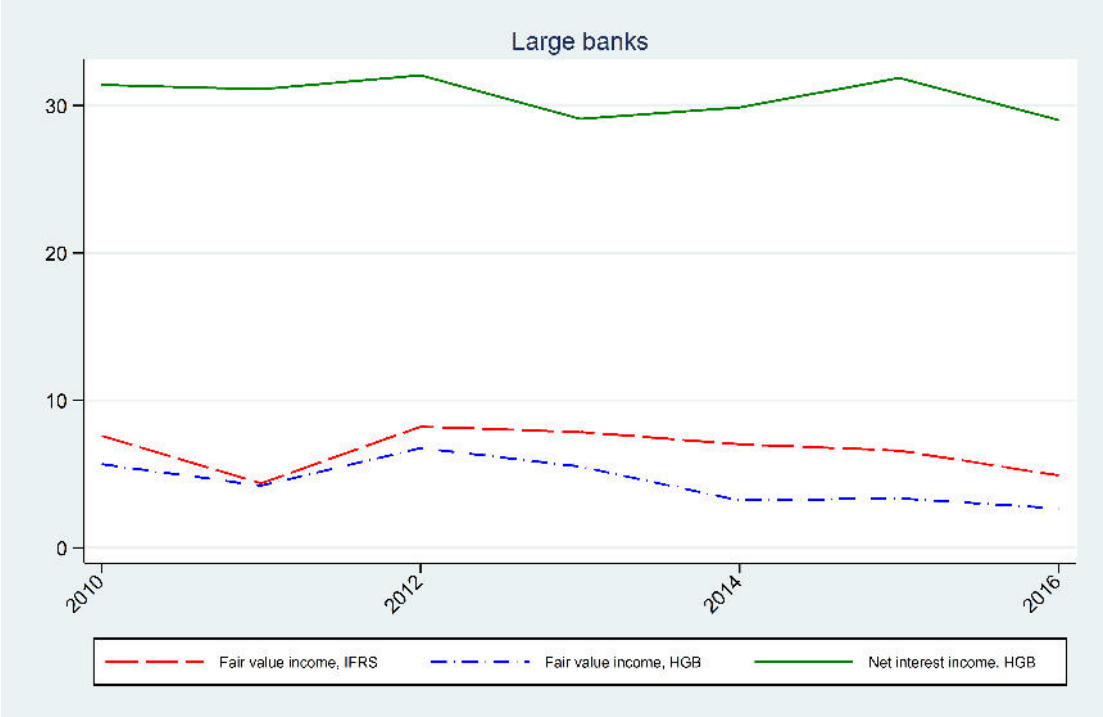
Source: Bundesbank Bank Balance Sheet Statistics. Own calculations. In percentage relative to total assets

Figure B.4: Average Composition of Total Liabilities Over Time



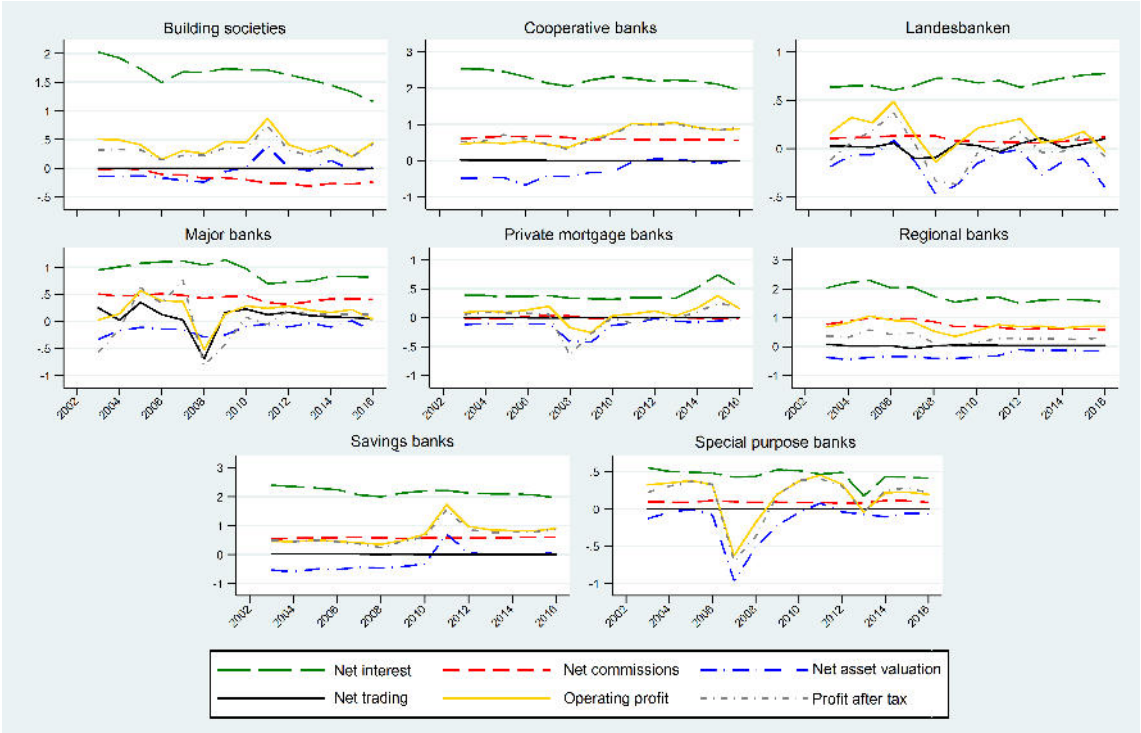
Source: Bundesbank Bank Balance Sheet Statistics. Own calculations. In percentage relative to total liabilities

Figure B.5: Total Income from Interest and Trading



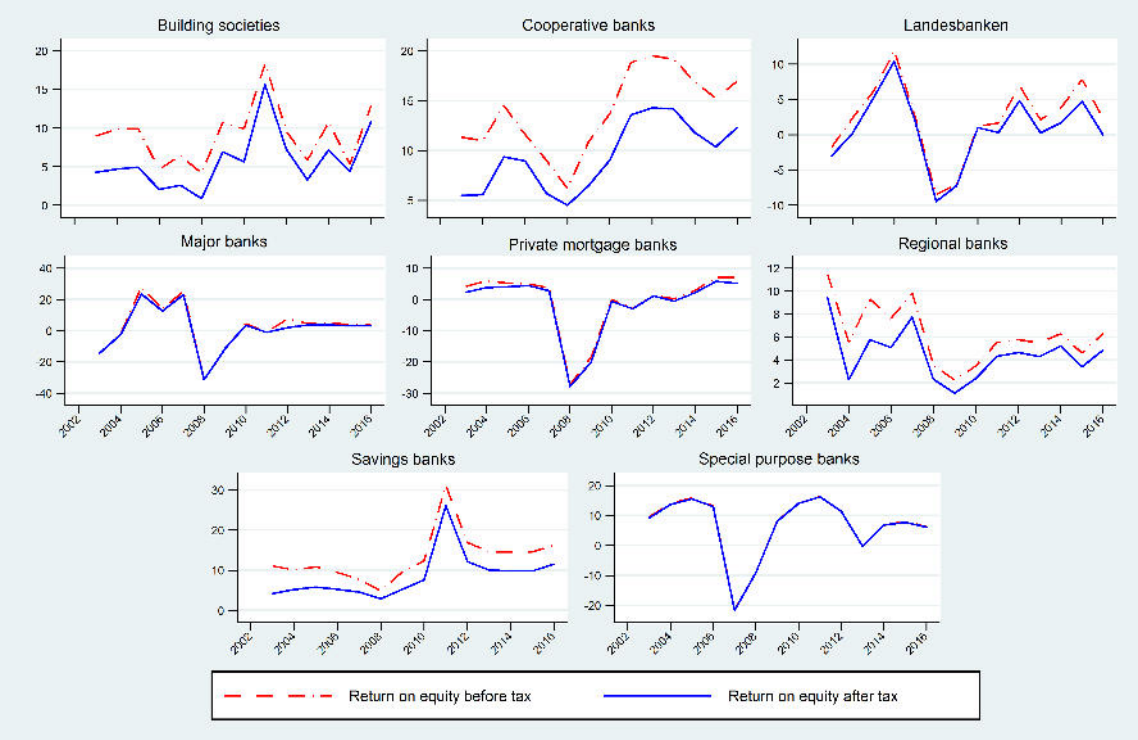
Source: Bundesbank. Own calculations. In billion EUR. IFRS trading income is only available as an aggregate statistic for all banks holdings under IFRS, which is roughly equivalent to the summed income over all Major banks, Landesbanken, and cooperative central banks.

Figure B.6: Average Net Income



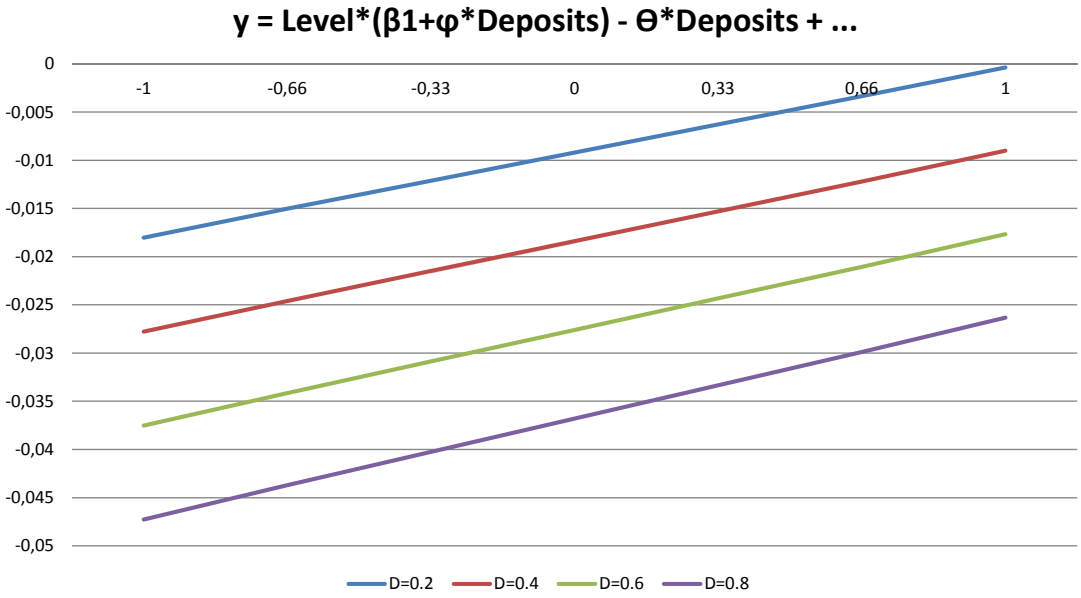
Source: Bundesbank P&L Statistics. Own calculations. Net income components relative to total assets by bank group. The averages are calculated as weighted averages of total assets.

Figure B.7: Evolution of Return on Equity



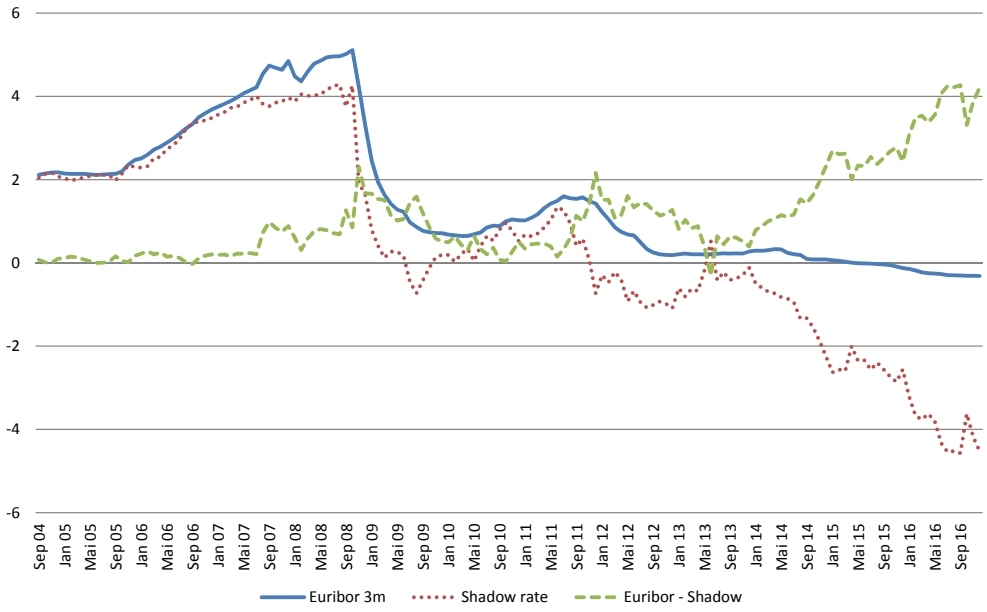
Source: Bundesbank P&L Statistics. Own calculations. The averages are calculated as weighted averages of total assets.

Figure B.8: Illustration of Impact of the Interaction Term on Net Interest Income



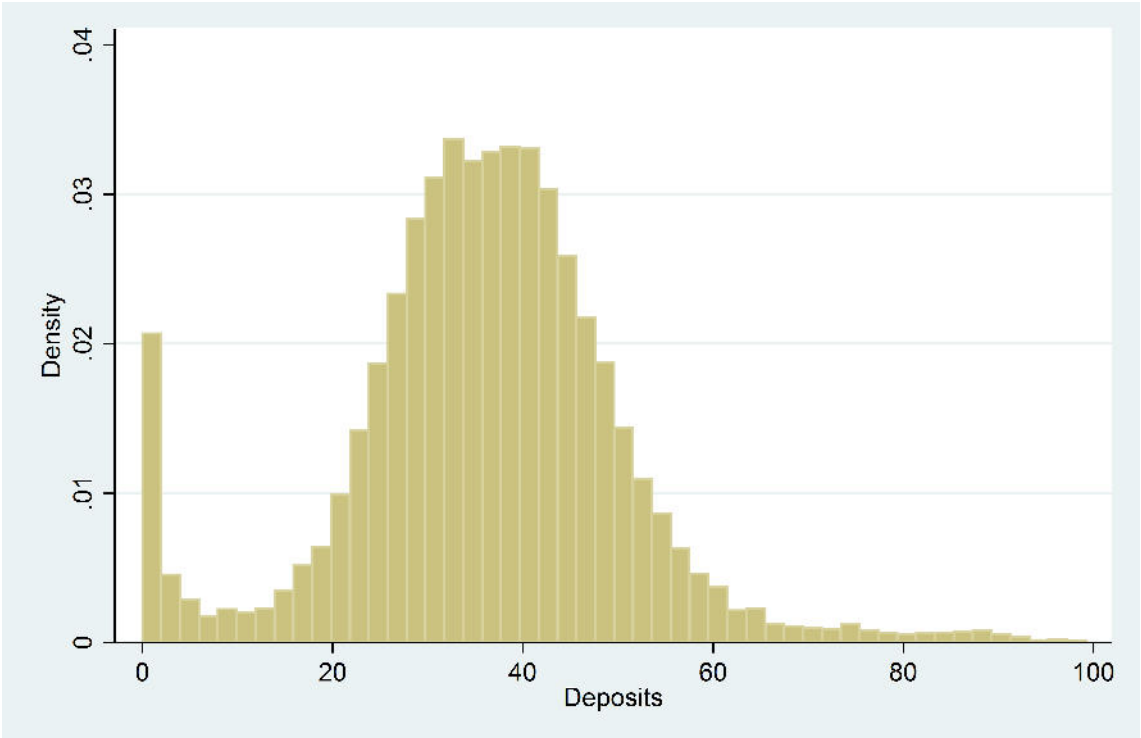
Source: Bundesbank. Own calculations based on the results of the System-GMM estimator for all banks. As the level of the interest rate increases, net interest income increases. However, higher levels of deposit shares imply a lower net interest income. This relationship becomes only significant when breaking through the ZLB.

Figure B.9: Development of Euribor and ECB Shadow Rates



Source: Wu and Xia (2017)

Figure B.10: Histogram on Monthly Bank Deposits



Source: Bundesbank Bank Balance Sheet Statistics.

Table B.2: Effect of Unconventional Monetary Policy on Net Interest Income

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Net interest, lag	0.5072***	0.5528***	0.2103*	0.5167***	0.4775***
	(0.0338)	(0.0391)	(0.1064)	(0.0118)	(0.0280)
Level	0.0315*	0.0074	-0.1886	0.0056	0.2241***
	(0.0177)	(0.0202)	(0.2524)	(0.0093)	(0.0424)
Level, sq.	-0.0080**	-0.0039	0.0327	-0.0069***	-0.0264***
	(0.0035)	(0.0028)	(0.0345)	(0.0014)	(0.0069)
Slope	0.0751***	0.0519***	0.0083	0.0641***	0.0664**
	(0.0069)	(0.0072)	(0.1261)	(0.0044)	(0.0267)
Deposit ratio * level	0.0004	-0.0004	-0.0037	0.0007***	-0.0004
	(0.0002)	(0.0005)	(0.0055)	(0.0002)	(0.0004)
Deposit ratio * UMP * level	0.0023***	0.0029***		0.0028***	0.0029**
	(0.0004)	(0.0004)		(0.0003)	(0.0014)
GDP growth YoY, lag	-0.0026***	-0.0014	0.0094	-0.0022***	0.0007
	(0.0009)	(0.0010)	(0.0325)	(0.0006)	(0.0036)
House price index, lag	-0.0023**	-0.0013	0.0000	-0.0007	0.0206***
	(0.0010)	(0.0013)	(0.0438)	(0.0007)	(0.0039)
Bank size, lag	-0.1477***	-0.1617***	0.2360	-0.0562***	-0.1021***
	(0.0211)	(0.0390)	(0.1786)	(0.0127)	(0.0319)
Leverage ratio, lag	-0.0018	-0.0225***	-0.0072	-0.0326***	-0.0205***
	(0.0044)	(0.0066)	(0.0415)	(0.0056)	(0.0039)
Efficiency, lag	-0.0236	0.1874***	-0.5110	0.1950***	0.0522
	(0.0395)	(0.0352)	(0.4624)	(0.0221)	(0.1397)
Loan ratio, lag	0.0019***	-0.0065***	0.0013	-0.0037***	-0.0041**
	(0.0006)	(0.0014)	(0.0038)	(0.0006)	(0.0017)
Deposit ratio, lag	-0.0007	-0.0048***	0.0375*	-0.0042***	-0.0001
	(0.0006)	(0.0013)	(0.0190)	(0.0006)	(0.0017)
Observations	20,485	20,485	84	17,954	1,737
Number of banks	1,599	1,599	14	1,383	155
R^2	0.4838		0.2240		
Autocorrelation 1		-4.581		-17.15	-2.729
Autocorrelation 2		0.0715		0.374	0.175

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two-step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. The regressions on small and regional banks also use the System-GMM estimator. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. Also, since this subset of the data set is a small N, small T sample the fixed effects estimator is employed. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.3: Effect of Unconventional Monetary Policy on Net Commissions

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Net commission, lag	0.6284***	0.8798***	0.4509***	0.8189***	0.8164***
	(0.0431)	(0.1255)	(0.1435)	(0.0133)	(0.0229)
Level	0.0013	0.0094	-0.0054	0.0016	0.0611
	(0.0106)	(0.0091)	(0.0597)	(0.0031)	(0.0380)
Level, sq.	-0.0010	0.0021	-0.0022	-0.0001	-0.0076
	(0.0018)	(0.0013)	(0.0076)	(0.0004)	(0.0070)
Slope	-0.0281***	-0.0126***	-0.0433	-0.0176***	-0.0269
	(0.0062)	(0.0031)	(0.0287)	(0.0016)	(0.0213)
Deposit ratio * level	-0.0000	-0.0007**	-0.0012**	0.0001**	-0.0008*
	(0.0003)	(0.0003)	(0.0005)	(0.0001)	(0.0004)
Deposit ratio * UMP * level	0.0012***	0.0014***		0.0009***	0.0025**
	(0.0003)	(0.0004)		(0.0001)	(0.0011)
GDP growth YoY, lag	-0.0028***	0.0008**	-0.0003	-0.0017***	-0.0048*
	(0.0008)	(0.0004)	(0.0060)	(0.0002)	(0.0026)
House price index, lag	0.0036***	0.0043***	0.0145	0.0052***	0.0109***
	(0.0007)	(0.0010)	(0.0089)	(0.0003)	(0.0036)
DAX, lag	-0.0818***	-0.1484***		-0.0922***	-0.2263***
	(0.0167)	(0.0175)		(0.0042)	(0.0577)
Bank size, lag	-0.1535***	0.0438	0.0867	0.0274***	0.0148
	(0.0469)	(0.0865)	(0.0780)	(0.0054)	(0.0284)
Leverage ratio, lag	0.0041	0.0021	-0.0100	-0.0107***	0.0041
	(0.0048)	(0.0130)	(0.0072)	(0.0027)	(0.0050)
Efficiency, lag	0.0470	0.0585**	0.1136	0.0331***	0.3996***
	(0.0320)	(0.0293)	(0.0777)	(0.0072)	(0.1498)
Loan ratio, lag	-0.0007	-0.0049***	0.0015	-0.0029***	-0.0053***
	(0.0006)	(0.0016)	(0.0018)	(0.0002)	(0.0016)
Deposit ratio, lag	0.0007	0.0011	0.0105*	-0.0005**	0.0003
	(0.0008)	(0.0012)	(0.0049)	(0.0002)	(0.0017)
Observations	20,485	20,485	84	17,954	1,737
Number of banks	1,599	1,599	14	1,383	155
R^2	0.4764		0.3770		
Autocorrelation 1		-3.863		-18.32	-4.158
Autocorrelation 2		-2.391		0.254	-2.327

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two-step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. The regressions on small and regional banks also use the System-GMM estimator. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. Also, since this subset of the data set is a small N, small T sample the fixed effects estimator is employed. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.4: Effect of Unconventional Monetary Policy on Net Provisions

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Net provision, lag	0.0416***	0.4764***	0.0082	0.4607***	0.3685***
	(0.0128)	(0.0353)	(0.1588)	(0.0237)	(0.0231)
Level	-0.3850***	-0.3290***	0.3534	-0.3847***	-0.1028**
	(0.0240)	(0.0386)	(0.3131)	(0.0261)	(0.0422)
Level, sq.	0.0510***	0.0534***	-0.0747	0.0654***	0.0091
	(0.0043)	(0.0063)	(0.0448)	(0.0041)	(0.0079)
Slope	0.0133	0.0300*	-0.0835	0.0708***	-0.0565**
	(0.0101)	(0.0172)	(0.1621)	(0.0119)	(0.0242)
Deposit ratio * level	-0.0002	0.0008*	0.0014	0.0011**	-0.0003
	(0.0002)	(0.0005)	(0.0070)	(0.0005)	(0.0002)
Deposit ratio * UMP * level	0.0019***	0.0061***		0.0074***	-0.0001
	(0.0006)	(0.0011)		(0.0008)	(0.0012)
GDP growth YoY, lag	0.0544***	0.0498***	0.0183	0.0596***	0.0065
	(0.0016)	(0.0027)	(0.0481)	(0.0018)	(0.0040)
House price index, lag	-0.0207***	0.0015	0.0346	-0.0052**	-0.0042
	(0.0014)	(0.0028)	(0.0454)	(0.0021)	(0.0033)
DAX, lag	-0.1064***	-0.3738***		-0.3666***	-0.0960
	(0.0259)	(0.0392)		(0.0296)	(0.0611)
Bank size, lag	0.0155	0.0535*	-0.2817	-0.1272***	0.0467*
	(0.0319)	(0.0302)	(0.2916)	(0.0313)	(0.0276)
Leverage ratio, lag	0.0067	0.0199	0.0866*	-0.1345***	0.0023
	(0.0049)	(0.0139)	(0.0410)	(0.0178)	(0.0032)
Efficiency, lag	-0.0541	3.4639***	-0.1873	3.6311***	1.1478***
	(0.0766)	(0.2343)	(0.3995)	(0.1522)	(0.1690)
Loan ratio, lag	-0.0061***	-0.0106***	-0.0024	-0.0106***	-0.0010
	(0.0008)	(0.0027)	(0.0065)	(0.0017)	(0.0011)
Deposit ratio, lag	0.0067***	0.0207***	-0.0093	0.0372***	-0.0014
	(0.0010)	(0.0041)	(0.0272)	(0.0022)	(0.0012)
Observations	20,485	20,485	84	17,954	1,737
Number of banks	1,599	1,599	14	1,383	155
R^2	0.2631		0.2717		
Autocorrelation 1		-21.16		-25.21	-5.820
Autocorrelation 2		-2.496		-4.678	0.401

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two-step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. The regressions on small and regional banks also use the System-GMM estimator. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. Also, since this subset of the data set is a small N, small T sample the fixed effects estimator is employed. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.5: Effect of Unconventional Monetary Policy on Net Trading Income

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Net trading, lag	-0.0784	0.0953	0.0070	0.0228	0.1562*
	(0.0605)	(0.0972)	(0.1148)	(0.0390)	(0.0946)
Level	-0.0008	-0.0002	-0.0893	-0.0009***	0.0037
	(0.0013)	(0.0009)	(0.0932)	(0.0003)	(0.0055)
Level, sq.	-0.0022***	-0.0017***	-0.0401	-0.0004	-0.0034
	(0.0007)	(0.0006)	(0.0449)	(0.0002)	(0.0026)
Slope	0.0082***	0.0065***	0.1464	0.0026***	0.0094
	(0.0024)	(0.0016)	(0.2345)	(0.0007)	(0.0092)
Trading book assets * DAX	-0.0001	0.0000	-0.0003	-0.0010	0.0000
	(0.0000)	(0.0001)	(0.0004)	(0.0007)	(0.0001)
Trading book liabilities * DAX	0.0000	-0.0000	-0.0001	0.0008	-0.0000
	(0.0001)	(0.0001)	(0.0003)	(0.0006)	(0.0001)
GDP growth YoY, lag	0.0015***	0.0012***	0.0406	0.0005***	0.0018
	(0.0004)	(0.0003)	(0.0401)	(0.0001)	(0.0019)
DAX, lag	0.0104**	0.0068**	0.0699	0.0026**	0.0207
	(0.0045)	(0.0033)	(0.3717)	(0.0011)	(0.0166)
Bank size, lag	-0.0015	0.0081	0.0699	0.0019	-0.0028
	(0.0017)	(0.0112)	(0.1996)	(0.0016)	(0.0077)
Leverage ratio, lag	-0.0003	0.0005	0.0251	0.0002	-0.0002
	(0.0002)	(0.0008)	(0.0257)	(0.0002)	(0.0006)
Efficiency, lag	0.0030*	0.0007	-0.0271	-0.0000	0.0137
	(0.0018)	(0.0010)	(0.1689)	(0.0005)	(0.0288)
Loan ratio, lag	-0.0000	0.0001	-0.0010	-0.0000	-0.0003
	(0.0001)	(0.0001)	(0.0028)	(0.0000)	(0.0005)
Deposit ratio, lag	0.0001	0.0001	0.0051	0.0000	-0.0000
	(0.0001)	(0.0001)	(0.0055)	(0.0000)	(0.0002)
Trading book assets, lag	-0.0007	0.0024	-0.0052	0.0131	0.0023
	(0.0012)	(0.0016)	(0.0053)	(0.0091)	(0.0016)
Trading book liabilities, lag	0.0014	-0.0015	0.0101	-0.0102	-0.0022
	(0.0012)	(0.0018)	(0.0064)	(0.0074)	(0.0015)
Observations	9,520	9,520	79	8,279	868
Number of banks	1,596	1,596	14	1,382	150
R^2	0.0202		0.3530		
Autocorrelation 1		-2.893		-3.203	-2.076
Autocorrelation 2		-0.728		-0.256	-0.393

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. The regressions on small and regional banks also use the System-GMM estimator. As fair value accounting for the trading portfolio starts only in 2010, the data set is reduced accordingly for all estimators. Also, since this subset of the data set is a small N, small T sample the fixed effects estimator is employed. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.6: Effect of UMP on Net Interest Income Using Shadow Rates

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Net interest, lag	0.5041***	0.5227***	0.2178**	0.4885***	0.4863***
	(0.0344)	(0.0434)	(0.0859)	(0.0124)	(0.0274)
Level	0.0341*	0.0063	-0.5233	0.0316***	0.2074***
	(0.0180)	(0.0151)	(0.4002)	(0.0078)	(0.0403)
Level, sq.	-0.0070**	-0.0055*	0.0748	-0.0089***	-0.0262***
	(0.0034)	(0.0029)	(0.0534)	(0.0014)	(0.0068)
Slope	0.0738***	0.0481***	-0.0959	0.0631***	0.0552**
	(0.0069)	(0.0074)	(0.1574)	(0.0044)	(0.0275)
Deposits * (level - shadow)	-0.0005***	-0.0006***	-0.0109	-0.0005***	-0.0009***
	(0.0001)	(0.0001)	(0.0086)	(0.0001)	(0.0003)
GDP growth YoY, lag	-0.0018**	-0.0014	-0.0061	-0.0022***	0.0013
	(0.0009)	(0.0009)	(0.0352)	(0.0006)	(0.0037)
House price index, lag	-0.0012	0.0012	0.0267	-0.0003	0.0229***
	(0.0012)	(0.0013)	(0.0497)	(0.0007)	(0.0039)
Bank size, lag	-0.1473***	-0.1901***	-0.0321	-0.0505***	-0.0934***
	(0.0212)	(0.0445)	(0.3088)	(0.0126)	(0.0300)
Leverage ratio, lag	-0.0012	-0.0235***	0.0124	-0.0252***	-0.0222***
	(0.0043)	(0.0065)	(0.0508)	(0.0054)	(0.0037)
Efficiency, lag	-0.0125	0.1898***	-0.3753	0.1742***	0.1036
	(0.0367)	(0.0334)	(0.4084)	(0.0218)	(0.1419)
Loan ratio, lag	0.0019***	-0.0056***	-0.0022	-0.0032***	-0.0041**
	(0.0006)	(0.0013)	(0.0038)	(0.0006)	(0.0016)
Deposit ratio, lag	0.0003	-0.0036***	0.0318	-0.0027***	0.0009
	(0.0007)	(0.0011)	(0.0239)	(0.0006)	(0.0016)
Observations	20,485	20,485	84	17,954	1,737
Number of banks	1,599	1,599	14	1,383	155
R^2	0.4838		0.2393		
Autocorrelation 1		-4.485		-17.06	-2.740
Autocorrelation 2		-0.103		-0.331	0.194

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. The regressions on small and regional banks also use the System-GMM estimator. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. Also, since this subset of the data set is a small N, small T sample the fixed effects estimator is employed. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.7: Effect of UMP on Net Commissions Using Shadow Rates

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Net commission, lag	0.6293***	0.8979***	0.4099**	0.8095***	0.8281***
	(0.0432)	(0.1086)	(0.1462)	(0.0122)	(0.0199)
Level	0.0113	-0.0005	-0.0952	0.0106***	0.0490
	(0.0104)	(0.0070)	(0.0644)	(0.0026)	(0.0392)
Level, sq.	-0.0026	0.0005	0.0090	-0.0011**	-0.0098
	(0.0018)	(0.0013)	(0.0086)	(0.0004)	(0.0079)
Slope	-0.0254***	-0.0162***	-0.0709**	-0.0160***	-0.0296
	(0.0062)	(0.0030)	(0.0242)	(0.0016)	(0.0219)
Deposits * (level - shadow)	-0.0003***	-0.0004***	-0.0028	-0.0002***	-0.0011***
	(0.0001)	(0.0001)	(0.0024)	(0.0000)	(0.0003)
GDP growth YoY, lag	-0.0031***	0.0004	-0.0045	-0.0018***	-0.0042
	(0.0008)	(0.0004)	(0.0044)	(0.0002)	(0.0026)
House price index, lag	0.0051***	0.0060***	0.0216**	0.0055***	0.0154***
	(0.0011)	(0.0010)	(0.0082)	(0.0003)	(0.0040)
DAX, lag	-0.0602***	-0.1251***		-0.0772***	-0.1832***
	(0.0184)	(0.0128)		(0.0043)	(0.0551)
Bank size, lag	-0.1550***	0.0539	0.0239	0.0209***	0.0076
	(0.0467)	(0.0764)	(0.0773)	(0.0052)	(0.0296)
Leverage ratio, lag	0.0037	0.0051	-0.0042	-0.0103***	0.0015
	(0.0048)	(0.0148)	(0.0073)	(0.0027)	(0.0056)
Efficiency, lag	0.0498	0.0568**	0.1458*	0.0319***	0.4976***
	(0.0325)	(0.0252)	(0.0760)	(0.0072)	(0.1478)
Loan ratio, lag	-0.0006	-0.0038***	0.0007	-0.0026***	-0.0062***
	(0.0006)	(0.0014)	(0.0017)	(0.0002)	(0.0017)
Deposit ratio, lag	0.0012	0.0005	0.0086	-0.0001	0.0017
	(0.0008)	(0.0012)	(0.0049)	(0.0002)	(0.0016)
Observations	20,485	20,485	84	17,954	1,737
Number of banks	1,599	1,599	14	1,383	155
R^2	0.4768		0.3876		
Autocorrelation 1		-4.085		-18.31	-4.226
Autocorrelation 2		-2.397		-0.0528	-2.330

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. The regressions on small and regional banks also use the System-GMM estimator. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. Also, since this subset of the data set is a small N, small T sample the fixed effects estimator is employed. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.8: Effect of UMP on Net Provisions Using Shadow Rates

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Net provisions, lag	0.0451***	0.5012***	0.0095	0.4966***	0.3646***
	(0.0128)	(0.0354)	(0.2088)	(0.0240)	(0.0227)
Level	-0.3528***	-0.2718***	0.6316	-0.3055***	-0.1163***
	(0.0241)	(0.0361)	(0.4799)	(0.0242)	(0.0430)
Level, sq.	0.0456***	0.0464***	-0.1113	0.0550***	0.0101
	(0.0043)	(0.0060)	(0.0689)	(0.0041)	(0.0080)
Slope	0.0218**	0.0425**	0.0006	0.0794***	-0.0548**
	(0.0102)	(0.0167)	(0.1776)	(0.0117)	(0.0245)
Deposits * (level - shadow)	-0.0010***	-0.0024***	0.0092	-0.0031***	-0.0002
	(0.0001)	(0.0002)	(0.0104)	(0.0002)	(0.0003)
GDP growth YoY, lag	0.0536***	0.0503***	0.0306	0.0583***	0.0071*
	(0.0016)	(0.0026)	(0.0572)	(0.0018)	(0.0040)
House price index, lag	-0.0151***	0.0104***	0.0114	0.0087***	-0.0032
	(0.0016)	(0.0030)	(0.0448)	(0.0024)	(0.0032)
DAX, lag	-0.0413	-0.2258***		-0.1392***	-0.0848
	(0.0278)	(0.0412)		(0.0309)	(0.0593)
Bank size, lag	0.0091	0.0216	-0.0788	-0.1664***	0.0402
	(0.0329)	(0.0290)	(0.4272)	(0.0304)	(0.0266)
Leverage ratio, lag	0.0052	0.0124	0.0777*	-0.1488***	0.0020
	(0.0049)	(0.0149)	(0.0413)	(0.0179)	(0.0031)
Efficiency, lag	-0.0164	3.6913***	-0.2554	3.8968***	1.1340***
	(0.0774)	(0.2376)	(0.2209)	(0.1541)	(0.1694)
Loan ratio, lag	-0.0059***	-0.0089***	-0.0001	-0.0075***	-0.0010
	(0.0009)	(0.0027)	(0.0083)	(0.0017)	(0.0011)
Deposit ratio, lag	0.0083***	0.0256***	-0.0098	0.0392***	-0.0014
	(0.0010)	(0.0041)	(0.0259)	(0.0021)	(0.0012)
Observations	20,485	20,485	84	17,954	1,737
Number of banks	1,599	1,599	14	1,383	155
R^2	0.2647		0.2810		
Autocorrelation 1		-21.53		-25.40	-5.816
Autocorrelation 2		-2.664		-4.530	0.396

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. The regressions on small and regional banks also use the System-GMM estimator. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. Also, since this subset of the data set is a small N, small T sample the fixed effects estimator is employed. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.9: Effect of Unconventional Monetary Policy on Bank Leverage Using Shadow Rates

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Leverage ratio, lag	0.9485***	0.8110***	0.9354***	0.9703***	0.9408***
	(0.0057)	(0.0261)	(0.0265)	(0.0071)	(0.0077)
Level	0.0047	0.0534***	-0.0499	0.0300***	-0.0112
	(0.0065)	(0.0193)	(0.0366)	(0.0018)	(0.0342)
Level, sq.	-0.0014*	-0.0071***	0.0040	-0.0045***	-0.0031
	(0.0008)	(0.0026)	(0.0050)	(0.0002)	(0.0048)
Slope	-0.0021	0.0130*	-0.0155	0.0039***	-0.0078
	(0.0021)	(0.0072)	(0.0306)	(0.0007)	(0.0195)
Deposits * (level - shadow)	-0.0003***	-0.0006***	0.0055	-0.0003***	-0.0003
	(0.0001)	(0.0001)	(0.0038)	(0.0000)	(0.0003)
GDP growth YoY, lag	0.0003	0.0028	0.0098	0.0010**	-0.0016
	(0.0008)	(0.0023)	(0.0085)	(0.0004)	(0.0068)
House price index, lag	0.0033***	0.0082***	-0.0008	0.0030***	0.0020
	(0.0005)	(0.0023)	(0.0092)	(0.0002)	(0.0035)
Bank size, lag	-0.0582**	0.4673***	0.0418	0.0477***	-0.1046***
	(0.0242)	(0.1065)	(0.0648)	(0.0091)	(0.0344)
Loan growth, lag	-0.0011***	0.0062***	-0.0002	-0.0008***	-0.0012**
	(0.0003)	(0.0016)	(0.0004)	(0.0001)	(0.0005)
Deposit ratio, lag	0.0009	-0.0076	0.0114	0.0014***	0.0001
	(0.0006)	(0.0048)	(0.0085)	(0.0004)	(0.0014)
Observations	233,787	233,787	896	205,062	19,637
Number of banks	1,622	1,622	15	1,403	160
R^2	0.9181		0.8822	0.9463	0.9112
Autocorrelation 1		-5.949			
Autocorrelation 2		2.205			

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two-step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. Since this regression is based on monthly balance sheet data, the T dimension is increased strongly decreasing the Nickell Bias. Hence, a fixed effects estimator is used for bank group specific regressions. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.10: Effect of Unconventional Monetary Policy on Loan Growth Using Shadow Rates

	(1) Fixed effects	(2) System-GMM	(3) Large banks	(4) Small banks	(5) Regional banks
Loan growth, lag	0.7971***	0.5780***	0.8556***	0.8758***	0.7318***
	(0.0111)	(0.0289)	(0.0219)	(0.0054)	(0.0181)
Level	-0.0085	-0.4620**	-1.4451	-0.0609**	-0.1284
	(0.0503)	(0.2276)	(1.0391)	(0.0270)	(0.4125)
Level, sq.	-0.0219***	-0.0169	0.1722	-0.0126***	0.0421
	(0.0072)	(0.0328)	(0.1320)	(0.0041)	(0.0708)
Slope	-0.0864***	-0.1149	-0.7662	-0.0766***	0.2979
	(0.0246)	(0.0729)	(0.7466)	(0.0141)	(0.2222)
Deposits * (level - shadow)	-0.0038***	-0.0079***	-0.0117	-0.0023***	0.0010
	(0.0006)	(0.0024)	(0.0637)	(0.0003)	(0.0026)
GDP growth YoY, lag	0.0854***	0.1334***	0.1075	0.0763***	-0.0766
	(0.0111)	(0.0295)	(0.1428)	(0.0069)	(0.0988)
House price index, lag	0.0012	-0.0400*	-0.0500	-0.0077***	-0.0064
	(0.0048)	(0.0241)	(0.2002)	(0.0025)	(0.0361)
Bank size, lag	0.1384	0.4087	-0.5377	0.3733***	0.2403
	(0.1521)	(0.7101)	(1.5462)	(0.0771)	(0.2478)
Leverage ratio, lag	0.0141*	0.5324***	0.0081	0.0337***	0.0009
	(0.0083)	(0.1044)	(0.0441)	(0.0047)	(0.0223)
Deposit ratio, lag	0.0286***	0.0848***	0.1812	0.0139***	0.0393***
	(0.0040)	(0.0269)	(0.1507)	(0.0020)	(0.0103)
Observations	234,154	234,154	960	205,210	19,703
Number of banks	1,626	1,626	16	1,404	161
R^2	0.6478		0.7487	0.7821	0.5410
Autocorrelation 1		-8.532			
Autocorrelation 2		1.676			

Notes: The fixed effects estimator uses clustered bank standard errors. The System-GMM estimator is specified as a two-step estimator with robust standard errors. The maximum number of lags used as instruments for the System-GMM estimator is capped at three. Since this regression is based on monthly balance sheet data, the T dimension is increased strongly decreasing the Nickell Bias. Hence, a fixed effects estimator is used for bank group specific regressions. To avoid the structural break through the Balance Sheet Modernisation Act, the data set for large banks is reduced to start in 2010. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.11: Diff-in-Diff on Net Interest Income

	(1) Net interest	(2) Net interest	(3) Net interest	(4) Net interest
Dep. ratio * UMP	-0.0163	-0.0902***	0.0069	-0.0634***
	(0.0492)	(0.0194)	(0.0501)	(0.0194)
Observations	7,965	7,965	7,965	7,965
Bank FE	N	Y	N	Y
Time FE	N	N	Y	Y
Number of banks		1,602		1,602

Notes: Treatment group is defined as banks with an above average deposit rate (`Deposit ratio` = 1 if > 35%). For yearly data, a time frame from 2012 to 2016 is chosen where `UMP` = 1 for $t \geq 2014$. Clustered bank standard errors are used if bank FE are included. Otherwise standard errors are defined as robust. All dummies other than the interaction term are suppressed in output. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Table B.12: Diff-in-Diff on Loan Growth

	(1) ln Loans	(2) ln Loans	(3) ln Loans	(4) ln Loans
Dep. ratio * UMP	-0.3182**	-0.1581	-0.4197***	-0.2584
	(0.1235)	(0.2920)	(0.1243)	(0.2962)
Observations	57,394	57,394	57,394	57,394
Bank FE	N	Y	N	Y
Time FE	N	N	Y	Y
Number of banks		1,600		1,600

Notes: Treatment group is defined as banks with an above average deposit rate (`Deposit ratio` = 1 if $> 35\%$). For monthly data, a time frame from 2013 to 2015 is chosen where `UMP` = 1 for $t \geq$ June 2014. Clustered bank standard errors are used if bank FE are included. Otherwise standard errors are defined as robust. All dummies other than the interaction term are suppressed in output. $***= p < 0.01$, $**= p < 0.05$, and $*= p < 0.1$.

Appendix C

Appendix to Chapter 4

C.1 Derivation of the Steady State

The analytical derivation of the steady state is fairly straight forward in our simple model. First of all, we set the values for N_S, N_M, and N_U equal to their empirical counterparts. Normalising all productivity levels equal to one in the steady state makes Y determined by parameters only. In the second step, firms optimise labour type demand via the FOC.

As standard in the literature

$$i = \frac{1}{\beta}.$$

Also, real marginal costs can easily be determined via the mark up mu

$$mc = \frac{P}{mu}.$$

Since we have a closed economy model and a fixed fraction of government consumption in steady state, we can derive household's total consumption easily via

$$Y = C + G \qquad \Rightarrow \qquad C = (1 - g)Y.$$

Our next goal is to determine skilled labour demand by firms. Note that the skilled, medium skilled, and unskilled demand are analogous in the neoclassical case[1], which is why we only show the skilled labour demand. The FOC for the demand of skilled labour was given by Equation (4.15). In steady state this reads as

$$w_S = mc(1 - \lambda - \kappa)^{\frac{1}{\zeta}} (\frac{Y}{N_S})^{\frac{1}{\zeta}}.$$

In contrast to the neoclassical model, the steady state wage for unskilled labour in the monopsony model is given by

$$w_U = \frac{mc(\lambda)^{\frac{1}{\zeta}} (\frac{Y}{N_U})^{\frac{1}{\zeta}}}{(1 + \varphi)}.$$

Given real wages, the amount of skilled, medium skilled, and unskilled working hours, and the levels of government spending, one can derive the steady state value of public transfers T via the budget constraint of the government ($G = T$). Aggregate profits in the economy are defined as $\Gamma = (P - mc)Y$. These profits are equally distributed between skilled and medium skilled households. Unskilled households do not obtain any profits since they are rule-of-thumb consumers.

To determine the distribution of consumption for each agent, we resort to the budget constraint of skilled, medium, and unskilled households (here under the assumption that the government runs a balanced budget).

For skilled and medium skilled we have

$$C_S = w_S N_S + \frac{1}{2}\Gamma - \frac{N_S}{N}T.$$

[1] The only difference being the respective weights of λ or κ.

Whereas unskilled rule-of-thumb consumers do not obtain any profits nor pay taxes

$$C_U = w_U N_U.$$

The Lagrangian multipliers for the M and S type households are analogously given by

$$\mu_S = C_S^{-\sigma}.$$

C.2 Derivation of the Wage Setting Equation

In order to save on notation, we suppress labour specific subscripts in this section.

Rewriting (4.26) in terms of real wage and wage inflation,

$$E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k N_{t,t+k} U_{C_{t+k}} \left(\frac{\tilde{w}_t w_{t+k} \prod_{i=0}^{k-1} \Pi_{t+i}^{\omega_w}}{\prod_{i=1}^{k} \pi_{t+i}^{w}} - \frac{\epsilon_w}{\epsilon_w - 1} mrs_{t,t+k} \right) = 0, \tag{C.1}$$

where $\tilde{w}_t = \widetilde{W}_t / W_t$, real wage $w_{t+k} = W_{t+k}/P_{t+k}$, and wage inflation $\pi_{t+k}^w = W_{t+k}/W_{t+k-1}$.

Log-linearising the previous expression around steady state yields

$$\widehat{\tilde{w}}_t = (1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k \left(\widehat{mrs}_{t,t+k} - \widehat{w}_{t+k} + \sum_{i=1}^{k} \widehat{\pi}_{t+i}^{w} - \sum_{i=0}^{k-1} \omega_w \widehat{\Pi}_{t+i} \right). \tag{C.2}$$

Considering the relationship of the marginal rate of substitution as,

$$\frac{mrs_{t,t+k}}{mrs_{t+k}} = \left(\frac{N_{t,t+k}}{N_{t+k}} \right)^{\varphi} = \left(\frac{\widetilde{W}_t \prod_{i=0}^{k-1} \Pi_{t+i}^{\omega}}{N_{t+k}} \right)^{-\epsilon\varphi}. \tag{C.3}$$

Applying first order approximation around steady state,

$$\begin{aligned} \widehat{mrs}_{t,t+k} &= \widehat{mrs}_{t+k} - \epsilon\varphi(\widehat{\widetilde{W}}_t - \widehat{W}_{t+k} + \sum_{i=0}^{k-1} \omega \widehat{\Pi}_{t+i}) \\ &= \widehat{mrs}_{t+k} - \epsilon\varphi(\widehat{\tilde{w}}_t - \sum_{i=1}^{k} \widehat{\pi}_{t+i}^{w} + \sum_{i=0}^{k-1} \omega \widehat{\Pi}_{t+i}). \end{aligned} \tag{C.4}$$

Plugging this into (C.2) and rearranging terms, we obtain

$$\begin{aligned} \widehat{\tilde{w}}_t = \quad & \frac{1 - \beta\theta_w}{1 + \epsilon\varphi} \sum_{k=0}^{\infty} (\beta\theta_w)^k \left(\widehat{mrs}_{t+k} - \widehat{w}_{t+k} \right) \\ & + (1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k \left(\sum_{i=1}^{k} \widehat{\pi}_{t+i}^{w} - \sum_{i=0}^{k-1} \omega \widehat{\Pi}_{t+i} \right). \end{aligned}$$

Consequently,

$$\widehat{\tilde{w}}_t - \beta\theta_w \widehat{\tilde{w}}_{t+1} = \frac{1 - \beta\theta_w}{1 + \epsilon\varphi} \left(\widehat{mrs}_t - \widehat{w}_t \right) + \beta\theta_w (\widehat{\pi}_{t+1}^{w} - \omega \widehat{\Pi}_t). \tag{C.5}$$

The log-linearised form of (4.21) can be written as

$$\widehat{W}_t = (1-\theta_w)\widehat{\widetilde{W}}_t + \theta_w \widehat{W}_{t-1} + \theta_w \omega \widehat{\Pi}_{t-1},$$

or equivalently,

$$\widehat{\widetilde{w}}_t = \frac{\theta_w}{1-\theta_w}(\widehat{w}_t - \widehat{w}_{t-1} - \omega\widehat{\Pi}_{t-1} + \widehat{\Pi}_t). \tag{C.6}$$

Plugging (C.6) into (C.5) and using $\widehat{\pi}_t^w = \widehat{w}_t - \widehat{w}_{t-1} + \widehat{\Pi}_t$ yields

$$\begin{aligned}(1+\beta)\widehat{w}_t = \beta\widehat{w}_{t+1} + \widehat{w}_{t-1} + \beta\widehat{\Pi}_{t+1} - (1+\beta\omega)\widehat{\Pi}_t + \omega\widehat{\Pi}_{t-1} + \\ + \frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\epsilon\varphi)}\left(\widehat{mrs}_t - \widehat{w}_t\right).\end{aligned} \tag{C.7}$$

C.3 Log-linear Version of the Model

The FOCs for consumption of optimising households (skilled and medium skilled) equals. For convenience, only the skilled cases are shown here

$$\hat{\mu}_{S,t} = e_{u,t} - \sigma\hat{C}_{S,t}.$$

For unskilled rule-of-thumb consumer we have

$$\hat{C}_{U,t} = \hat{N}_{U,t} + \widehat{w}_{U,t}.$$

Marginal rate of substitution between consumption and labour

$$e_{S,t} + e_{u,t} + \varphi\hat{N}_{S,t} = \widehat{mrs}_{S,t} + \hat{\mu}_{S,t}.$$

Unskilled do not have wage setting power, hence

$$\widehat{w}_{U,t} = e_{U,t} + \varphi\hat{N}_{U,t} - \sigma\hat{C}_{U,t}.$$

In the case of a binding minimum wage, ($w_{U,t} < \frac{\underline{w}-w_U}{w_U}$) the unskilled wage becomes

$$\widehat{w}_{U,t} = \underline{w} = \alpha w_U.$$

The Ricardian households' Euler equation for bonds reads as

$$\hat{\mu}_{S,t} = \hat{\mu}_{S,t+1} + \hat{i}_t - \hat{\Pi}_{t+1} + \delta\hat{C}_{S,t}.$$

Wage setting by skilled households is

$$(1+\beta)\widehat{w}_{S,t} = \beta\widehat{w}_{S,t+1} + \widehat{w}_{S,t-1} + \beta\widehat{\Pi}_{t+1} - (1+\beta\omega_S)\widehat{\Pi}_t + \omega_S\widehat{\Pi}_{t-1} + \\ + \frac{(1-\beta\theta_{w,S})(1-\theta_{w,S})}{\theta_{w,S}(1+\epsilon_S\varphi)}\left(\widehat{mrs}_{S,t} - \widehat{w}_{S,t}\right).$$

The production function of firm i is given by

$$Y^{\frac{\zeta-1}{\zeta}}(\hat{Y}_{i,t} - \widehat{e^{A_t}}) = +\lambda^{\frac{1}{\zeta}} N_U^{\frac{\zeta-1}{\zeta}}(\widehat{e^{A_{U,t}}} + \widehat{N}_{U,i,t}) + \kappa^{\frac{1}{\zeta}} N_M^{\frac{\zeta-1}{\zeta}}(\widehat{e^{A_{M,t}}} + \widehat{N}_{M,i,t}) + (1-\lambda-\kappa)^{\frac{1}{\zeta}} N_S^{\frac{\zeta-1}{\zeta}}(\widehat{e^{A_{S,t}}} + \widehat{N}_{S,i,t}).$$

Labour demand of firm i from type ℓ for the neoclassical benchmark equals

$$\widehat{w}_{\ell,t} = \frac{1}{\zeta}(\widehat{Y}_{i,t} - \widehat{N}_{\ell,i,t}) + \frac{\zeta-1}{\zeta}\left((\widehat{e^{A_t}}) + (\widehat{e^{A_{\ell,t}}})\right) + \widehat{mc}_{i,t}.$$

In this version of the model, while the steady state wage in the case of monopsony is lower the log-linearised labour the demand of unskilled labour is unchanged. Thus, in case of monopsony we have

$$\widehat{w}_{U,t} = \frac{1}{\zeta}(\widehat{Y}_{i,t} - \widehat{N}_{U,i,t}) + \frac{\zeta-1}{\zeta}\left((\widehat{e^{A_t}}) + (\widehat{e^{A_{U,t}}})\right) + \widehat{mc}_{i,t}.$$

Equilibrium in the goods market is given by

$$Y\hat{Y}_t = C_S\hat{C}_{S,t} + C_M\hat{C}_{M,t} + C_U\hat{C}_{U,t} + G\hat{G}_t.$$

The Taylor rule of the central bank is defined as

$$\hat{i}_t = \phi_i\hat{i}_{t-1} + (1-\phi_i)\left(\phi_y\hat{Y}_t + \phi_\Pi\hat{\Pi}_t\right) + v_t.$$

Finally, the New Keynesian Phillips Curve is

$$\hat{\Pi}_t - \chi\hat{\Pi}_{t-1} = \frac{(1-\theta)(1-\theta\beta)}{\theta}\hat{mc}_t + \beta(1-\theta)(\hat{\Pi}_{t+1} - \chi\hat{\Pi}_t).$$

Bibliography

Adrian, T. and Shin, H. S. (2010): "Financial intermediaries and monetary economics". *Federal Reserve Bank of New York, Staff Report* 2010(398).

Ahtik, M., Banerjee, B., and Remsak, F. (2016): "Net interest margin in a low interest rate environment: Evidence for Slovenia". *Bancni vestnik (The Journal for Money and Banking)* 65(11), pp. 77–89.

Alessandri, P. and Nelson, B. D. (2015): "Simple banking: Profitability and the yield curve". *Journal of Money, Credit and Banking* 47(1), pp. 143–175.

Altavilla, C., Boucinha, M., and Peydró, J.-L. (2014): "Monetary policy and bank profitability in a low interest rate environment". *ECB Working Paper Series* (2105).

Altavilla, C., Carboni, G., and Motto, R. (2015): "Asset purchase programmes and financial markets: Lessons from the Euro Area". *ECB Working Paper Series* (1864).

Amlinger, M., Bispinck, R., and Schulten, T. (2016): "Ein Jahr Mindestlohn in Deutschland - Erfahrungen und Perspektiven". *WSI Report - Hans-Böckler-Stiftung* 1/2016(28).

Andrade, P. et al. (2016): "The ECB's Asset Purchase Programme: An early assessment". *ECB Working Paper Series* (1956).

Arellano, M. and Bover, O. (1995): "Another look at the instrumental variable estimation of error-components models". *Journal of Econometrics* 68(1), pp. 29–51.

Arni, P. et al. (2014): "Kein Mindestlohn ohne unabhängige wissenschaftliche Evaluation". *IZA Standpunkte* 2014(65).

Ashenfelter, O. C., Farber, H., and Ransom, M. R. (2010): "Labor market monopsony". *Journal of Labor Economics* 28(2), pp. 203–210.

Bachmann, R. and Frings, H. (2017): "Monopsonistic competition, low-wage labour markets, and minimum wages: An empirical analysis." *Applied Economics* 49(51), pp. 5268–5286.

Basten, C. and Mariathasan, M. (2018): "How banks respond to negative interest rates: Evidence from the Swiss exemption threshold". *CESifo Working Paper Series* (6901).

Beatty, A. and Liao, S. (2014): "Financial accounting in the banking industry: A review of the empirical literature". *Journal of Accounting and Economics* 58(2-3), pp. 339–383.

Bech, M. L. and Malkhozov, A. (2016): "How have central banks implemented negative policy rates?" *BIS Quarterly Review* 2016(March).

Bhaskar, V. and To, T. (1999): "Minimum wages for Ronald McDonald monopsonies: A theory of monopsonistic competition". *The Economic Journal* 109(455), pp. 190–203.

Blattner, T. S. and Joyce, M. A. S. (2016): "Net bebt supply shocks in the Euro Area and the implications for QE". *ECB Working Paper Series* (1957).

Blundell, R. and Bond, S. (1998): "Initial conditions and moment restrictions in dynamic panel data models". *Journal of Econometrics* 87(1), pp. 115–143.

Boal, W. M. and Ransom, M. R. (1997): "Monopsony in the labor market". *Journal of Economic Literature* 35(1), pp. 86–112.

Boeckx, J. et al. (2014): "Effectiveness and transmission of the ECB's balance sheet policies". *CESifo Working Paper Series* (4907).

Bolt, W. et al. (2012): "Bank profitability during recessions". *Journal of Banking and Finance* 36(9), pp. 2552–2564.

Borio, C. and Gambacorta, L. (2017): "Monetary policy and bank lending in a low interest rate environment: Diminishing effectiveness?" *Journal of Macroeconomics*, pp. 1–15.

Borio, C., Gambacorta, L., and Hofmann, B. (2017): "The influence of monetary policy on bank profitability". *International Finance* 20(1), pp. 48–63.

Borio, C. and Zhu, H. (2012): "Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism?" *Journal of Financial Stability* 8(4), pp. 236–251.

Brunnermeier, M. K. and Koby, Y. (2017): "The reversal interest rate: The effective lower bound of monetary policy". *mimeo* 2017(July).

Burdett, K. and Mortensen, D. T. (1998): "Wage differentials, employer size, and unemployment". *International Economic Review* 39(2), pp. 257–273.

Busch, R. and Memmel, C. (2015): "Banks' net interest margin and the level of interest rates". *Bundesbank Discussion Paper* 2015(16).

— (2016): "Quantifying the components of the banks' net interest margin". *Financial Markets and Portfolio Management* 30(4), pp. 371–396.

Campbell, J. Y. and Mankiw, N. G. (1989): "Consumption, income, and interest rates: reinterpreting the time series evidence". *NBER Macroeconomics Annual* 4, pp. 185–216.

Card, D. and Krueger, A. B. (1994): "Minimum wages and employment: A case study of the fast-food industry in New Jersey and Pennsylvania". *American Economic Review* 84(4), pp. 772–793.

Charpe, M. and Kühn, S. (2012): "Inequality, aggregate demand and crises". *mimeo* 2012(April).

Chen, H., Curdia, V., and Ferrero, A. (2012): "The macroeconomic effects of large scale asset purchase programmes". *Economic Journal* 122(11), pp. 289–315.

Chodorow-Reich, G. (2014): "Effects of unconventional monetary policy on financial institutions". *Brookings Papers on Economic Activity* 2014(Spring), pp. 155–228.

Christensen, J. H. E. and Krogstrup, S. (2014): "Swiss unconventional monetary policy: Lessons for the transmission of quantitative easing". *Federal Reserve Bank of San Francisco Working Paper Series* 2014(18).

Christopoulou, R. and Vermeulen, P. (2012): "Markups in the Euro Area and the US over the period 1981 2004: A comparison of 50 sectors". *Empirical Economics* 42(1), pp. 53–77.

Claeys, G. and Leandro, L. (2016): "The European Central Bank's quantitative easing programme: Limitis and risks". *Bruegel Policy Contribution* 2016(04).

Claeys, G., Leandro, A., and Mandra, A. (2015): "The European Central Bank's quantitative easing programme: The detailed manual". *Bruegel Policy Contribution* 2015(02).

Clemens, J. and Wither, M. (2014): "The minimum wage and the Great Recession: Evidence of effects on the employment and income trajectories of low-skilled workers". *NBER Working Paper Series* 2014(20724).

Cœuré, B. (2016): "Assessing the implications of negative interest rates". *Speech at the Yale Financial Crisis Forum, Yale School of Management, New Haven, 28.07.2016.*

Cúrdia, V. and Woodford, M. (2011): "The central-bank balance sheet as an instrument of monetarypolicy". *Journal of Monetary Economics* 58(1), pp. 54–79.

D'Amico, S. and King, T. B. (2013): "Flow and stock effects of large-scale treasury purchases: Evidence on the importance of local supply". *Journal of Financial Economics* 108(2), pp. 425–448.

Darracq Paries, M., Halaj, G., and Kok, C. (2016): "Bank capital structure and the credit channel of central bank asset purchases". *ECB Working Paper Series* (1916).

De Santis, R. A. (2016): "Impact of the Asset Purchase Programme on Euro Area government bond yields using market news". *ECB Working Paper Series* (1939).

Dell'Ariccia, G., Laeven, L., and Marquez, R. (2014): "Real interest rates, leverage, and bank risk-taking". *Journal of Economic Theory* 149(1), pp. 65–99.

Dell'ariccia, G., Laeven, L., and Suarez, G. A. (2017): "Bank leverage and monetary policy's risk-taking channel: Evidence from the United States". *Journal of Finance* 72(2), pp. 613–654.

Demertzis, M. and Wolff, G. B. (2016): "What impact does the ECB's quantitative easing policy have on bank profitability?" *Bruegel Policy Contribution* 2016(20).

Demiralp, S., Eisenschmidt, J., and Vlassopoulos, T. (2017): "Negative interest rates, excess liquidity and bank business models: Banks reaction to unconventional monetary policy in the Euro Area". *mimeo* 2017(May).

Deutsche Bundesbank (2016): "Financial stability review". *Deutsche Bundesbank*.

Dombret, A., Gündüz, Y., and Rocholl, J. (2017): "Will German banks earn their cost of capital?" *Bundesbank Discussion Paper* 2017(01).

Drechsler, I., Savov, A., and Schnabl, P. (2017): "The deposits channel of monetary policy". *The Quarterly Journal of Economics* 132(4), pp. 1819–1876.

Dube, A., Lester, T. W., and Reich, M. (2010): "Minimum wage effects across state borders: Estimates using contiguous counties". *The Review of Economics and Statistics* 92(4), pp. 945–964.

Dube, A., Lester, T. W., and Reich, M. (2016): "Minimum wage shocks, employment flows and labor market frictions". *Journal of Labor Economics* 34(3), pp. 663–704.

ECB (2014): "Euro Area risk-free interest rates: Measurement issues, recent developments and relevance to monetary policy". *ECB Monthly Bulletin* 2014(July), pp. 79–98.

Eggertsson, G. B., Juelsrud, R., and Wold, E. G. (2017): "Are negative nominal interest rates expansionary?" *NBER Working Paper Series* 2017(24039).

Eggertsson, G. B. and Woodford, M. (2003): "The zero bound on interest rates and optimal monetary policy". *Brookings Papers on Economic Activity* 2003(1), pp. 139–235.

English, W. B. (2002): "Interest rate risk and bank net interest margins". *BIS Quarterly Review* 2002(10), pp. 67–82.

English, W. B., Heuvel, S. den, and Zakrajsek, E. (2014): "Interest rate risk and bank equity valuations". *University of Pennsylvania, Working Paper Series* 2014(05).

Eser, F. and Schwaab, B. (2016): "Evaluating the impact of unconventional monetary policy measures: Empirical evidence from the ECBs Securities Markets Programme". *Journal of Financial Economics* 119(1), pp. 147–167.

Flinn, C. J. (2006): "Minimum wage effects on labor market outcomes under search, matching, and endogenous contact rates". *Econometrica* 74(4), pp. 1013–1062.

Fratzscher, M., Lo Duca, M., and Straub, R. (2014): "ECB unconventional monetary policy actions: Market impact, international spillovers and transmission channels". *International Monetary Fund* (15th Jacques Polak Annual Research Conference).

Gagnon, J. et al. (2011): "The financial market effects of the federal reserve's large-scale asset purchases". *International Journal of Central Banking* 7(1), pp. 3–43.

Gali, J., López-Salido, J. D., and Vallés, J. (2007): "Understanding the effects of government spending on consumption". *Journal of the European Economic Association* 5(1), pp. 227–270.

Gambacorta, L., Hofmann, B., and Peersman, G. (2014): "The effectiveness of unconventional monetary policy at the zero lower bound: A cross country analysis". *Journal of Money, Credit and Banking* 46(4), pp. 615–642.

Giuliano, L. M. (2013): "Minimum wage effects on employment, substitution, and the teenage labor supply: Evidence from personnel data". *Journal of Labor Economics* 31, pp. 155–194.

Guerrieri, L. and Iacoviello, M. (2015): "OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily". *Journal of Monetary Economics* 70, pp. 22–38.

Harhoff, D. and Körting, T. (1998): "Lending relationships in Germany: Empirical rvidence from survey data". *Journal of Banking and Finance* 22, pp. 1317–1353.

Heberer, E.-M. (2010): "The effects of a minimum wage in a DSGE model: An extension of the Benassy model". *Panorama Economico* 10, pp. 7–39.

Heider, F., Saidi, F., and Schepens, G. (2017): "Life below zero: Bank lending under negative policy rates". *mimeo* 2017(May).

Henzel, S., Engelhardt, K., et al. (2014): "Arbeitsmarkteffekte des flächendeckenden Mindestlohns in Deutschland – Eine Sensitivitätsanalyse". *Ifo Schnelldienst* 67(10), pp. 23–29.

Hirsch, B., Schank, T., and Schnabel, C. (2010): "Differences in labor supply to monopsonistic firms and the gender pay gap: An empirical analysis using linked employer-employee data from Germany". *Journal of Labor Economics* 28(2), pp. 291–330.

Hirsch, B. and Jahn, E. J. (2015): "Is there monopsonistic discrimination against immigrants?" *ILR Review* 68(3), pp. 501–528.

Ioannidou, V., Ongena, S., and Peydró, J. L. (2015): "Monetary policy, risk-taking, and pricing: Evidence from a quasi-natural experiment". *Review of Finance* 19(1), pp. 95–144.

Jiménez, G. et al. (2014): "Hazardous times for monetary policy: What do twenty-three million bank loans say about the effects of monetary policy on credit tisk-taking?" *Econometrica* 82(2), pp. 463–505.

Jobst, A. and Lin, H. (2016): "Negative interest rate policy (NIRP): Implications for monetary transmission and bank profitability in the Euro Area". *IMF Working Papers* 2016(172).

Jordan, T. (2016): "Monetary policy using negative interest rates : A status report". *Speech, Swiss National Bank* 2016(October).

Joyce, M. A. S., Lasaosa, A., et al. (2011): "The financial market impact of quantitative easing in the United Kingdom". *International Journal of Central Banking* 7(3), pp. 113–161.

Joyce, M. A. S. and Tong, M. (2012): "QE and the gilt market: A disaggregated analysis". *Economic Journal* 122(564), pp. 348–384.

Kapetanios, G. et al. (2012): "Assessing the economy wide effects of quantitative easing". *Economic Journal* 122(564), pp. 316–347.

Kerbl, S. and Sigmund, M. (2017): "Negative interest rates: Forecasting banks ' profitability in a new environment". *International Journal of Forecasting* (Forthcoming).

Krishnamurthy, A. and Vissing-Jorgensen, A. (2011): "The effects of quantitative easing on interest rates: Channels and implications for policy". *Brookings Papers on Economic Activity* 2011(2), pp. 215–287.

Krusell, P. et al. (2000): "Capital-skill complementarity and inequality: A macroeconomic analysis". *Econometrica* 68(5), pp. 1029–1053.

Lambert, F. and Ueda, K. (2014): "The effects of unconventional monetary policies on bank soundness". *IMF Working Papers* 2014(152).

Lewis, V. et al. (2015): "The financial market effects of the ECB's balance sheet policies". *KU Leuven - Discussion Paper Series* 2015(20).

Maddaloni, A. and Peydró, J.-L. (2011): "Bank risk-taking, securitization, supervision, and low interest rates: Evidence from the Euro Area and the US lending standards". *The Review of Financial Studies* 24(6), pp. 2121–2165.

Manning, A. (2003): "Monopsony in motion: Imperfect competition in labor markets". *Princeton University Press.*

— (2006): "A generalised model of monopsony". *The Economic Journal* 116(508), pp. 84–100.

Mattoo, A., Neagu, I. C., and Özden, Ç. (2008): "Brain waste? Educated immigrants in the US labor market". *Journal of Development Economics* 87(2), pp. 255–269.

Moser, C. and Stähler, N. (2009): "Spillover effects of minimum wages in a two-sector search model". *Bundesbank Discussion Paper* 2009(01).

Naidu, S., Nyarko, Y., and Wang, S.-Y. (2014): "Monopsony power in migrant labor markets: Evidence from the United Arab Emirates". *Journal of Political Economy* 124(6), pp. 1735–1792.

Neely, C. J. (2015): "Unconventional monetary policy had large international effects". *Journal of Banking and Finance* 52, pp. 101–111.

Neumark, D., Salas, J. M. I., and Wascher, W. (2014): "More on recent evidence on the effects of minimum wages in the United States". *IZA Journal of Labor policy* 3(24).

Neumark, D. and Wascher, W. (1992): "Employment effects of minimum and submininimum wages: Panel data on state minimum wage laws". *Industrial & Labor Relations Review* 46(1), pp. 55–81.

Pesaran, M. H. and Smith, R. (1995): "Estimating long-run relationships from dynamic heterogeneous panels". *Journal of econometrics* 68(1), pp. 79–113.

Peters, H. (2015): "Mindestlohn: Erste negative Effekte werden sichtbar". *Deutsche Bank Research.*

Pissarides, C. A. (2000): "Equilibrium unemployment theory". *MIT press.*

Porter, Nathan and Vitek, F. (2008): "The impact of introducing a minimum wage on business cycle volatility: A structural analysis for Hong Kong SAR". *IMF Working Papers* 2008(285).

Ransom, M. R. and Oaxaca, R. L. (2010): "New market power models and sex differences in pay". *Journal of Labor Economics* 28(2), pp. 267–289.

Ransom, M. R. and Sims, D. P. (2010): "Estimating the firm's labor supply curve in a new monopsony framework: School teachers in Missouri". *Journal of Labor Economics* 28(2), pp. 331–355.

Riksbank (2015): "Monetary policy report - February 2015". 2015(February).

Robin, J.-M. (2011): "On the dynamics of unemployment and wage distributions". *Econometrica* 79(5), pp. 1327–1355.

Robinson, J. (1969): "The economics of imperfect competition". *Springer*.

Rognlie, M. (2016): "What lower bound? Monetary policy with negative interest rates". *mimeo* 2016(July).

Scheiber, T., Silgoner, M. A., Stern, C., et al. (2016): "The development of bank profitability in Denmark, Sweden and Switzerland during a period of ultra-low and negative interest rates". *Focus on European Economic Integration* 2016(Q3).

Schenkelberg, H. and Watzka, S. (2013): "Real effects of quantitative easing at the zero lower bound: Structural VAR-based evidence from Japan". *Journal of International Money and Finance* 33, pp. 327–357.

Smets, F. and Wouters, R. (2003): "An estimated dynamic stochastic general equilibrium model of the Euro Area". *Journal of the European Economic Association* 1(5), pp. 1123–1175.

Staiger, D. O., Spetz, J., and Phibbs, C. S. (2010): "Is there monopsony in the labor market? Evidence from a natural experiment". *Journal of Labor Economics* 28(2), pp. 211–236.

Stein, J. C. (2014): "Incorporating financial stability considerations into a monetary policy framework". *Speech at the International Research Forum on Monetary Policy, Washington, D.C., March 21, 2014*.

Stigler, G. J. (1946): "The economics of minimum wage legislation". *The American Economic Review* 36(3), pp. 358–365.

Strobl, E. and Walsh, F. (2014): "Monopsony, minimum wages and migration". *Ipag Business School - Working Paper Series* 2014(069).

Svensson, L. E. O. (2015): "Monetary policy and macroprudential policy: Different and separate". *mimeo* 2015(February).

Szczerbowicz, U. (2015): "The ECB unconventional monetary policies: Have they lowered market borrowing costs for banks and governments?" *International Journal of Central Banking* 11(4), pp. 91–127.

The Basel Committee (2011): "Basel III: A global regulatory framework for more resilient banks and banking systems". *Bank for International Settlements*.

Tobin, J. (1969): "A general equilibrium approach to monetary theory". *Journal of Money, Credit and Banking* 1(1), pp. 15–29.

Ugai, H. (2007): "Effects of the quantitative easing policy: A survey of empirical analyses". *Bank of Japan Working Paper Series* 2007(March).

Vayanos, D. and Vila, J.-L. (2009): "A preferred-habitat model of the term structure of interest rates". *NBER Working Paper* (15487).

Wallace, N. (1981): "A Modigliani-Miller theorem for open-market operations". *American Economic Review* 71(3), pp. 267–274.

Windmeijer, F. (2005): "A finite sample correction for the variance of linear efficient two-step GMM estimators". *Journal of Econometrics* 126(1), pp. 25–51.

Wu, J. C. and Xia, F. D. (2017): "Time-varying lower bound of interest rates in Europe". *Chicago Booth Research Paper* 2017(06).