Currency Areas, Monetary Policy, and the Macroeconomy

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Zusammenfassung

Die vorliegende Dissertation gliedert sich in zwei Teile. Der erste Teil umfasst zwei Forschungsarbeiten und analysiert die Auswirkungen der Euroeinführung auf die Mitgliedsstaaten der Eurozone. Der zweite Teil hingegen diskutiert die Modellierung eines Kreditmarktes.

Die erste Arbeit unternimmt einen Vergleich der Geldpolitik von EZB und von ausgewählten Zentralbanken des Europäischen Währungssystems (EWS). Es wird untersucht, inwiefern sich bei makroökonomischen Schocks die systematische Reaktionen der EZB von denen der nationalen Zentralbanken des EWS unterscheiden. Dabei wird in der Analyse auf die Währungshüter der vier größten Volkswirtschaften des EWS Deutschland, Frankreich, Italien und Spanien, zurückgegriffen und im Rahmen eines Mehrländer-vektorautoregressiven-Modells behandelt. Die betrachteten Schocks unterscheiden sich hinsichtlich zweier Ausprägungen. Zum einen wird zwischen Angebots- und Nachfrageschocks unterschieden, wobei die erste Art von Schock zu einer gegenläufigen Reaktion von Produktionsmenge und Verbraucherpreisinflation führt, während die zweite Art von Schock eine gleichläufige Reaktion der beiden Variablen verursacht und zusätzlich zu einem geldpolitisch motivierten Anstieg der Zinsen führt. Zum anderen unterscheiden sich die Schocks in der Symmetrie ihrer Wirkungsweise. Das heißt, es wird zwischen nationalen (asymmetrischen) und länderübergreifenden (symmetrischen) Schocks unterschieden. Die Ergebnisse der Analyse legen nahe, dass es in der Tat Unterschiede in den systematischen Re-

aktionen der Währungshüter von EWU und EWS gibt. Während des EWS fällt die Deutsche Bundesbank durch ihren preisstabilitätsorientierten Kurs auf, da sie im Gegensatz zu den anderen Zentralbanken mit Zinserhöhungen auf inflationäre nationale Angebotsschocks reagiert. Nur bei einem symmetrischen Angebotsschock sind signifikante Zinserhöhungen in allen vier Ländern festzustellen, was im Einklang mit der Konstruktionsweise des EWS ist. Im EWS waren alle Mitgliedsländer durch bilaterale Wechselkursparitäten aneinander gebunden. Dabei hatte Deutschland eine hervorgehobene Rolle, da die deutsche Währung als nominaler Anker des EWS fungierte. Erhöhte die Deutsche Bundesbank die Zinsen, so kamen die anderen Währungen unter Abwertungsdruck und mussten ihre Währungen mit Zinssteigerungen stützen. Im Gegensatz dazu wird in der EWU eine andere geldpolitische Orientierung beobachtet. Hier verhält es sich so, dass die EZB potentiell mit Zinssenkungen auf jegliche Art von Angebotsschock reagiert, was eine Orientierung auf Outputstabilisierung nahelegt. Darüber hinaus kann bei der Reaktion auf Nachfrageschocks insbesondere der asymmetrische Charakter der Geldpolitik in einer Währungsunion gezeigt werden. Bei einem länderspezifischen Nachfrageschock sollten gemäß dem Taylor-Prinzip die Zinsen stärker steigen als die Preise, um ein Ansteigen des Realzinses zu erreichen. Dies ist zum Beispiel für einen Nachfrageschock in Deutschland während des EWS beobachtbar. In der EWU hingegen reagiert die EZB aufgrund der Ausrichtung auf die gesamte Eurozone nur partiell auf nationale Nachfrageschocks, wodurch ein Ansteigen des Realzinses in den jeweiligen Ländern nicht erfolgt (außer in Deutschland). Bei einem länderübergreifenden Nachfrageschock hingegen kann die Europäische Zentralbank adäquat reagieren und setzt durch den Anstieg der Nominalzinsen eine Realzinserhöhung in fast allen analysierten Ländern durch.

Nach der allgemeinen geldpolitischen Analyse der beiden Währungssystemen beschäftigt sich das zweite Arbeitspapier mit den Auswirkungen der Euroeinführung anhand eines konkreten Beispiels. Der jüngste Boom-Bust-Zyklus auf dem spanischen Immobilienmarkt und die spiegelbildliche Verschlechterung und nachfolgende Stabilisierung der Leistungsbilanz Spaniens stehen dabei im Mittelpunkt. Um die Ursachen für diese gegenläufige Entwicklung genauer zu untersuchen, werden die Daten auf vier Hypothesen hin analysiert. Dafür werden die vier Hypothesen in einem DSGE-Modell simuliert und theoretische Vorzeichenrestriktionen abgeleitet, die anschließend mithilfe eines vektorautoregressiven Modells (VAR) auf ihren empirischen Gehalt hin evaluiert werden. Bei den Schocks werden zwischen zwei Spanien-spezifischen Pull-Hypothesen und zwei EWU-spezifischen Push-Hypothesen unterschieden. Zur ersten Gruppe gehören eine Lockerung der Kreditfinanzierungskonditionen in Spanien und ein spekulativer Immobilienpreisschock auf dem spanischen Immobilienmarkt. Zur zweiten Gruppe zählen ein Risikoprämienschock auf spanische Staatsanleihen sowie ein Konsumpräferenzschock im Rest der Eurozone. Die Studie liefert die folgenden Ergebnisse: Alle Schocks, bis auf die Lockerung der Kreditkonditionen, können die negative Korrelation zwischen dem Immobilienmarkt und der Leistungsbilanz erklären. Im Kontrast dazu führt die Lockerung von Kreditkonditionen zu einer Kontraktion in Immobilienpreisen und in Investitionen für Wohnbauten. Bezüglich dem Erklärungsgehalt der einzelnen Schocks ergibt sich ein homogenes Bild, welches die Hervorhebung eines spezifischen Schocks oder Schockgruppe verhindert.

Abschließend beschäftigt sich das letzte Forschungspapier mit der Modellierung des Kreditmarktes. In diesem Modell wird die Kreditmenge durch das Zusammenspiel von profitmaximierenden Banken auf der Angebotsseite und dem kreditnachfragenden Nichtbankensektor auf der Nachfrageseite bestimmt. Des weiteren übt die Zentralbank Einfluss auf den Bankensektor und damit auf das Kreditangebot aus, indem sie die Zinsen für Zentralbankgeldreserven bestimmt. Neben der Refinanzierung bei der Zentralbank und Depositeneinwerbung kann sich der Bankensektor ebenfalls durch die Emission von Anleihen am Kapitalmarkt refinanzieren. Zusätzlich halten Banken Eigenkapital vor. Um das theoretische Modell empirisch zu unterlegen, wird ein Kreditmarkt für den deutschen Unternehmenssektor geschätzt. Die Variablen für Angebots- und Nachfrageseite werden nach den ihr entsprechenden Pendants im theoretischen Modell ausgewählt. Aufgrund der Informationsstruktur auf Kreditmärkten wird ein Ungleichgewichtsmodell geschätzt, welches die Möglichkeit eröffnet, dass Angebot und Nachfrage divergieren und deshalb eine Marktseite rationiert ist.

Die Ergebnisse des Arbeitspapiers sind die folgenden: Die Resultate der Schätzung weisen auf eine signifikante Rolle von Preisvariablen in der Bestimmung der Kreditmenge hin. Dies unterstützt den preistheoretischen Modellierungsansatz des theoretischen Modells. Im Speziellen beeinflussen ertragswirksame Variablen des Bankensektors das Kreditangebot. Auf der Nachfrageseite hingegen haben gesamtwirtschaftliche Produktion und Opportunitätskosten der Finanzierung einen signifikanten Einfluss auf die Kreditnachfrage.

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Chapter 1

Introduction

"The whole is greater than the sum of its parts."

Aristotle

This thesis comprises three papers, whose research agendas can be organized into two categories. The first two papers focus on the economics of the Economic and Monetary Union (EMU), while the third paper presents a model of the credit market. Although the two areas are not directly connected, a synthesis of the three papers is provided at the end of this thesis.

I begin the introduction by focusing on the first two papers, which analyze features of the EMU. In summary, the first two papers study the extent to which the introduction of the Euro and the formation of a monetary union influence the behavior of agents and macroeconomic aggregates in the Eurozone. It is widely recognized that the launch of the EMU has had repercussions at many levels; it is impossible to capture these diverse effects in a single work, as evidenced by the multitude of studies on the subject. Therefore, the goal of these two studies is to focus on certain macroeconomic developments of the recent past and evaluate how they are linked to the creation of the EMU. In other words, the scope of the analysis is to pinpoint and classify changes and innovations that are potential sources for some of the patterns observed in Eurozone data.

Chapter 2 comprises the first paper, beginning the investigation of the EMU with a historic review in which the EMU is compared with the monetary regime which preceded it, the European Monetary System (EMS). As a preliminary stage of the EMU, the EMS was essential in paving the way for the former's establishment. In contrast to the EMU, where a single monetary authority, the European Central Bank (ECB), is in charge of conducting monetary policy, the EMS still featured national monetary authorities that could theoretically engage in an independent monetary policy. However, the agreement of the members to keep bilateral exchange rates between the participating countries within a parity band of ±2,5% (±6% for the Italian Lira) represented a constraint on monetary policy.[1]

In this paper, I analyze the two monetary regimes by studying the systematic monetary policy responses to macroeconomic shocks. This is one possible approach for identifying differences or similarities in central banks' reaction functions during the EMS and the EMU. For this purpose, I estimate a panel vector autoregression (PVAR) that includes the four largest economies of the current Eurozone: France, Germany, Italy, and Spain. In total, two PVAR models are estimated, where each model is based on a sample that exclusively covers one regime. In order to outline differences in how monetary policy is conducted, I identify sign-restricted aggregate demand and aggregate supply shocks and compare the endogenous responses of those money market rates which reflect the monetary policy stance of the considered monetary authority. A further defining characteristic of the shocks is their symmetry: I study country-specific (asymmetric) shocks that exogenously impact a single national economy and symmetric shocks that exogenously impact all countries in the model. Demand shocks push prices and output in the same direction, whereas supply shocks trigger opposing reactions in the variables. The conclusions from this study are as follows. During the EMS, conditional on idiosyncratic inflationary supply shocks, only the German central bank seems to react by increasing interest rates in the medium-run, thus favoring price stabilization rather than output stabilization. The other national central banks do not seem to react significantly with interest rate increases. When a symmetric supply shock occurs in the member countries of the

[1] After the ERM crisis in 1992/93, the bands were widened to ±15%.

EMS, however, all countries follow the German central bank in increasing money market rates. This illustrates the institutional character of the EMS, in which the German currency acted as nominal anchor for the monetary system. This situation implied that the other members of the EMS imported partially the policy of the German Bundesbank by following its interest rate decisions in order to protect the currency parity. This observation contrasts with those for the EMU. When facing an inflationary supply shock, the ECB decreases interest rates, apparently favoring output stabilization over price stabilization. One explanation for this observation could be a change in the preferences of monetary policy makers. Moreover, the asymmetric character of monetary policy in a currency union is uncovered via the analysis. According to the Taylor principle, an increase in inflation should be countered by a greater than one-to-one increase in the interest rate. In other words, the real interest rate should be increased to curb the economic expansion. Studying the response of real market rates after a country-specific inflationary demand shock during the EMU, I am unable to detect a significant increase in real market rates. This finding can be explained by the fact that the ECB targets the general price level of the EMU rather than a specific national price level. In the case of a symmetric demand shock, the ECB responds in an optimal manner, increasing the interest rate more than proportionally to the price level increases. This yields a significant increase in real market rates for the majority of the countries in the sample.

Following a general study that focuses on the differences in monetary policy of two monetary systems, the second paper, comprising Chapter 3, departs from considerations of the pre-EMU period and concentrates specifically on the special features of the EMU. More concretely, in this paper my co-authors and I study the recent boom-bust cycle of the housing market in Spain, which coincided with rising and subsequently falling current account deficits. Investigating the case of the Spanish economy allows us to uncover mechanisms that apply to every member country of a currency union, despite country-specific characteristics. This analysis, therefore, contributes to the literature on currency unions and the implications of such frameworks for their member countries.

The analysis is based on an open-economy mixed-frequency VAR model in which Spain and the rest of the EMU, as an aggregate, are jointly modeled. The theoretical foundation is provided by a New Keynesian DSGE model that is tailored to capture the specific features of a monetary union. The model incorporates two country blocks, namely the domestic country (Spain) and the foreign country block (rest of the EMU). In addition, the model exhibits several nominal and real frictions. We use the DSGE model to obtain robust sign restrictions that can be applied in our empirical model to identify shocks via the sign-restriction approach. In total, we analyze four innovations that are likely to be among the drivers of the recent boom-bust cycle in Spain. In particular, within our specification we test which of these innovations are able to explain the negative correlation between the housing market and the current account, and evaluate their quantitative importance in explaining fluctuations in the data.

The four hypotheses can be divided into two categories: *pull factors* and *push factors*. The first category includes factors that originate in the home country, i.e., Spain, whereas the second category comprises those innovations whose source is located outside of the home country, i.e. somewhere else in the EMU or at the EMU level. We analyze two shocks from each category. Representatives of *pull factors* include a financial easing shock and a housing bubble shock. We interpret these two shocks in the following way. The financial easing shock represents a general easing of credit standards that increased the credit supply to the Spanish economy and led, in turn, to an expansion of aggregate demand. The second pull factor example is the housing bubble shock, which captures the dynamics of a speculative bubble in the housing market where the belief of perpetual housing price increases spur the demand for housing which, in the sense of a self-fulfilling prophecy, further increases housing prices. The wealth effects stemming from increases in property values may affect the dynamics in other sectors of the economy. The push factor representatives, meanwhile, comprise a risk premium shock and a discount factor shock in the rest of the EMU. The risk premium shock captures dynamics from Euro-related institutional changes. Both the creation of and preceding expectations about a common capital market led to the elimination of country-specific risk premia and thereby to a convergence of sovereign bond rates. The result was substantial easing in financing conditions for selected EMU member states, which stimulated aggregate demand in those countries. Finally, a discount factor shock in the rest of the EMU[2] deals with the diverging dynamics when comparing Spain with core countries like Germany. Spain joined the Euro Area with greater economic momentum, as illustrated by lower saving rates in comparison with the rest of the EMU. As a consequence, low nominal interest rates at the Euro level that were consistent with respect to a Eurozone Taylor rule, as well as relatively high inflation rates in Spain, implied low Spanish real rates that incentivized expansion in (real) investment.

The results of our study are as follows. All shocks aside from the financial easing shock are able to explain the negative correlation between housing markets and the current account in Spain. In contrast, the financial easing shock fails to explain the observed correlation and suggests a decline in residential investment as well as housing prices. With respect to the forecast error variance decomposition, we obtain a homogenous picture that prevents us from singling out any shock, or any category of shocks, as the source which best explains macroeconomic variation.

From a broader perspective, the two preceding studies are complementary in that they provide insights into different aspects of the EMU. The first paper, in Chapter 2, focuses explicitly on the monetary policy of the ECB and contrasts it with the monetary policy of former national central banks during the EMS. The second paper, in Chapter 3, focuses exclusively on the EMU period and studies the implications of being a member of a currency union through the example of the Spanish economy.

The third and last paper, comprising Chapter 4, differs from the previous studies. In this paper my co-authors and I present a basic model of the market for bank credit that emphasizes the endogenous character of money creation in a monetary economy. In this model, credit is determined by the interaction of the profit-maximizing banking sector on the supply side and the credit-demanding non-bank sector on the demand side. Furthermore, the central bank enters the framework by setting the refinancing conditions for the banking sector. In addition to deposits and central

[2] In the actual paper we label the discount factor shock as a savings glut shock.

bank credit as a source of refinancing, the banks have the opportunity to refinance their business via the issuance of bonds and holdings of equity. We complement our theoretical model with an empirical analysis of the German credit market for firms to verify the adequacy of our theoretical foundation. Due to the specific information structure in credit markets, we estimate a disequilibrium model that allows for non-equilibrating demand and supply quantities.

Our findings are as follows. The regression results indicate that prices play an important role in determining credit, a result which underlines our price-theoretic modeling approach. In particular, price variables that influence the revenue of banks exert a positive influence on credit supply. On the demand side, economic activity and financing costs contribute significantly to the determination of credit demand. Finally, the empirical model singles out two periods that are characterized by disequilibrium in the German firm credit market. During the early 2000s, the economic slowdown in Germany was indicative of a surplus in the supply of credit, whereas in the run-up to the financial crisis, dynamics in the real economy were stronger and credit demand exceeded credit supply.

Chapter 2

Monetary Policy and Shock Transmission: EMS and EMU

2.1 Introduction

As the Maastricht-Treaty celebrates its twenty-fifth birthday, the European Union looks back on a long process of economic and political integration. Undoubtedly, in this process the launch of the currency union brought about deep institutional changes. By completing stage three of the European Economic and Monetary Union (EMU) in 1999, the founding countries moved from a system of linked exchange rates (EMS) to complete monetary integration. The Euro became the new common currency and the European Central Bank (ECB) was created as the sole manager of monetary policy in the Eurozone.[1]

Within this new institutional framework, the question arises whether the macroeconomic adjustment following shocks is altered. In other words, is it the case that the same types of shocks propagate differently, and do policy-makers respond alterna-

[1] A survey on the views by economists who critically followed the European monetary unification is provided by Jonung and Drea (2010).

tively under the new institutional regime. The economic mechanisms in a monetary union have been studied in detail (De Grauwe, 2016; Angeloni and Ehrmann, 2004). Notably, idiosyncratic (country-specific) inflationary shocks – such as aggregate demand and aggregate supply shocks – have different implications in a currency union because member countries can no longer attenuate the effects of these shocks by monetary tightening, e.g., raising interest rates. Furthermore, it is unlikely that the ECB responds to idiosyncratic inflationary shocks in the same way national central banks would have responded since the ECB's mandate for price stability targets a harmonized price index of the whole EMU rather than the price level of a specific country. This means that the ECB is likely to react if there is pressure on the union-wide price level. This entails two consequences. The first consequence, known as the "Walters Critique", suggests diverging dynamics in a currency union stemming from inflation differentials. An idiosyncratic shock that drives up the national price level of a member state, decreases the real interest rate in that country as nominal rates are fixed at the area level. Since the ECB reacts only partially to the price increase, the decrease in real rates is not fully offset, which further spurs aggregate demand and inflation. The second consequence results from the loss of the nominal exchange rate. Each country that enters a currency union finds itself in a fixed exchange rate system with its fellow member countries. Relative competitiveness among them is now determined by the relation of national price levels. In this situation, price increases in a single country translate immediately into a loss of competitiveness with respect to its peer members. Since external devaluation via the exchange rate is no longer an option, the only way to regain competitiveness is by devaluating internally, i.e., via deflation. Such an adjustment measure is costly in economic terms and politically difficult to push through (Wasmer, 2012). Yet, it is not clear whether the costs of abandoning the exchange rate outweigh the benefits or vice versa. It depends on whether the nominal exchange rate is a source of shocks or rather a shock absorber.[2]

[2]Friedman (1953) and Mundell (1961) emphasize the shock-mediating role of flexible exchange rates. In case of a negative external demand shock, an exchange rate depreciation helps to insulate the domestic economy and stabilize output. Empirically, Edwards and Yeyati (2005) support the shock-absorbing role of flexible exchange rates. Artis and Ehrmann (2006) study four advanced economies where findings vary from one economy to the other. Finally, on the other end of the

Aside from the specific shock transmission in a monetary union, analyzing the behavior of the ECB is an intriguing subject to study as well. As a newly created institution, there was a great deal of uncertainty surrounding the way it would manage the monetary policy of the currency union. Instead of establishing a reputation over time, the ECB was designed after the Bundesbank with a high degree of policy independence and a narrow mandate of price stability, which helped endow the ECB with credibility from the outset (Woodford, 2007). Exemplified by the two-pillar strategy of the ECB, the emphasis on monetary analysis (first pillar) next to economic analysis (second pillar) bears witness of the monetarist mindset of the Bundesbank.[3] With that in mind, it is interesting to analyze the ECB's reaction to economic disturbances and compare its behavior with the reaction of former national monetary authorities of the EMS.

For the analysis of the two monetary regimes, we estimate a Bayesian panel vector autoregression (PVAR) with the four largest economies of the Eurozone: France, Germany, Italy, and Spain. The joint modeling approach has the advantage of taking into account international linkages and feedback effects between these major Eurozone countries. For each monetary regime we estimate a separate PVAR. The EMS sample period extends from 1980 to 1991, whereas the EMU sample period starts with the advent of the Euro in 1999 and ends in 2008, before the financial crisis spilled over to real activity. This sample split separates the two regimes and presents a solid basis to uncover the macroeconomic shock transmission and policy reactions during the two monetary systems. We exclude the interim period from the estimation because it includes the convergence process towards the monetary union, illustrated by merging interest and inflation rates. To study the change in the transmission process between the two regimes, we closely track the macroeconomic adjustment following two types of inflationary shocks. The first shock, an aggregate demand shock, creates inflation, increases output, and raises interest rates, which reflects the monetary policy reaction. The second shock, an aggregate supply shock,

spectrum, Farrant and Peersman (2006) identify a prominent role for autonomous exchange rate fluctuations, fostering the source-of-shocks view.

[3]Empirically, it is not at all clear to what extent money growth (first pillar) has played a significant role in the ECB's policy decisions (Carstensen and Colavecchio, 2006).

pushes inflation and output in opposite directions. To make the analysis more refined, we differentiate between country-specific and symmetric shocks, where the former shock originates in a specific country, while the latter shock impacts all countries in the sample simultaneously. Making this distinction has several merits. First, it allows to investigate if there is a difference in the propagation of symmetric and asymmetric shocks. Second, the analysis at the aggregated and disaggregated level helps detect changes in the conduct of monetary policy, which changed from reaction functions of national central banks, responding to country-specific economic conditions, to a single policy rule of one institution, monitoring the average evolution of the EMU.

For inference we apply the estimation approach proposed by Giannone et al. (2015). They use a Bayesian hierarchical model structure in which relatively uninformative hyperpriors control the distribution of the priors. Their approach has at least two advantages. First, a data-driven algorithm automatically chooses the optimal amount of shrinkage and, second, the algorithm induces enough shrinkage to deal with problems arising from parameter proliferation and small samples (curse of dimensionality).

The main findings are as follows. First, when comparing the results from the EMS with the EMU, we find a change in the systematic reaction to shocks by the monetary authorities of the respective regimes. During the EMS, the German central bank reacted with an interest rate increase to an inflationary supply shock, which indicates a tendency towards inflation stabilization. In the case of a symmetric supply shock, all central banks react in lockstep and raise interest rates. Since the Deutsche Mark acted as anchor currency of the EMS, interest rate increases by the Bundesbank led to downward pressure on the other currencies, which had to be stabilized by their national monetary authorities via interest rate increases. Thus, the German central bank played the role of a leader in setting monetary policy during the EMS. Second, during the EMU, however, monetary policy seems to be oriented towards output stabilization, i.e., interest rates are lowered in the face of an inflationary supply shock. Third, we document the asymmetric character of monetary policy in a currency union. In the case of idiosyncratic demand shocks, the ECB does not raise nominal interest rates enough to achieve an increase in national real market rates. However, the reaction to a symmetric demand shock is strong enough to achieve an increase in real market rates via a higher nominal rate.

The paper is organized as follows. Section 2.2 provides an overview of related literature. Section 2.3 presents the empirical model and estimation approach. Section 2.4 illustrates the empirical findings and Section 2.5 concludes.

2.2 Related literature

There is a large strand of literature that focuses on the economic implications of the EMU (Mongelli and Vega, 2006; Alesina and Giavazzi, 2010). In the following, we relate our study to areas of research that are closest. This comprises studies that analyze the monetary policy of the ECB, of former national central banks of the EMS, and the transmission of macroeconomic shocks under the new institutional framework.

Focusing on the conduct of monetary policy, economists have analyzed the reaction function of the ECB and compared it with reaction functions of other central banks. Studies that estimate reaction functions of central banks typically specify a Taylor rule-type of response function, which targets a measure of economic activity (e.g. the output gap) and inflation. Depending on the analysis, the model is augmented with additional variables to which the central bank might respond as well. Faust et al. (2001) represents an early assessment of the monetary policy by the ECB. They estimate a forward-looking reaction function in spirit of Clarida et al. (2000) for the Bundesbank, based on data prior to 1999, and perform a counterfactual experiment by predicting ECB interest rates with the Bundesbank parameters and EMU data. Their main result is that actual interest rates have been lower than what is predicted by the model.[4] Offering several explanations, they eventually attribute the discrepancy to differing preferences of the two central banks, with the ECB putting more weight on the output gap. Evidence from later studies, like Hayo

[4]See also Gerlach and Schnabel (2000); Gerdesmeier and Roffia (2003); Clausen and Hayo (2005) for results on a synthetic Euro Area. An analysis of the German central bank can be found in Bernanke et al. (1997); Clarida et al. (1998).

and Hofmann (2006), support the hypothesis of a change in preferences of monetary authorities. With more data being available, they go beyond the analysis by Faust et al. (2001) and estimate separate policy functions for the Bundesbank and the ECB. They find similar weight estimates for inflation, but the ECB's weight for output is larger. Belke and Polleit (2007) compare Taylor rules for the ECB and the FED and incorporate money growth variables and the Euro-Dollar exchange rate into the model to improve the estimation fit.[5] Interestingly, their estimation results of the ECB response function even go as far as to reverse the importance of output and inflation stabilization. The response to inflation is rather small, whereas the quantitative importance of the output gap is comparatively much larger. This implies a violation of the Taylor principle, which states that the interest rate increase should be greater than the increase in inflation.[6]

Instead of specifying and testing a particular reaction function of the monetary authorities during the EMS and EMU period, we document the monetary policy reaction to inflationary shocks in a panel VAR framework by tracking movements in money market rates. They should reflect the actual policy stance of the monetary authority concerned and provide information on its policy orientation towards inflation or output stabilization.

Closest to our study is Amisano et al. (2009), who analyze the effect of the EMU on the transmission mechanism of idiosyncratic demand and cost-push shocks in a time-varying VAR model for Italy. Except for the elimination of idiosyncratic monetary policy shocks as a source of relative performance variability, the authors do not find strong evidence that the EMU changed the transmission of shocks. Their study is appealing as they estimate a time-varying parameter VAR. Time variation is introduced by specifying a smooth transition function that models the transition from the pre-EMU regime to the EMU regime.[7] This results into state-dependent impulse responses that arise from the same model. We deviate from their

[5]For the ECB they use a sample period from January 1999 to August 2005. The FED sample starts in August 1987, including the "Greenspan era".

[6]Related studies obtain similar results. See, e.g., Gerdesmeier and Roffia (2003); Surico (2003); Ullrich (2003).

[7]The word "smooth" refers to the functional form, e.g., logistic, that specifies the transition path between states. The opposite would be a discrete specification that jumps between states as in Markov switching models.

approach and estimate a constant parameter VAR because the model size would render inference in a time-varying framework unstable. Moreover, the selection of an appropriate sample that is representative for a specific regime suffices to capture its innate dynamics. Even though the model in this study is time-invariant, the approach in this paper surpasses the design of their study in several respects. First, they estimate a VAR for Italy in relative terms, which has several drawbacks. By focusing on one country alone, international linkages and spillovers are not taken into account. Second, modeling the VAR in relative terms makes it impossible to locate the origin of the shock, e.g., a domestic shock in Italy versus a foreign shock in the rest of the Eurozone, and assumes that both shocks propagate in the same way. The authors concede these points and are aware that an alternative approach can yield qualitatively different results. In contrast, our modeling approach accounts for both of these shortcomings.

2.3 Model

2.3.1 A panel VAR model

We model the behavior of the four major EMU economies - France, Germany, Italy, and Spain - in a panel vector autoregression (PVAR). The virtues of modeling macroeconomic relationships with VARs were first pointed out in the seminal paper by Sims (1980) and have become a standard approach in empirical macroeconomics ever since. Advances in computing power and better data quality made it feasible to start applying the multi-country extensions of VAR models, whose estimation procedures are more demanding (Canova and Ciccarelli, 2009). PVARs have the advantage that they can account for international linkages and open up the avenue for investigating the transmission of (idiosyncratic) shocks across economies. Alternative multi-country models comprise global VARs and factor models, however, they lack the complexity of a PVAR by casting the data into a lower dimensional space (Korobilis, 2016). A PVAR is able to explicitly model international correlations and is therefore more adequate to analyze the transmission of shocks among

Eurozone countries, whereas abstracting from cross-country linkages would lead to biased results. The model reads as:

$$\mathbf{Y}_t = \sum_{i=1}^{p} \mathbf{A}_i \mathbf{Y}_{t-i} + \mathbf{U}_t, \text{where } \mathbf{U}_t \overset{iid}{\sim} (\mathbf{0}, \mathbf{\Sigma_U}) \text{ for } t = 1, ..., T. \tag{2.1}$$

$\mathbf{Y}'_t = [\mathbf{y}'_{1t}, ..., \mathbf{y}'_{nt}]$ is a vector of nk_1 endogenous variables from n countries with k_1 variables each and $\mathbf{U}_t$ is a vector of reduced-form residuals with zero mean and a $nk_1 \times nk_1$ variance-covariance matrix $\mathbf{\Sigma_U}$. $\mathbf{A}_i$ is the $nk_1 \times nk_1$ matrix that contains the autoregressive coefficients of the endogenous variables and p indicates the lag order.

2.3.2 Data

The sample contains monthly data from 1980 to 2008. The sample is split into two subsamples where the first subsample ranges from 1980 to 1991, prior to the ERM Crisis in 1992.[8] The second subsample starts with the inception of the Euro in 1999 and ends in 2008, before the effects of the crisis affected real activity. Starting and ending points are chosen such that each period covers one regime (EMS and EMU). The baseline specification for the EMS regime comprises the following endogenous variables:

$$\mathbf{Y}_t^{\text{EMS}} = [\texttt{IP}_{1t}, \pi_{1t}^{\texttt{CPI}}, \texttt{REER}_{1t}, \texttt{MMR}_{1t}, ..., \texttt{IP}_{nt}, \pi_{nt}^{\texttt{CPI}}, \texttt{REER}_{nt}, \texttt{MMR}_{nt}]'. \tag{2.2}$$

The endogenous variable vector for the EMU regime reads slightly different:

$$\mathbf{Y}_t^{\text{EMU}} = [\texttt{IP}_{1t}, \pi_{1t}^{\texttt{CPI}}, \texttt{REER}_{1t}, ..., \texttt{IP}_{nt}, \pi_{nt}^{\texttt{CPI}}, \texttt{REER}_{nt}, \texttt{EURIBOR}_{t}]'. \tag{2.3}$$

With the introduction of the Euro, national money market rates were replaced by union-wide rates. For the EMS regime, we use the national 3-month money market rate (`MMR`) to reflect the stance of monetary policy. Concordantly, we employ the 3-month Euro Interbank Offered Rate (`EURIBOR`) during the EMU regime.[9] The

[8] Another reason for not going beyond 1991 are the non-linear dynamics that emanate from the German reunification and result into not well-behaved impulse responses.

[9] Even though EONIA is closer to the monetary policy target, EURIBOR is used in order to preserve consistency with the maturity of EMS interest rates.

other variables do not change in number throughout the sample. Industrial production (IP) is included as a measure of economic activity, the monthly consumer price inflation ($\pi^{\mathtt{CPI}}$) represents the price variable, and the real effective exchange rate (REER) tracks the competitiveness of an individual country.[10] All variables are in levels and logs, except for interest rates and inflation rates that are in levels. Whenever necessary, variables are adjusted for linear and quadratic trends as well as seasonality. By including variables in levels, we allow for implicit estimation of long-run relationships in the data (Sims et al., 1990). All data are drawn from public sources. For further information see Section 2.6.3.

2.3.3 Econometric approach

We estimate the Bayesian PVAR following the procedure in Giannone et al. (2015). They use a hierarchical model structure in which prior and likelihood are complemented by a hyperprior, which is a prior for the parameters of the prior. The authors observe that choosing the informativeness of the prior is conceptually equivalent to doing inference on any other parameter of the model. Hence, they consider the parameters of the prior as random variables that follow a distribution on their own (hyperprior), parametrized by so-called hyperparameters.

Their method is appealing because of their data-driven selection of shrinkage, i.e., larger models with little data get tighter priors than smaller models with many observations. Besides the good results from forecasting exercises, their method also performs well in terms of the accuracy of impulse response functions for identified VAR models.

[10] In this analysis, An increase of the real effective exchange rate index represents a real appreciation.

The authors choose a general setting for their Bayesian estimation of a vector autoregression. The VAR coefficients, represented by $\mathbf{\Phi}$, and the variance-covariance matrix, $\mathbf{\Sigma}$, belong to a Normal-Inverse-Wishart family:

$$\mathbf{\Sigma} \sim \mathrm{IW}(\Psi, d) \text{ and} \tag{2.4}$$

$$\mathbf{\Phi}|\mathbf{\Sigma} \sim \mathrm{N}(b, \mathbf{\Sigma} \otimes \mathbf{\Omega}), \tag{2.5}$$

where $\mathbf{\Sigma}$ follows an Inverse-Wishart distribution and $\mathbf{\Phi}$ conditional on $\mathbf{\Sigma}$ a Normal distribution. The prior distributions of $\mathbf{\Sigma}$ and $\mathbf{\Phi}$ are parametrized by Ψ, d, b and $\mathbf{\Omega}$, which themselves are determined by prior distributions, parametrized by a vector of hyperparameters γ. This exemplifies the hierarchical structure of the model. The degrees of freedom for the prior distribution of $\mathbf{\Sigma}$ are set to $d = n + 2$. The scale matrix, Ψ, is assumed to be diagonal and its diagonal entries, ψ_l, can be treated as hyperparameters.

In the following, we briefly illustrate the authors' choice of priors and hyperpriors that shape the conditional prior for $\mathbf{\Phi}$. They rely on a combination of symmetrically applied conjugate priors: the Minnesota prior, sum-of-coefficients prior, and dummy-initial-observation prior. The basis of their estimation is the Minnesota prior (Litterman, 1979, 1980). This prior allows to introduce preconceptions about the behavior of variables. For a persistent time series like GDP a random walk specification may be appropriate, which amounts to setting the prior mean of the first own lag equal to one. On the contrary, it is unusual for growth rates to exhibit trends such that they are rather described by mean-reverting behavior, which would justify a first lag coefficient equal to zero. Formally, the preceding ideas take the following form:

$$\mathbb{E}\Big[(\mathbf{A}_i)_{kl}\Big|\mathbf{\Sigma}\Big] = \begin{cases} \eta_l \in [0,1], & \text{if } l = k \text{ and } i = 1 \\ 0, & \text{otherwise,} \end{cases} \tag{2.6}$$

$$\mathrm{Cov}\Big[(\mathbf{A}_i)_{kl}, (\mathbf{A}_j)_{mn}\Big|\mathbf{\Sigma}\Big] = \begin{cases} \lambda^2 \frac{1}{i^2} \frac{\mathbf{\Sigma}_{km}}{\psi_l/(d-n-1)}, & \text{if } n = l \text{ and } i = j \\ 0, & \text{otherwise.} \end{cases} \tag{2.7}$$

Accordingly, η_l, the first order autoregressive coefficient, is set to a value between zero and one to capture the persistence in the behavior of a time series. The off-diagonal elements of the first lag matrix and all coefficient matrices of higher lag order are assigned a prior mean of zero. Coefficients of the same variable and lag order are allowed to co-vary across equations, which enriches the correlation structure in the model. λ controls the overall shrinkage of the covariances. $1/i^2$ is a factor that describes the rate at which prior covariances decrease in lag length. The last term, involving ψ_l, represents a scaling factor that corrects for different measurement and data variability.

The other two priors help to correct for dynamics originating from deterministic components. More precisely, it turns out that empirically fitted VARs exhibit stronger deviations from the data in the beginning of the sample than at the end of the sample when conditioned on initial observations (Sims, 1992). As a consequence, priors have been introduced to limit the influence of the deterministic components. This is done by augmenting the data with dummy observations. The sum-of-coefficients prior assumes that the sum of the own lags of a variable is equal to one, whereas the sums of the other variables' lags are centered at zero. The prior also creates correlation among the coefficients across equations. The hyperparameter μ controls the variability of the sum-of-coefficients prior. For μ going to infinity, the prior becomes uninformative, whereas a value close to zero implies a unit root in each equation without any cointegration relationship. Complementing the sum-of-coefficients prior, the dummy-initial-observation prior implies that the initial observations (average of first p lags) represent a good forecast. This prior is controlled by the hyperparameter δ. As δ goes to infinity, the prior becomes uninformative. For δ approaching zero, all variables are forced to be at their unconditional mean. In contrast to the sum-of-coefficients prior, this specification is consistent with cointegration. For the setting of the hyperparameters, we concur with the authors' value choices. λ, μ, and δ follow Gamma distributions with mode 0.2, 1, and 1, respectively. Standard deviations are set to 0.4, 1, and 1, respectively. Likewise, the hyperprior of ψ follows an Inverse-Gamma distribution with both parameters fixed at $(0.02)^2$. The chosen hyperpriors are rather uninformative.

2.3.4 Identification of shocks

The identification of structural shocks is based on the sign-restriction approach.[11] Let $\mathbf{E}_t$ denote the vector of structural innovations from Model (2.1). $\mathbf{E}_t$ can be linked to the white-noise error vector, $\mathbf{U}_t$, via a matrix $\tilde{\mathbf{P}}$, such that $\tilde{\mathbf{P}}\mathbf{E}_t = \mathbf{U}_t$. Using the Cholesky-decomposition, the variance-covariance matrix, $\mathbf{\Sigma_U}$, can be factorized into the product of a triangular matrix and its transpose, i.e., $\mathbf{\Sigma_U} = \mathbf{PP}'$. Clearly, $\mathbf{PP}'$ equals $\mathbf{PQQ}'\mathbf{P}'$, where $\mathbf{Q}$ is an orthonormal matrix. Consequently, setting $\tilde{\mathbf{P}} = \mathbf{PQ}$ yields the matrix that maps $\mathbf{E}_t$ linearly into $\mathbf{U}_t$. A whole range of structural impulses can be generated by repeatedly drawing $\mathbf{Q}$ matrices and combining them with the estimated Cholesky factors $\mathbf{P}$. This is where sign restrictions become important in the sense that only those candidate impulses are kept which satisfy the pre-imposed sign restrictions and discarding the others. The number of restricted horizons in the baseline estimation is 9 months, i.e., 3 quarters.[12] In order to obtain the rotation matrix $\mathbf{Q}$, we use the algorithm suggested by Rubio-Ramirez et al. (2010). Draw a $nk_1 \times nk_1$ matrix $\mathbf{N}$ of standard normally distributed random variables and derive $\mathbf{Q}$ from $\mathbf{N}$ with a QR-decomposition, such that $\mathbf{N} = \mathbf{QR}$ with $\mathbf{QQ}' = \mathbf{I}$. Finally, the diagonal elements of $\mathbf{P}$ are normalized to be positive.

The aggregate demand and aggregate supply shocks are based on a simple identification scheme and absorb a broad range of shocks, which could be separated within a more elaborate model with a more detailed set of restrictions. The restrictions we impose are consistent with a large class of macroeconomic models.[13]

First, the aggregate demand shock is identified as an innovation that drives up inflation, industrial production, and the interest rate. A non-exhaustive list of prominent shocks that are subsumed by the aggregate demand shock are government spending shocks, investment shocks, risk premium shocks, preference shocks, and credit supply shocks. Notably, restricting the money market rate to increase separates the aggregated demand shock from the monetary policy shock. Monetary policy shocks are usually identified by restricting the policy instrument to fall

[11] See, e.g., Faust (1998); Canova and De Nicolo (2002); Uhlig (2005); Peersman (2005).
[12] In robustness exercises the number of restricted horizons has been varied from 3 to 9 months.
[13] This includes, e.g., Peersman (2005); Peersman and Straub (2006); Smets and Wouters (2007).

when prices and output increase. On the contrary, an aggregate demand shock is identified by an increase in the policy rate that mirrors the contractionary policy response of the central bank. If the transmission channels of monetary policy function smoothly, market rates should follow the policy rate and thereby reflect the course of monetary policy actions. In order to sort out these two shocks, we restrict the money market rate to increase in the second month for one period and leave it otherwise unrestricted.

Second, the aggregate supply shock decreases industrial production and creates inflation. The identification of this shock also covers numerous shocks. Important supply shock representatives are technology shocks and oil supply shocks. In contrast to the aggregate demand shock, we leave the interest rate unrestricted and let the data determine the response. Since it is a priori not clear if the monetary authority values output stability higher than price stability, we restrain from precluding the qualitative outcome.[14] The real effective exchange rate is left unrestricted.

Table 2.1: Benchmark sign restrictions

Variable	Aggregate Demand	Aggregate Supply
Industrial Production	+	-
Inflation	+	+
Real Effective Exchange Rate		
Money Market Rate	+*	

Notes: we impose the restrictions for nine months as ≤ 0 or ≥ 0.
* The money market rate is only restricted in the second month after impact.

[14] In contrast to our identification scheme, Peersman (2005); Fratzscher et al. (2009), for example, restrict the interest rate to increase following a supply shock in a VAR framework. Furthermore, DSGE models usually also imply an increase in the nominal rate because the monetary authority follows the Taylor principle. See, e.g., Peersman and Straub (2006); Canova and Paustian (2011).

2.4 Results

2.4.1 Baseline model

The results include impulse response estimates of the EMS and EMU period. We present the results of individual demand and supply shocks as well as for symmetric demand and supply shocks. In the baseline scenario we apply 12 lags for both PVAR estimations.[15] After a burn-in phase we select every tenth draw of a total of 10000 draws from the posterior distribution. This results in 1000 Bayesian draws which in combination with a **Q** draw yield one candidate impulse response. The estimation procedure stops when a total of 1000 sign-consistent draws for each shock are reached. Impulse responses are presented as 68 percent posterior probability intervals (shaded area) with the solid line representing the median response. All responses are based on innovations with unit variance. Technically, reporting the median and 68 percent intervals mixes up responses from different structural models. Therefore, Fry and Pagan (2011) suggest to indicate the response of the model that is closest to the median response (median target). For the sake of illustrative clarity, results are displayed with median responses and 68 percent posterior probability intervals.

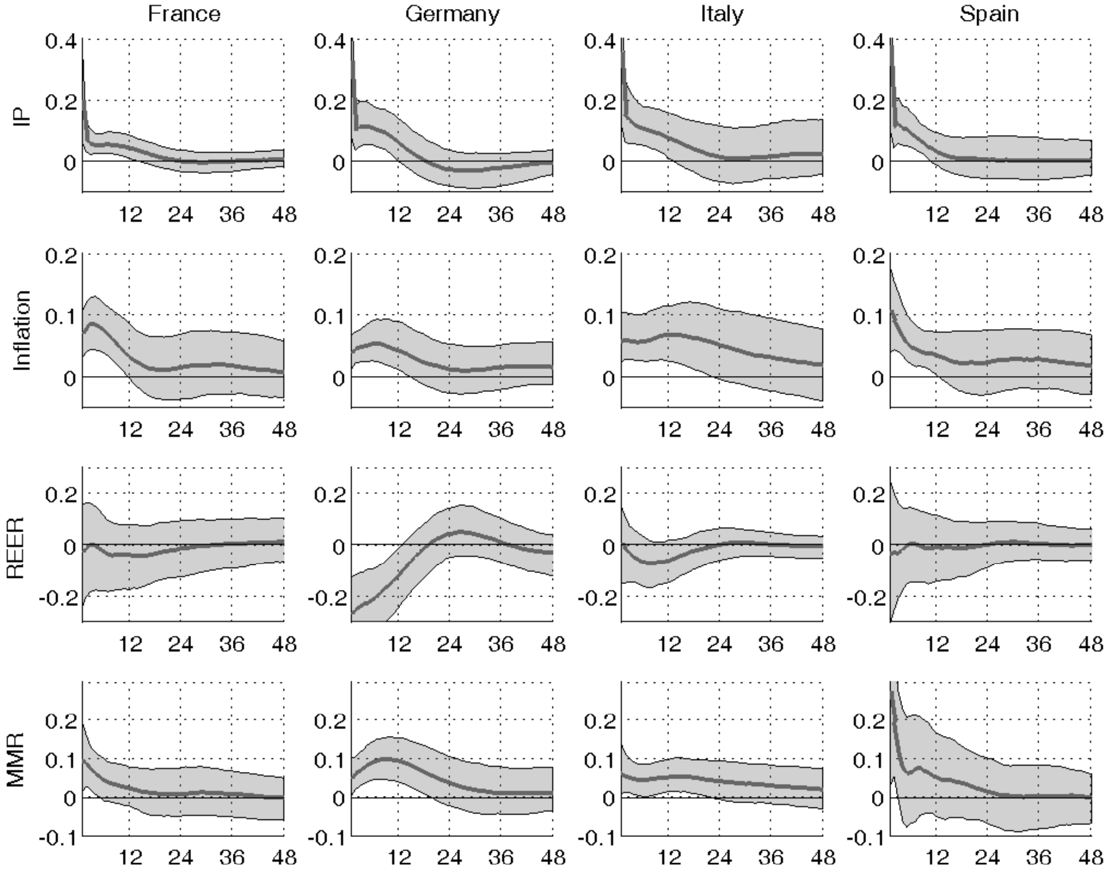
2.4.2 EMS impulse responses

Figure 2.1 displays the effects of idiosyncratic demand shocks in each country for the EMS period. For Germany, Italy, and Spain, we see an increase in industrial production of about 0.35 percent and for France around 0.2 percent. The significant increase extends beyond the restricted horizon of 9 months up to 12 months. The inflation response is similar but more persistent in most cases. The increase in inflation is significant from 12 to 20 months.

On impact, the median response varies around 0.05 percentage points for France, Germany, and Italy, while Spain has a larger response of about 0.1 percentage points.

[15] All models are tested for robustness with respect to their lag lengths by varying the lag length. See Section 2.4.4.

Figure 2.1: EMS: Ididosyncratic demand shock

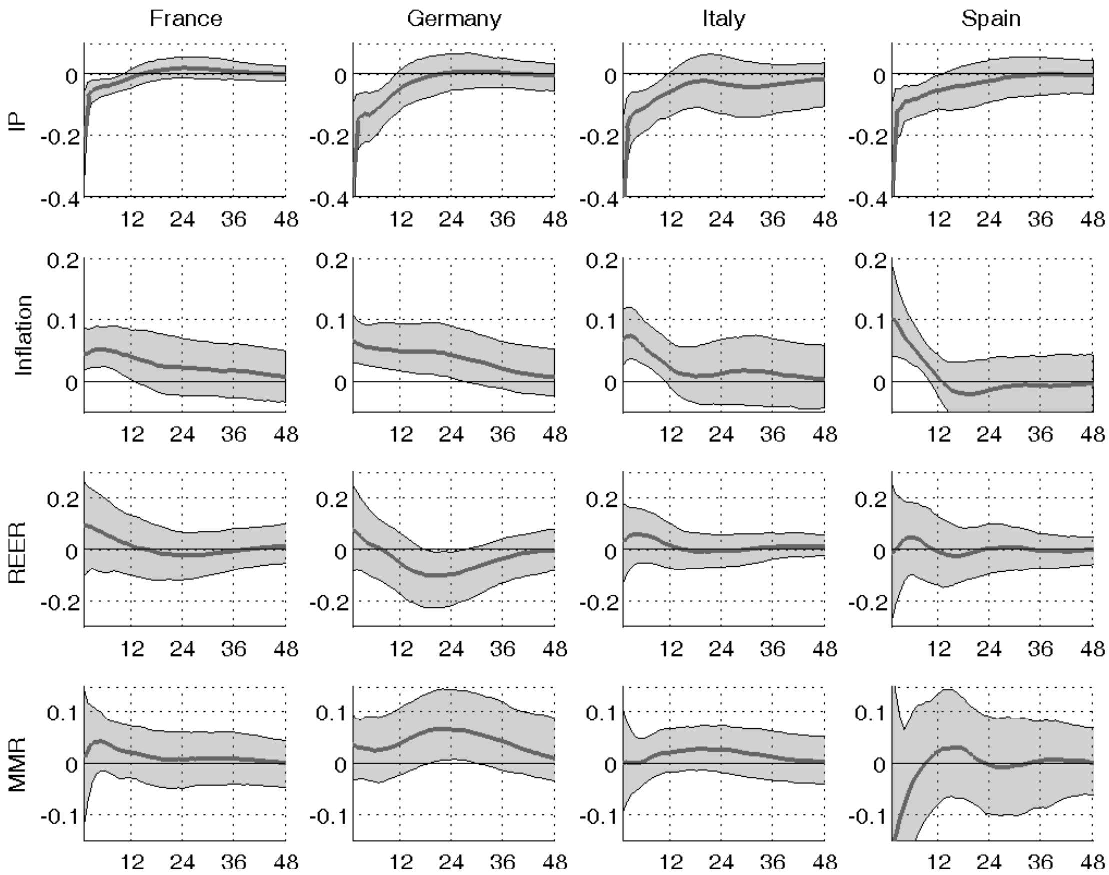


Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

The interest rate responses are somewhat more diverse. For France, Germany, and Italy, we detect a median increase from 0.05 to 0.1 percentage points, while the median of the Spanish rate increases around 0.25 percentage points. For France and Spain, the response is significant for 3 to 6 months. For Germany and Italy, we observe a much more prolonged and significant response up to 2 years. The magnitude of the Spanish response comes from the fact that the Spanish central bank targeted money supply throughout the eighties leading to volatile interest rates (Cabrero et al., 1997). The increase in interest rates reflects the response of monetary authorities to counter the increase in inflation.

In all four cases, the reaction of monetary authorities keeps the real interest rate

Figure 2.2: EMS: Idiosyncratic supply shock

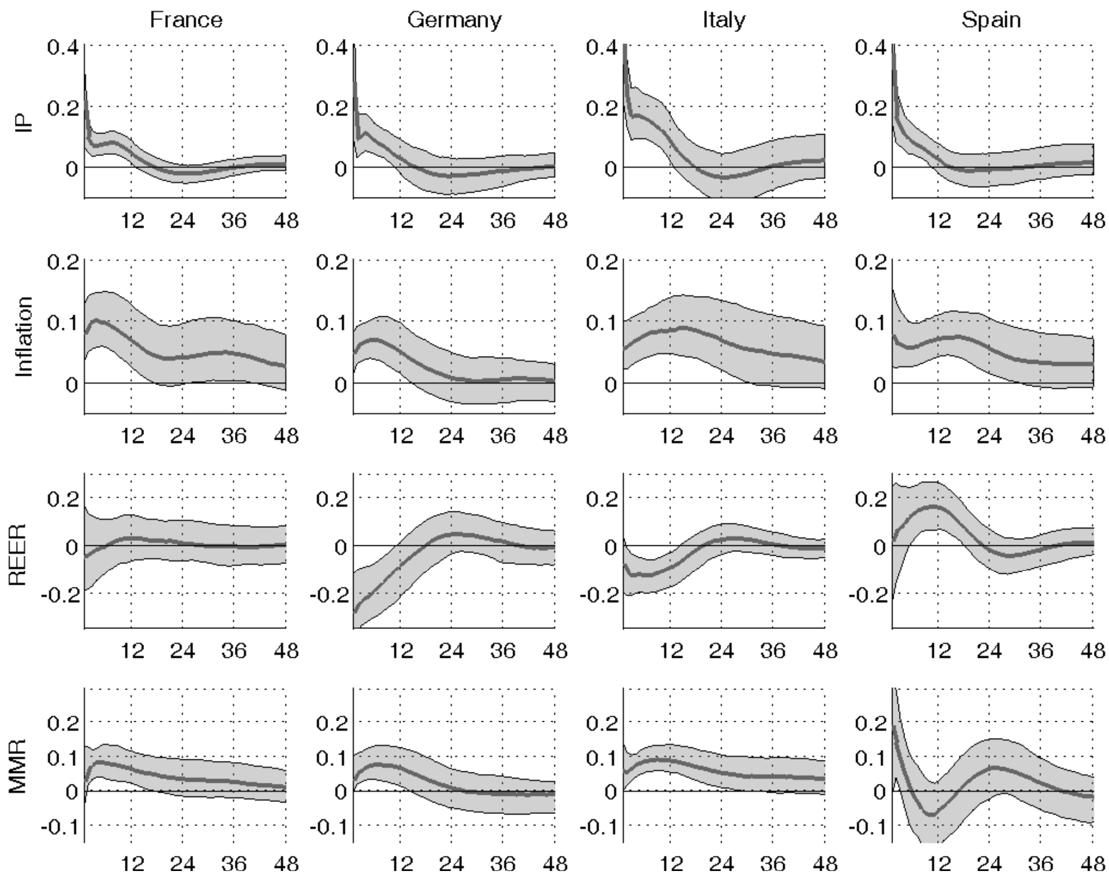


Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

from decreasing significantly and in the case of Germany real market rates even increase significantly from 6 to 24 months after impact. Finally, we detect a significant real effective depreciation for Germany, whereas all other responses are insignificant. Figure 2.2 shows the responses of a country-specific supply shock. The responses have similar characteristics as the demand shock responses. The impulse responses of inflation are comparatively more short-lived and the real effective exchange rates do not show a significant response (except for Germany). The interest rate reactions to a supply shock are of particular interest because the opposing movements in output and inflation put the central bank in the position of choosing between one of the two variables to stabilize. In the case of France, Italy, and Spain, we do not obtain significant interest rate responses. This finding suggests that the preferences for output and inflation stabilization balance each other out for these countries. For Germany, however, we find a significant increase of the interest rate in the medium-run. The significant response of the German money market rate is in line with the focus of the German Bundesbank on price stability.

Figure 2.3 and 2.4 show the responses of a symmetric demand and symmetric supply shock, respectively. The case of a symmetric demand shock is relatively similar to the idiosyncratic case, although interest rate responses are partially more persistent. The only marked difference is in the responses of real competitiveness.

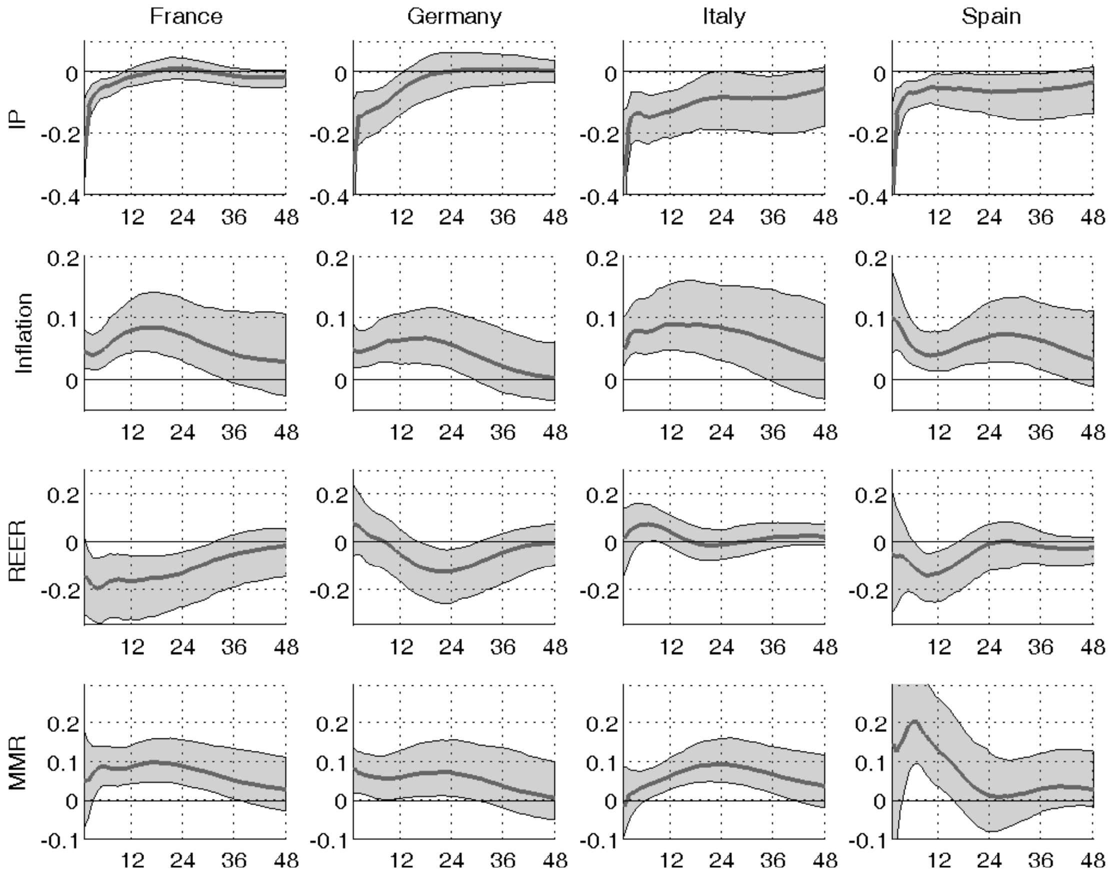
Figure 2.3: EMS: Symmetric demand shock



Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

In contrast to the case of the idiosyncratic demand shock, Germany and Italy depreciate in real terms and Spain appreciates. The French real effective exchange rate shows no reaction. The case of the symmetric supply shock is more informative. Notably, the reaction of the price variable is much more persistent and stays significantly above zero in all countries for approximately 3 years. As in the case of a country-specific supply shock, the German money market rate increases on impact and stays significant above zero for over 2 years.

Figure 2.4: EMS: Symmetric supply shock



Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

In contrast to the individual supply shocks, the other national money market rates now show a lagged and significant reaction that persists for approximately 3 years in the cases of France and Italy, and for over one year in the case of Spain. This result is consistent with the design of the EMS, in which the German Mark acted as the nominal anchor currency. When Germany increased interest rates, other countries were obliged to increase their interest rates in order to prevent divergences in the exchange rates. This explains the significant interest rate response from France, Italy, and Spain. Finally, France, Germany, and Spain become more competitive in real terms, whereas Italy loses slightly in real competitiveness after a symmetric supply shock.

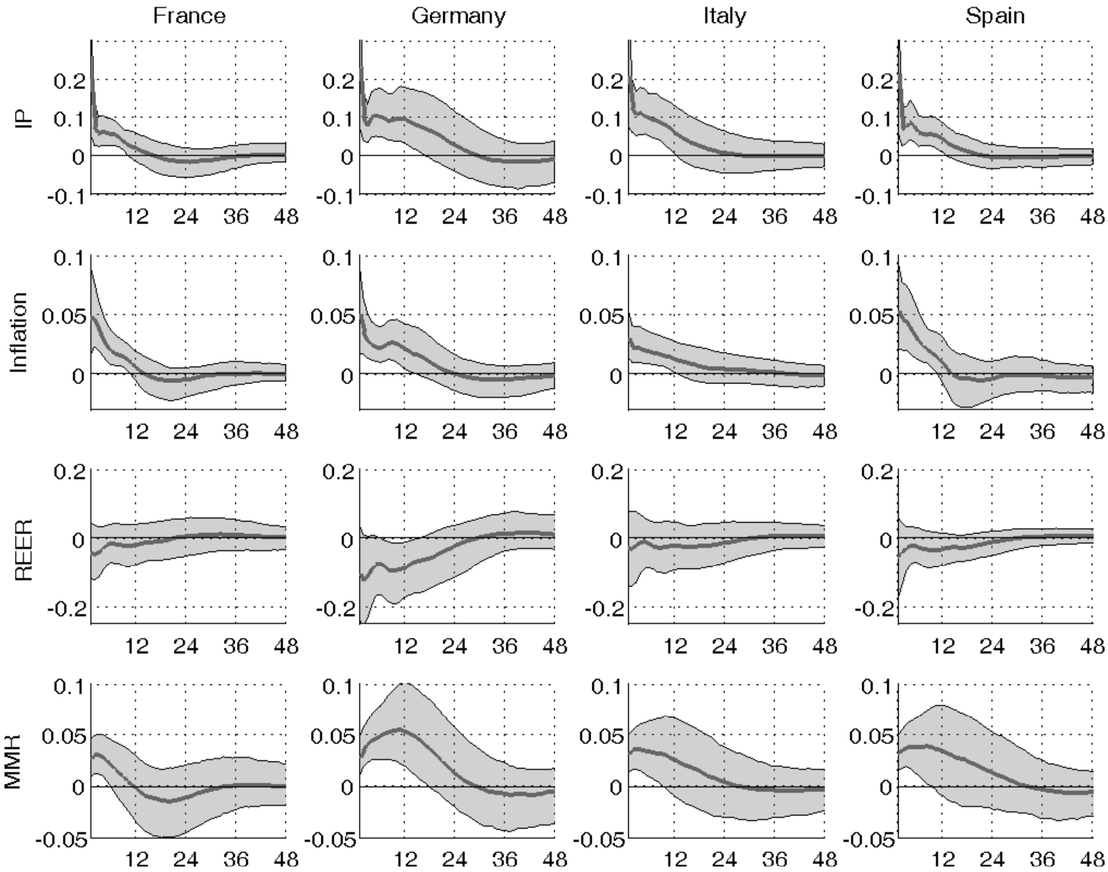
It is difficult to draw a coherent conclusion from the reactions of the real effective exchange rate. The one recurring observation is that Germany depreciates in real terms in all shock scenarios. This finding can be explained with the uncovered interest rate parity. Since the German Bundesbank is the only central bank that increases interest rate in all shock scenarios, the nominal exchange rate of the German Mark is to depreciate. On closer inspection, we can observe that the timing of the significant real depreciations is matched by the interest rate response.

Because of the prominent role of bilateral exchange rates, we include the reactions of the exchange rate between national currencies and the European currency unit (ECU) in Figure 2.11. Furthermore, due to the leading role of the German currency, Figure 2.12 displays the responses of the bilateral Deutsche Mark exchange rates.

2.4.3 EMU impulse responses

This Section discusses the impulse responses from the EMU period. Figure 2.5 shows the impulse responses of a country-specific demand shock. The demand shock pushes up the median response of industrial production by approximately 0.2 percent on impact in all four countries, and all responses stay significantly above zero beyond the restricted period. The median response of inflation ranges between 0.03 and 0.05 percent and shares the dynamics of the output variable. The increase of the median response of the money market rate, i.e., the EURIBOR, is around 0.03 percentage points for all countries. In the case of France, Italy, and Spain, the response is significant from 6 to 12 months after impact. In the German case, the interest rate response is more persistent and remains significantly positive up to 18 months. The real effective exchange rate depreciates significantly only in the case of Germany.

Figure 2.5: EMU: Idiosyncratic demand shock

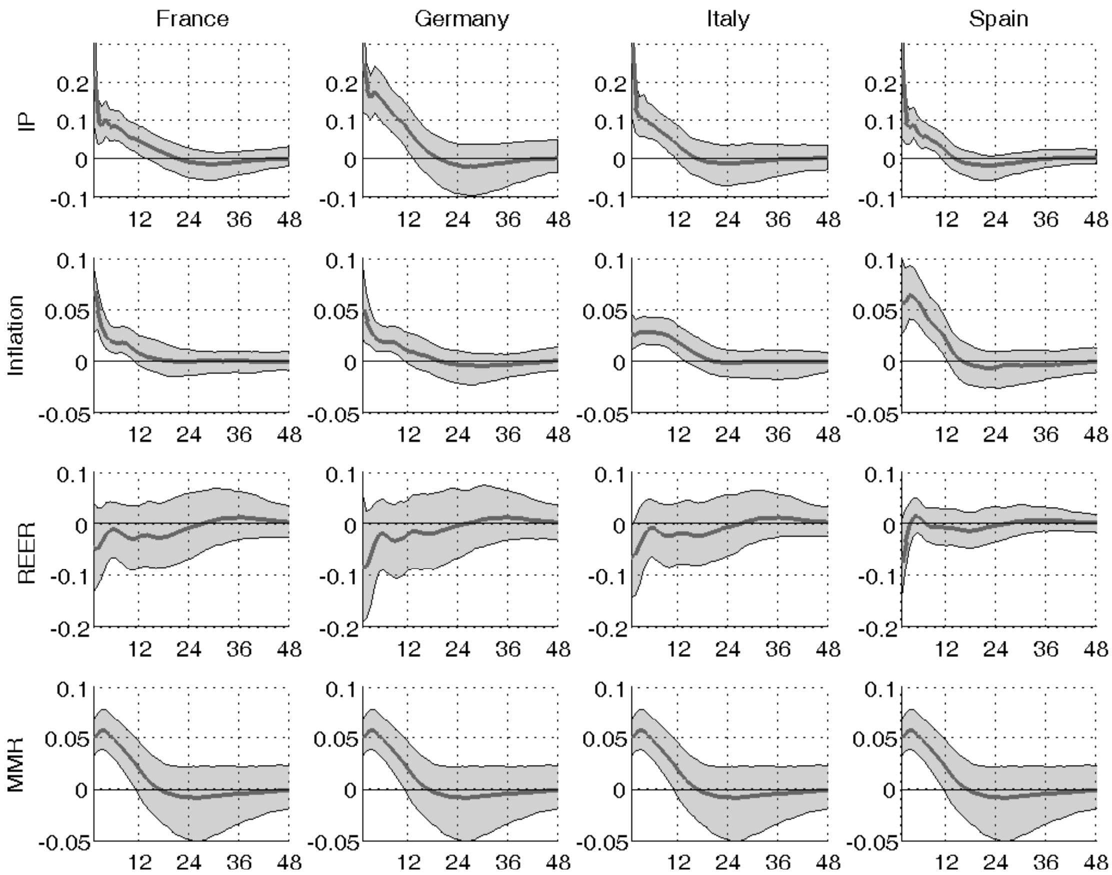


Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

In Figure 2.6, we document the responses to a symmetric demand shock.[16] The dynamics of output and inflation are similar to the individual demand shocks. Although the movement of the real exchange rate for each country is similar, no significant reaction is found. The hump-shaped increase in the market rate is significant up to 12 months and the median response is close to 0.05 percentage points on impact. This is larger than the median impact to country-specific demand shocks and, therefore, documents the asymmetric policy response depending on the origin of shocks.

[16]For symmetric shocks we obtain only one interest rate response by the ECB. The four money market response panels are just copies of the one response.

Figure 2.6: EMU: Symmetric demand shock

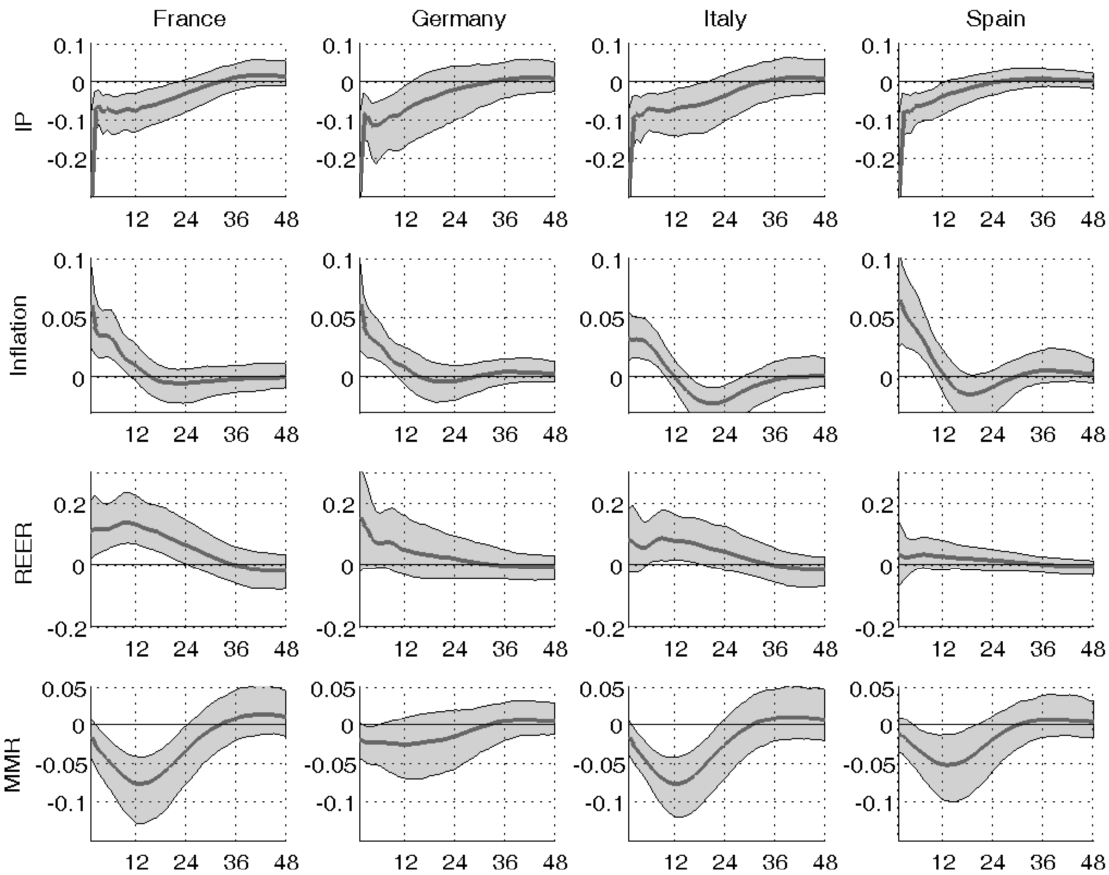


Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

A closer examination of the asymmetry of monetary policy in the EMU is provided at the end of this Section. Figure 2.7 illustrates the reactions to a country-specific supply shock. Magnitudes and dynamics of the output and price variable are similar to the idiosyncratic demand shock. The most interesting observation is the reaction of the money market rate. In contrast to the supply shock during the EMS period, we now find the tendency of the ECB to stabilize output, rather than inflation, by lowering the interest rate.

In particular, we detect a significant and hump-shaped decrease of the EURIBOR shortly after impact up to 2 years for France, Italy, and Spain. Also the German supply shock provokes a short and significant decrease in the short-term rate, but

Figure 2.7: EMU: Idiosyncratic supply shock

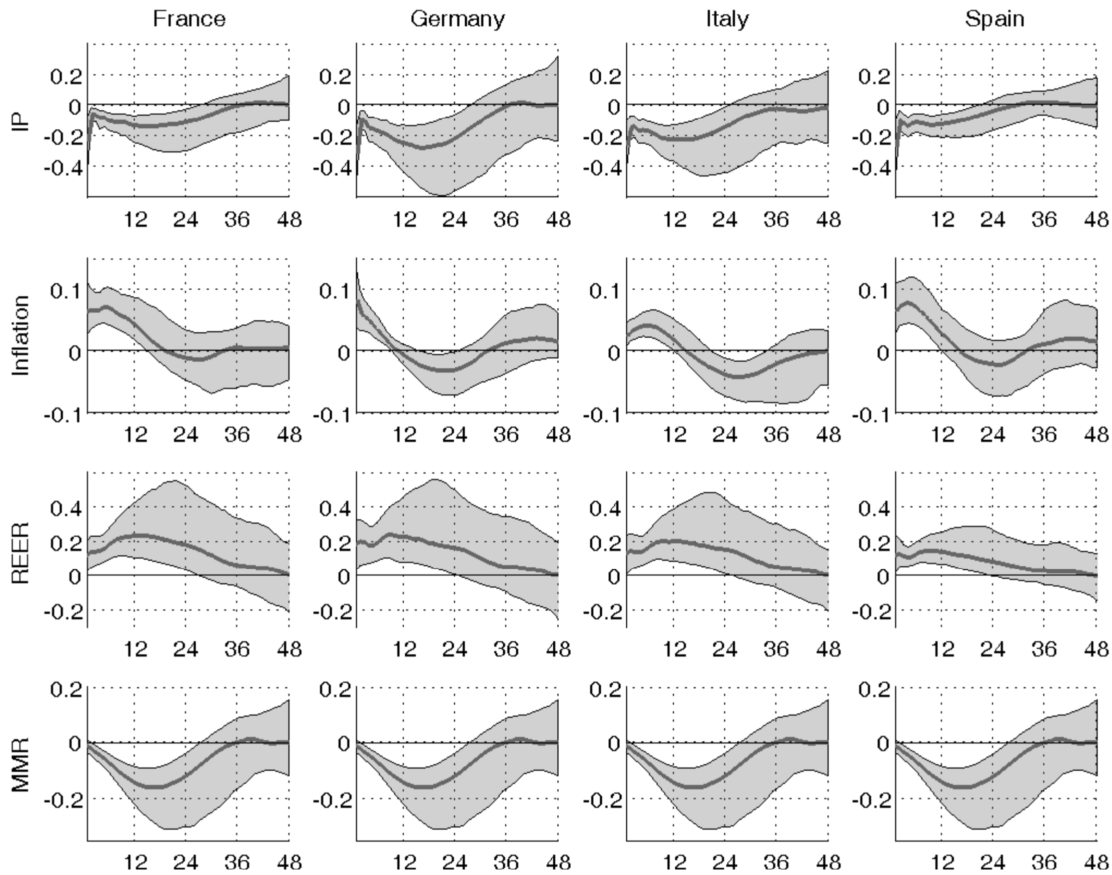


Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

the reaction is much more muted. In contrast to the demand shock scenarios, we observe a tendency of national real exchange rates to increase. The French and Italian effective real exchange rates even increase significantly.

Finally, Figure 2.8 depicts the responses to the symmetric supply shock. Contrary to the country-specific supply shocks, the symmetric shock shows more persistent responses in industrial production, inflation, and the money market rate. The response of the EURIBOR points clearly to an orientation towards output stabilization. The symmetric supply shock provokes a significant decrease in the money market rate that stays significantly below zero for more than 2 years. Likewise, all countries undergo a persistent real appreciation that is significant up to 2 years.

Figure 2.8: EMU: Symmetric supply shock



Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

Comparing this result with the results from the EMS period, this finding suggests a change in the preferences of the monetary authority towards output stabilization. During the EMS, the German Bundesbank responded with a monetary tightening in the case of an inflationary supply shock. A symmetric supply shock even led the fellow countries to imitate the response of the German central bank in order to preserve the currency peg. With the introduction of the ECB, the preferences over output and price stabilization seem to have changed. Now, monetary policy loosens as a reaction to a supply shock that increases inflation and decreases production.

These findings are in line with results from the literature on Taylor-type monetary reaction functions. As mentioned in Section 2.2, there is considerable evidence for a difference in the weights of inflation and the output gap when comparing the German Bundesbank to the ECB. This is consistent with our findings, which suggest that the emphasis moved from price stabilization towards output stabilization. Similar results are obtained by Conti et al. (2017), who analyze the drivers of inflation in the EMU after 2013 with a Bayesian VAR model. They work with a larger set of variables that allows them to identify a larger set of shocks. They differentiate between an aggregate supply and an oil supply shock that are identical to the supply shock in this paper in that they push prices and output in opposite directions.[17] In both cases they find that an inflationary supply shock leads to a tentative decrease in the ECB policy rate.[18]

Finally, to zoom in more closely on the asymmetric effects of monetary policy in a currency union, Figure 2.9 presents the implied real market rate responses following demand shocks during the EMU. In the first row we see the real market responses after idiosyncratic demand shocks in the EMU. Only the German demand shock leads to a reaction by the ECB that is strong enough to increase real market rates significantly at the margin.

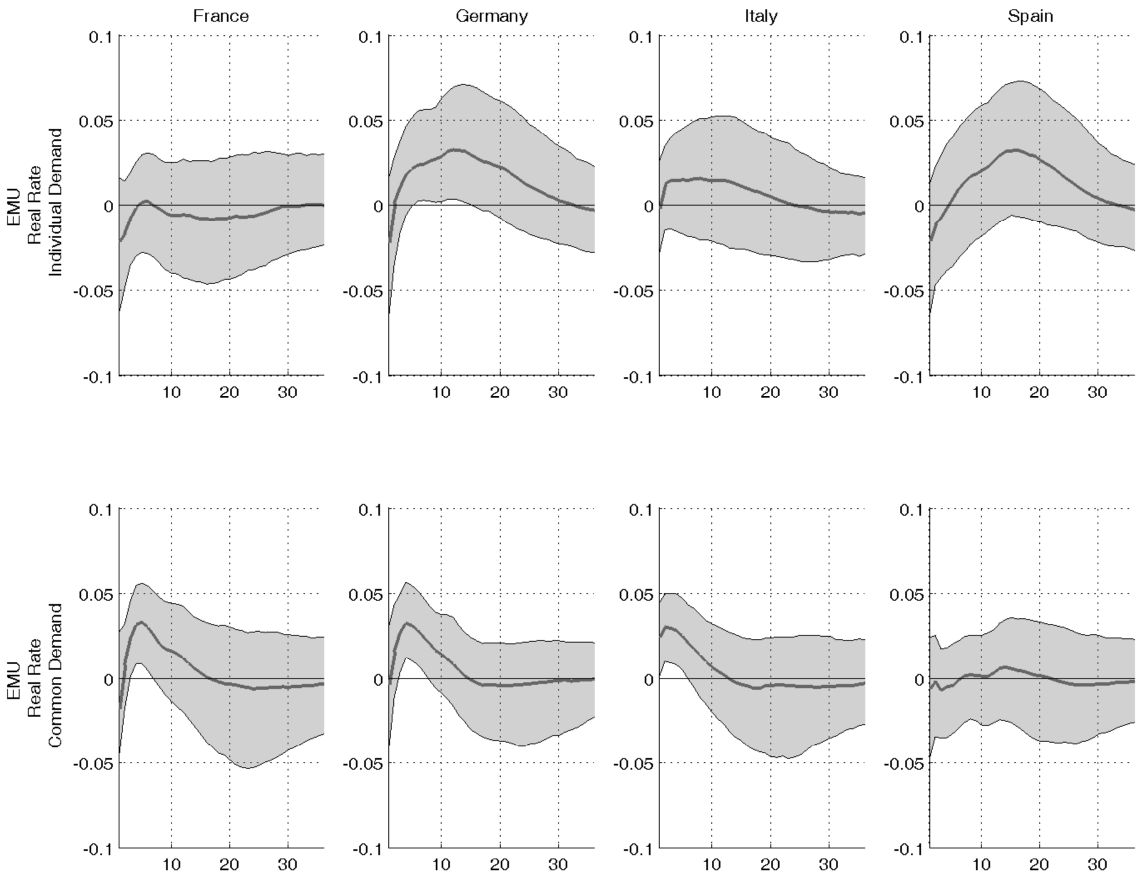
The responses of the other EMU countries are not significant. This is consistent with the ECB's goal of price stability for the entire Eurozone, in which only Germany (as the economically strongest economy) has the weight to provoke a relatively strong response by the ECB. On the contrary, the responses of real market rates to a symmetric demand shock are mostly positive and significant. Here, the ECB increases interest rates appropriately and achieves a rise in real market rates for almost all countries. In Spain, however, it seems that symmetric demand shocks are associated with stronger than the average increases in inflation (see Figure 2.6), which prevent a significant increase in real market rates.

Focusing on the national real competitiveness indicators of the EMU period, their endogenous responses to supply and demand disturbances follow a consistent pattern. Following an individual supply shock, the real effective exchange rate

[17]In addition, to identify an aggregate supply shock, they restrict the real oil price to increase. For an oil supply shock they restrict the real oil price to decrease and the rest-of-the-world output to increase.

[18]Peersman and Straub (2009); Forni et al. (2015) find opposing results.

Figure 2.9: EMU: Real rates after idiosyncratic and symmetric demand shock



Notes: Impulse responses are based on a one standard deviation shock. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

indices increase, i.e., all countries tend to appreciate in real terms, with significant responses in France and Italy. This is the result of two effects. First, national price increases tend to undermine the competitiveness, which is reflected in an upward movement of the real effective exchange rate. Second, the expansionary interest rate reaction of the ECB, likewise, adds to the decrease in competitiveness. According to the uncovered interest rate parity, the country with the decrease in interest rates is expected to appreciate in nominal terms. Therefore, we have two effects that push the real effective exchange rate index upwards. Following a symmetric supply shock, the interest rate reaction by the ECB is stronger and more pronounced such that the real appreciation becomes significant for all countries.

In the case of demand disturbances, we obtain the opposite results. Now, instead of appreciating in real terms, all countries tend to depreciate. Since the response of inflation is qualitatively the same as for supply shocks, the different response in real competitiveness must come from the interest rate. And indeed, the contractionary interest rate reaction would predict, according to the uncovered interest rate parity, a nominal depreciation of the Euro. This counteracts and overcompensates the effects from inflation and results into a tendency to improve the real competitiveness of all countries.

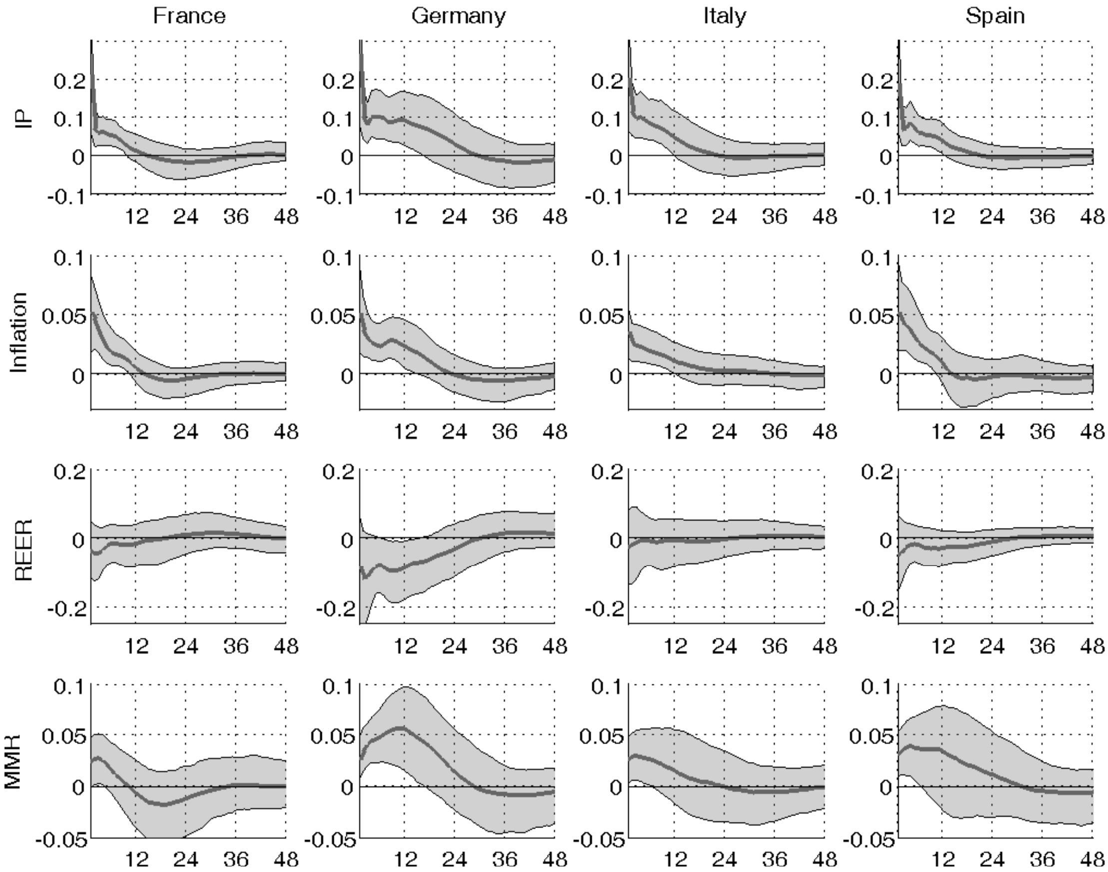
When we compare the transmission of shocks from both periods, we observe that the endogenous variable responses of the EMS period tend to exhibit a higher degree of persistence. In particular, the responses of inflation persist beyond the restricted horizons and provoke an equally persistent reaction in interest rates.

2.4.4 Extensions and robustness

First, we present the results from an alternative identification scheme of idiosyncratic demand shocks during the EMU period. Instead of restricting the money market rate, we leave the interest rate response unrestricted. In a monetary union, the possibility of national monetary policy shocks is eliminated because of a single monetary policy. Therefore, it is no longer necessary to restrict the money market rate to differentiate between idiosyncratic demand shocks and idiosyncratic monetary policy shocks. Figure 2.10 shows the responses from the alternative identification scheme. The results do not change qualitatively. In the short-run (up to 6 months) the money market responses for France, Italy, and Spain are overall weaker than in the baseline identification. The response to the German demand shock is as strong as before.

Robustness exercises include varying the lag length for the EMS and the EMU model up to 12 lags. Additionally, the sensitivity of the results is tested with respect to the number of restricted horizons in the sign-restriction approach (from 3 to 9 months). We detect no qualitative changes in the model dynamics, however, the impulse responses become more pronounced with restrictions set at higher horizons. Furthermore, we vary sample size and sample selection. For the EMU model, we

Figure 2.10: EMU: Idiosyncratic demand shock (alternative identification)



Notes: Impulse responses are based on a one standard deviation shock. Industrial production and the real exchange rate are in percentages, inflation and the interest rate in percentage points. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

extend the sample horizon beyond the financial crisis until 2014, without getting qualitative changes in the results. Moreover, we estimate all models with additional exogenous variables. This includes a commodity price index for producers ($\texttt{PPI}_{\text{COM}}$), the 3-month treasury bill rate ($\texttt{TBR}_{\text{U.S.}}$), and "world" demand ($\texttt{D}_{\text{ROW}}$). "World" demand is a composite indicator. It is calculated as the weighted sum of "world" GDP and domestic demand net of exports for the Euro Area. The exogenous variables capture dynamics in the rest of the world that potentially have an effect on the domestic countries. Estimating all specifications with exogenous variables changes some of the dynamics in the variables, however, the main conclusions concerning the systematic reaction of monetary policy are not affected.

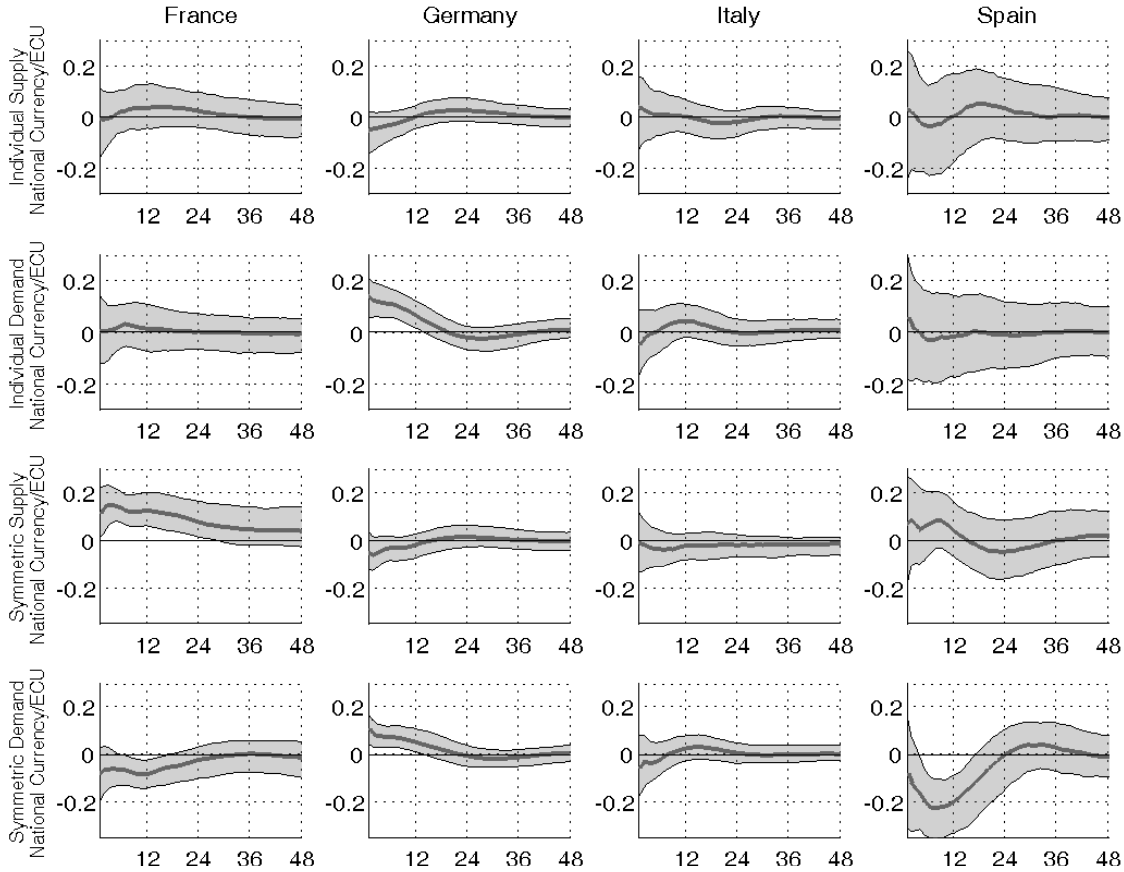
2.5 Conclusion

We compare the transmission and accommodation of inflationary macroeconomic shocks during the EMS and the EMU. In this analysis, we differentiate between idiosyncratic (country-specific) and symmetric shocks. Special interest lies on the differences in the systematic response of monetary policy authorities during the two currency regimes, conditional on the nature of shocks, i.e., supply vs. demand and idiosyncratic vs. symmetric. Focusing first on idiosyncratic inflationary demand shocks, all monetary authorities of the EMS period raise interest rates enough to prevent a decrease in real (short-term) market rates. But only the response of the German Bundesbank leads to an increase in real market rates and therefore satisfies the Taylor principle. In contrast, the ECB targets a harmonized average of the price levels of all Eurozone countries and therefore reacts only partially to country-specific shocks. This asymmetry reveals itself when comparing the endogenous response of real market rates following country-specific shocks with symmetric shocks in the EMU. In the case of a symmetric demand shock, the ECB responds optimally and increases the interest rate more than proportionally to the price level increases, which yields a significant rise in real market rates for almost all countries in the sample. Next, zooming in on inflationary supply shocks, during the EMS the German Bundesbank is the only central bank that seems to follow the goal of inflation stabilization by raising money market rates. Only in the case of a symmetric supply shock do we detect an increase in all money market rates. This finding can be explained by the architecture of the EMS where policies were trimmed to protect the currency peg to the German currency, the anchor currency of the EMS. If Germany raised interest rates, other countries of the EMS also had to act and increase interest rates to protect the exchange rate parity. In comparison with the results from the EMU, the orientation of monetary policy seems to have changed. Results from the EMU suggest an orientation towards output stabilization, i.e., the ECB lowers market rates when facing inflationary supply shocks.

2.6 Appendix to Chapter 2

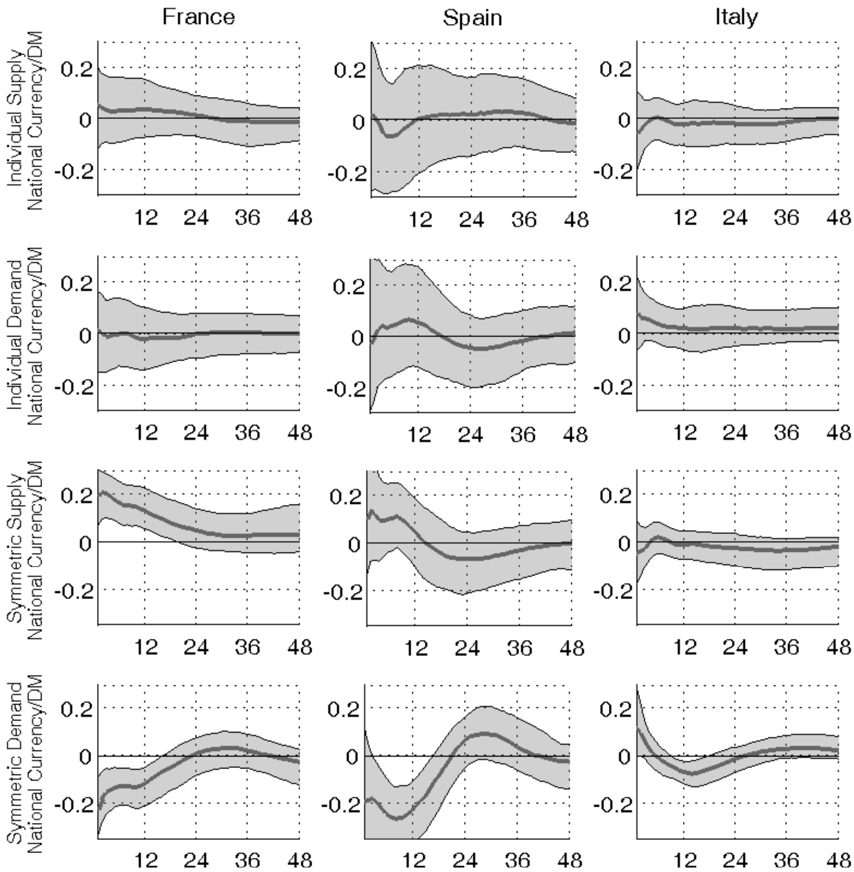
2.6.1 Impulse responses

Figure 2.11: EMS: Responses of national nominal exchange rates (national currency to ECU)



Notes: Impulse responses are based on a one standard deviation shock. The scale is in percentages. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

Figure 2.12: EMS: Responses of national nominal exchange rates (national currency to DM)



Notes: Impulse responses are based on a one standard deviation shock. The scale is in percentages. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

2.6.2 Figures

Figure 2.13: Money market rates of selected EMU member states

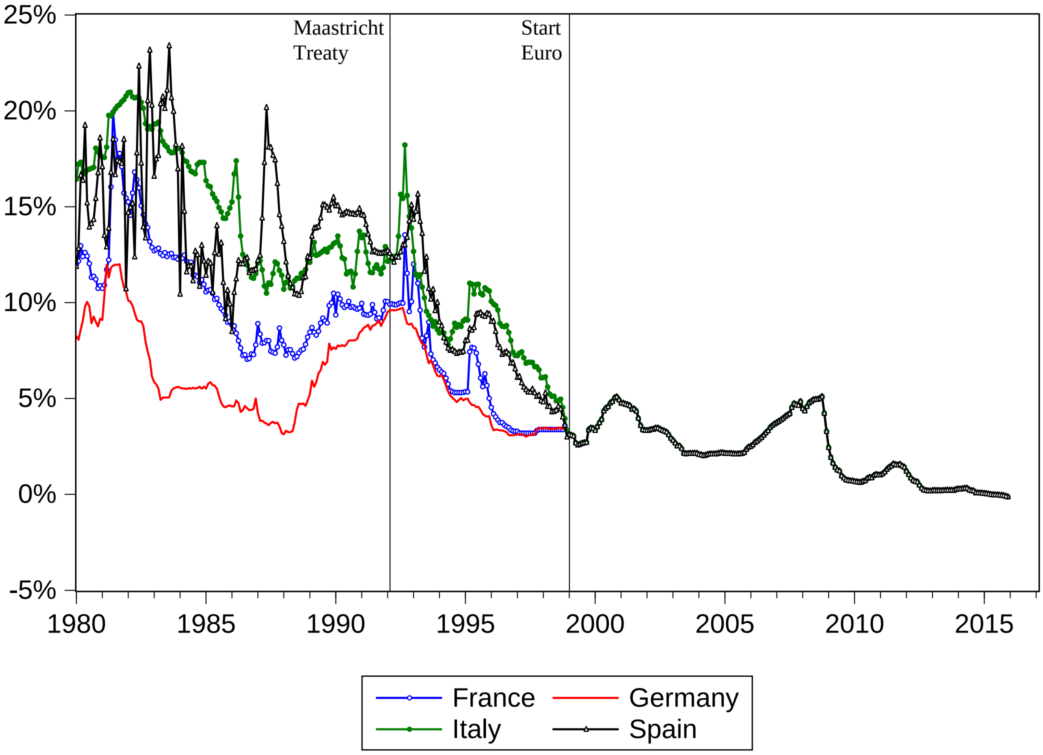


Figure 2.14: Year-on-year inflation rates of selected EMU member states

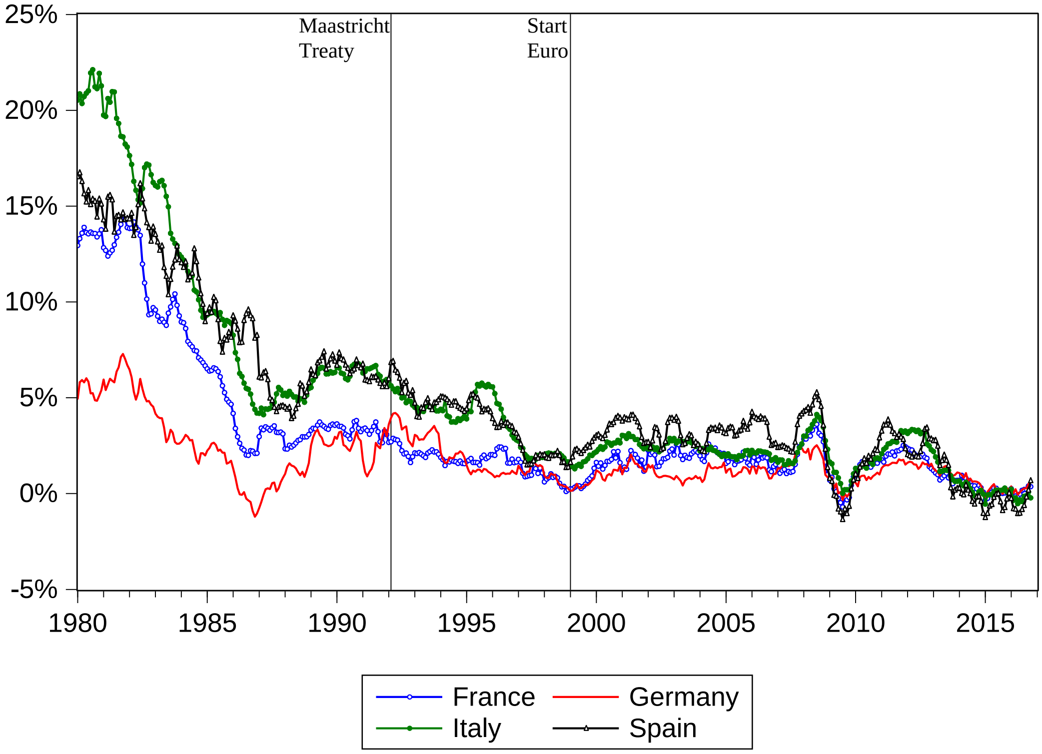


Figure 2.15: Industrial production (index) of selected EMU member states

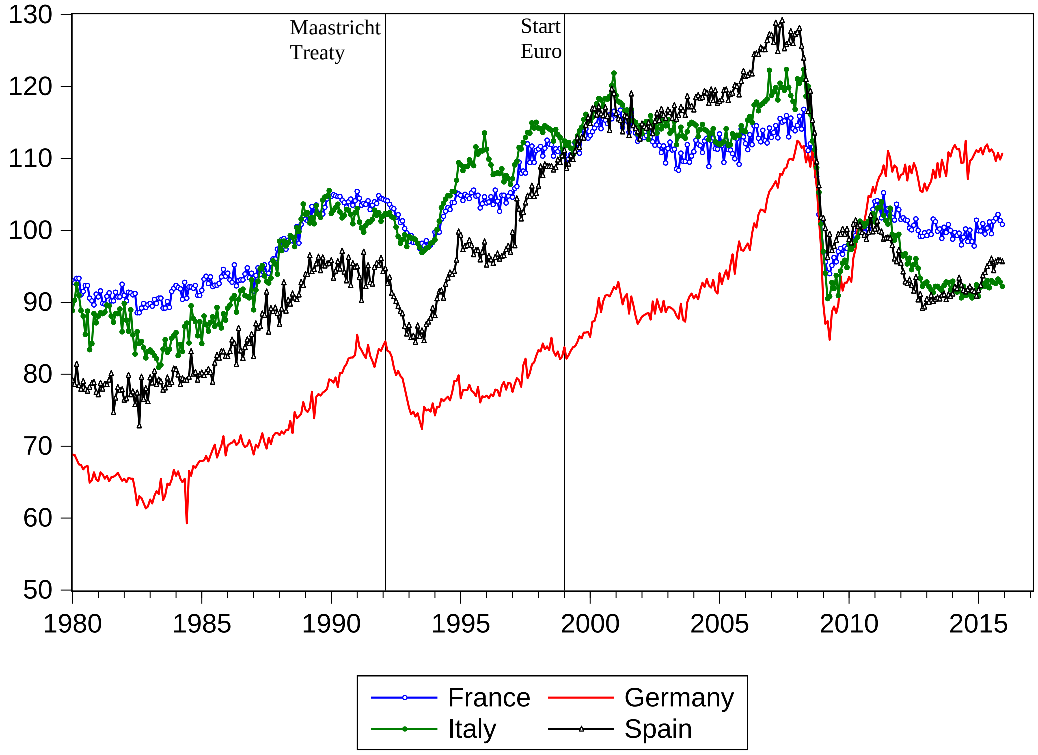
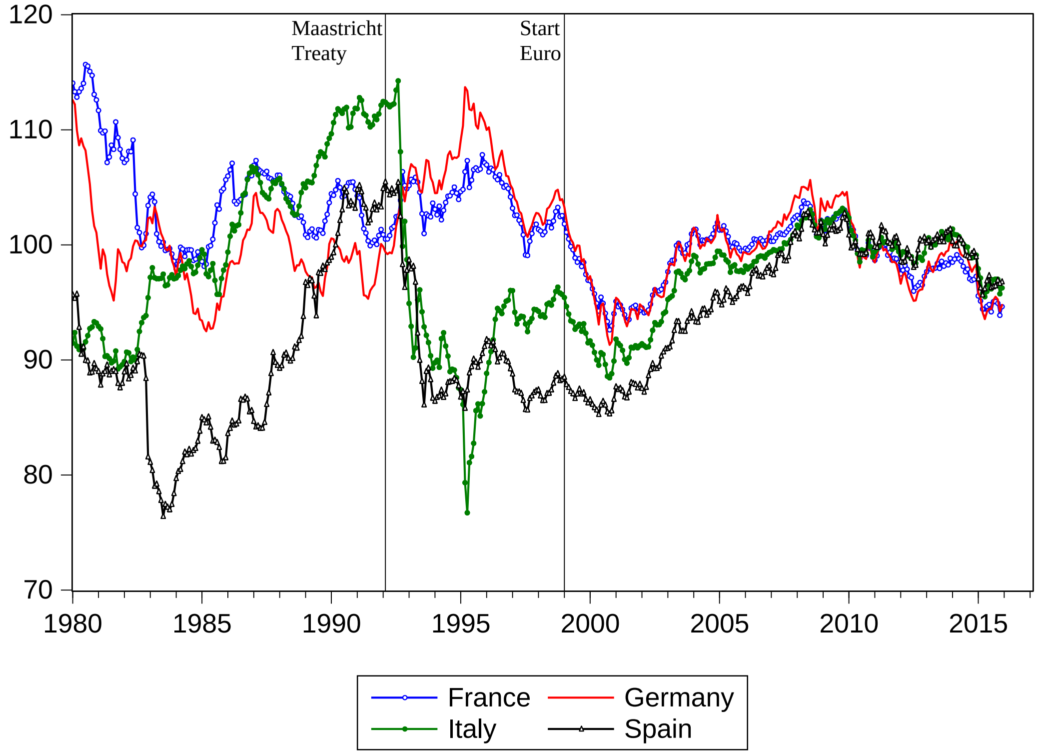


Figure 2.16: Real effective exchange rate (index) of selected EMU member states



2.6.3 Data

Table 2.2: Description of variables

Abbr.	Variable	Source	Transf.
IP	Industrial production	IFS/IMF	2
$\pi^{\texttt{CPI}}$	Year-on-year inflation	OECD	0
REER	Real effective exchange rate	BIS	2
MMR	Money market rates (short-term)	OECD	0
EURIBOR	Euro Interbank Offered Rate	OECD	0
$\texttt{PPI}_{\text{COM}}$	Producer price index	FRED	2
$\texttt{TBR}_{\text{U.S.}}$	3-month treasury bill rate	FRED	0
$\texttt{D}_{\text{ROW}}$	Rest of world demand	AWM	3

Notes: Data are transformed as follows: 0: levels, 1: log-levels, 2: log-levels, detrended (quadratic), 3: interpolated, log-levels, detrended (quadratic). IP, $\pi^{\texttt{CPI}}$, and $\texttt{PPI}_{\text{COM}}$ are seasonally adjusted with the Census X-12 filter.

- The real effective exchange rate indices are the narrow indices from the BIS. An increase in the index represents a real appreciation.
- The “world” demand variable is taken from the Area Wide Model Database. The variable is a composite indicator, calculated as the weighted sum of “world” GDP and domestic demand net of exports for the Euro Area.

Chapter 3

Current Account Dynamics and the Housing Cycle in Spain

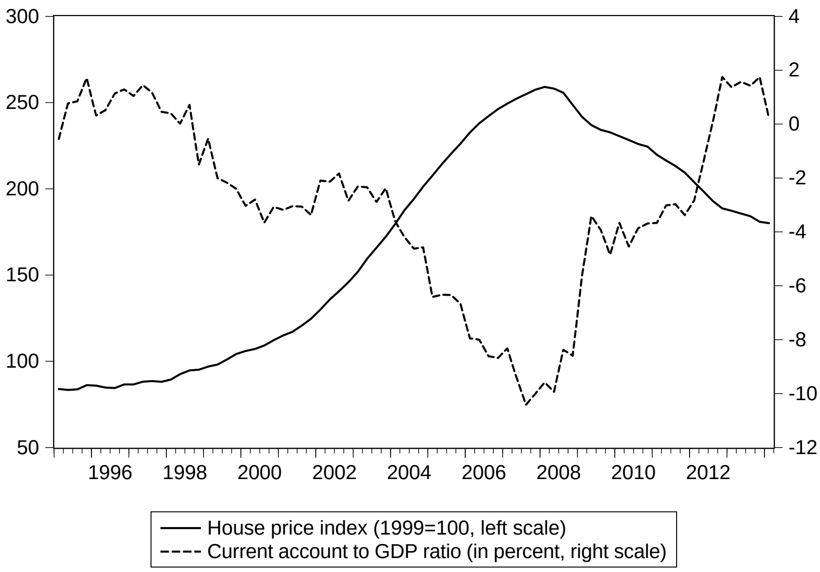
3.1 Introduction[1]

What are common drivers of the well-established, negative correlation between housing markets and the current account in Spain? Spain witnessed a pronounced boom and bust cycle in housing[2] that coincided with a deterioration and subsequent contraction of its current account (see Figure 3.1). From 1995 to 2008, real square-meter property prices tripled on average, and during the culmination of the boom, one-fourth of the Spanish male labor force was employed in the construction sector, which temporarily accounted for 20 percent of GDP growth. At the peak of the boom, the current-account-to-GDP ratio recorded minus 10 percent, and was followed by a sharp correction after the bust.

[1]This Chapter is based on joint work with Sebastian Rüth and Eric Mayer. An earlier version appeared as Maas et al. (2015).

[2]Fernández-Villaverde et al. (2013), Gonzalez and Ortega (2013), and Akin et al. (2014) provide an overview of the Spanish cycle of housing markets. In general, housing is of particular importance in Spain because the rate of home ownership and the share of private wealth allocated to housing both exceed 80 percent, which is considerably beyond the European average.

Figure 3.1: Current account and house price dynamics



Notes: The Figure presents the current account to GDP ratio and house prices for Spain. We obtain the data from Eurostat and BIS.

This paper tests four popular hypotheses in terms of their ability to generate the joint behavior of housing markets and the current account present in Spanish data. In this regard, we account for Spain-specific and external shocks emerging in the rest of the Eurozone. The comparison of such "pull" (domestic) and "push" (foreign) factors, at least, dates back to Calvo et al. (1993) and remains subject to research on the sources of capital flows (Fratzscher, 2012).

The pull hypothesis emphasizes the importance of domestic factors as potential drivers of the housing boom in Spain. By initiating a domestic boom, these factors ultimately attract capital inflows from the rest of the Eurozone. Prime candidates for this hypothesis are a relaxation of credit standards that foster credit supply by the banking industry (see, e.g., Helbling et al., 2011; Bassett et al., 2014) and housing bubble shocks that fuel markets against the backdrop of the belief of ever surging house prices (see, e.g., Shiller, 2005, 2007; In't Veld et al., 2011).

In contrast, the push hypothesis explains housing markets by external factors that proactively allocate capital to Spain. One representative is the risk premium shock (see In't Veld et al., 2014). The creation of the common Euro-denominated market eliminated risk premia among the member countries, which led core Eurozone investors to invest in Spain and further lowered risk-free rates. Vice versa, the economic turmoil in 2008 reintroduced risk spreads and reverted capital flows. A further push representative is a European version of the "savings glut" shock originally proposed by Bernanke (2005) for the US. The rationale of this shock is that Spain—as a member of a monetary union—was overheated by excessively low interest rates compared to a Taylor rate. As a consequence, and in line with consumption dynamics, core Europe had systematically higher saving rates than Spain and lower economic momentum during the run-up phase. Consequently, excess savings from the core broke its way through to Spanish housing markets.

We empirically analyze how the competing shocks impact the current account and housing market variables. We study how the shocks propagate through the economy, and furthermore, we judge their quantitative relevance by applying a robust sign restrictions approach as in Peersman and Straub (2009) to data for Spain and the rest of Euro Area. We derive restrictions from a single currency union DSGE model incorporating two countries, i.e., Spain and the rest of the Euro Area. The model builds on Rabanal (2009) and Iacoviello and Neri (2010) and features a variety of nominal and real frictions. Following Kiyotaki and Moore (1997), households consist of two subgroups according to their time preferences, i.e., savers and borrowers (see Monacelli, 2009). As in Iacoviello (2005), borrowers face a collateral constraint such that their borrowing is limited to the present value of their housing multiplied by a loan-to-value (LTV) ratio. In the empirical analysis, we employ an open-economy vector auto-regressive (VAR) model, which allows for the discrimination of push and pull forces. Due to the small sample size, we follow Eraker et al. (2015) and draw on a Bayesian mixed-frequency approach for estimation and inference. The identification of structural shocks is along the lines of Uhlig (2005). Concretely, we identify a savings glut, risk premium, financial easing, and housing bubble shock. Except for the financial easing shock, all identified disturbances are capable of generating the observed, negative correlation of the current account and housing markets. In contrast to the competing macroeconomic disturbances, the financial easing shock predicts no robust, significant drop in the current account, and most notably, it forecasts a decline in residential investment and house prices. Comparing the shocks quantitatively, we find that push factor representatives (savings glut shocks and risk premium shocks) play a more important role in explaining variations in the housing market variables than the competing pull factor representatives. Focusing on the current account, however, the financial easing shock, a pull factor representative, accounts for most variation.

Our contribution to the current literature aligns with the following dimensions. First, we add a further facet to the literature on push versus pull factors by applying this perspective—which usually centers around capital flows between advanced and emerging market economies—to the case of a currency union. Related to this point, a number of theoretical and empirical studies for the US analyze the joint dynamics of the current account and housing markets (see, e.g., Sá and Wieladek, 2015; Justiniano et al., 2014). However, prima facie, it is not evident which conclusions drawn from US data can be applied to Spain.[3] Most importantly, Spain is member of a currency union, and net capital inflows did not come from Asia and oil-exporting countries but rather largely from the rest of the Euro Area. Thus, the study of Spain as an example for a monetary union member state, in particular, helps to understand the specifics of the nexus between housing markets and the current account inside a monetary union, where shocks propagate differently due to the common conduct of monetary policy.[4] Despite different currency regimes, we reinforce the results of Sá and Wieladek (2015) for the US by also revealing the importance of savings glut shocks for Spain.

Second, In't Veld et al. (2014) estimate a rich DSGE model by using Bayesian techniques with Spanish data. They find a strong influence of falling risk premia,

[3]For instance, Spain has a bank-based financial system that operates under the tight Basel regulatory framework, in which new constructions were only moderately fueled by sub-prime residential mortgage-backed securities. In contrast, the US is known to be a predominantly market-based financial system, where sub-prime markets were loosely regulated, which took center stage in the crisis (see, e.g., Goddard et al., 2007).

[4]By studying the Spanish economy—which among the housing-bubble-countries in the monetary union was subject to a particular strong inflow of capital—we analyze a relevant Eurozone country representative. Of course, we acknowledge that, e.g., different characteristics in country-specific housing markets, various rigidities in labor or product markets, different structures of financial systems, or a different conduct of fiscal policy, can lead to discrepancies in the quantitative importance of shocks. However, it is unlikely that country specifics incur qualitative differences in the propagation mechanism. In addition, we have at least no ex ante reason to believe that the four shocks we consider are not relevant for other countries within the monetary union as well. In the same vein, the *policy instrument externality* for an individual member country due to the ECB's common conduct of monetary policy is a crucial channel that *should generally apply to all Eurozone economies.*

a loosening of collateral constraints, and asset price shocks on the Spanish output boom and capital inflows. We complement their analysis with a time series approach that imposes less structure on the data by using the theoretical DSGE model only for qualitative purposes and basing our quantitative results and inferences on a VAR model taking both parameter and model uncertainty into account. In our approach, the relations between the VAR variables—including the current account—are data-determined. In the estimated DSGE model in In't Veld et al. (2014), however, the law of motion and the co-movement of the current account with other variables are entirely determined by the model structure.[5] In addition, given the importance of net foreign income and transfers in a currency union, we also account for this feature in the data by estimating our model with current account data, rather than trade balance data, as in In't Veld et al. (2014). The balance of net foreign income and transfers, namely, has steadily turned negative during the Spanish housing bubble and accounted for approximately 30% of the current account deficit at the peak of the cycle. Furthermore, we focus on the *housing boom rather than the Spanish output cycle*. We find little support for financial easing shocks in explaining the negative correlation of housing markets and the current account, in line with In't Veld et al. (2014).

Third, due to limited data availability, contributions such as Hristov et al. (2012) or Ciccarelli et al. (2015) rely on panel data approaches to achieve efficiency gains. Likewise, single country VAR approaches often resort to data samples that extend the relevant time period for the same reason. To tackle this issue, we simultaneously employ monthly and quarterly data for Spain in the Bayesian mixed-frequency framework as in Eraker et al. (2015).

The paper is structured as follows. In Section 3.2, we explain the different hypotheses that we empirically test in detail. Section 3.3 discusses the model employed to derive the sign restrictions, while Section 3.4 describes the econometric framework and presents the results. Finally, Section 3.5 provides some extensions and robustness, while Section 3.6 concludes.

[5] In light of the discussions on sustainable current account fluctuations versus persisting disequilibrium effects with lengthy periods of imbalanced current account movements, our agnostic empirical approach, which allows for permanent deviations of the current account, is favorable.

3.2 Four hypotheses

To motivate the empirical analysis, we further discuss four different sources that potentially link the housing and current account[6] cycles in Spain. We recall historic, economic and housing-market-specific developments faced by the Spanish economy and the rest of the Eurozone. Based on this *narrative* evidence, we rationalize why these developments might putatively result in a housing boom-bust cycle that was paralleled by an opposed swing in the Spanish current account. The subsequent Section 3.3, then, allows us to *theoretically* validate the individual hypotheses' capability to generate the negative correlation under consideration. We do so by means of a broad range of structural DSGE models that we derive through perturbations of the models' structural parameters. In addition to the theoretical validation of the four hypotheses, the DSGE model exercise, moreover and more importantly, theoretically pins down robust differences in the propagation of the individual developments into the broader economy. By deriving such robust sign restrictions, we theoretically disentangle the four hypotheses, i.e., we give them a structural interpretation as aggregate shocks. To sum up, in this Section we argue that all of the considered hypotheses can be potential demand boosters for the Spanish economy, specifically the housing market, and may at the same time worsen the current account by causing capital inflows. We further propose narratives that might distinguish the hypotheses based on their macroeconomic repercussions. Section 3.3, by contrast, will help to find theoretically robust differences between the structural disturbances that we will use for identification.

We begin the exposition with pull factors of capital flows, that is, with developments originating in the Spanish economy. The first hypothesis we propose is that Spain underwent a relaxation of the overall and housing-specific effective loan supply relative to the rest of the Eurozone. A sample of some anecdotal evidence attests to

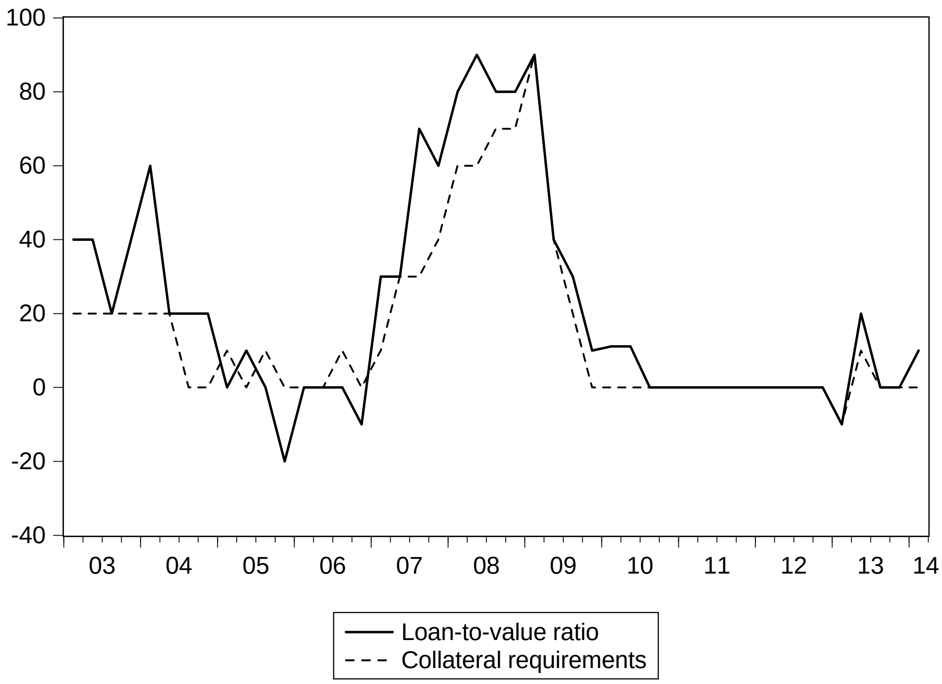
[6] As argued in Shin (2012) and Acharya and Schnabl (2010), gross financial flows are more crucial for overall financing conditions than net capital flows as reflected by the current account. Yet, Obstfeld (2012) emphasizes the importance of the current account for the scrutiny of policy makers (see Fratzscher et al., 2010). Catão and Milesi-Ferretti (2014) point out the current account as a predictor of external crises. Furthermore, Giavazzi and Spaventa (2011) stress the relevance of the current account, in particular, for the case of a monetary union.

this hypothesis, to which we refer in summary as financial easing shocks: In Spain's bank-based financial system the majority of mortgages was supplied by the banking industry, which makes the banking sector a prime suspect to have proactively triggered the housing cycle. Formally, under the Basel regulatory framework, banks faced stricter equity requirements, once LTV ratios exceeded 80 percent of the collateral value. In practice, banks placed 40 percent of all mortgage loans exactly on the limit of 80 percent, which implied substantially looser credit access for Spanish borrowers compared to many other European countries. Furthermore, Spanish appraisal firms systematically overstated property values (Akin et al., 2014), thereby effectively raising LTV ratios in terms of market values and further softening lending standards before the crisis (see Figure 3.2). Because the fraction of collateral constrained households is sizable in Spain (Hristov et al., 2014), the effective loosening of collateral requirements is of first-order macroeconomic importance and, above, may have spurred residential investment activity. Beyond, and induced inter alia by tough competition in the banking sector, Spanish mortgage rates were 21 percent below the European average, which—given the well-documented excess interest rate sensitivity of residential construction—might have strongly stimulated housing demand. The expansion in the effective loan supply of Spanish banks, of course, could also have been driven by changes in the conduct of local banking supervision and the regulatory environment as well as shifts in industry strategies (e.g., Bassett et al., 2014). Independent from the quantitative importance of these individual developments, the financial easing hypothesis can putatively account for a housing cycle in Spain.

In addition, as the rapid mortgage growth caused by banks' financial easing was not entirely backed by domestic wholesale funding, it triggered capital inflows predominantly from core Eurozone countries. The Spanish banking sector's effective financial easing is thus also in line with a deterioration of the Spanish current account and ultimately is a candidate to explain the negative correlation in Spanish data, which is the subject of this paper.

The strong dynamics in the residential sector—where prices tripled from 1995 to 2008, the number of dwellings increased by 20 percent from 2001 to 2008, and

Figure 3.2: Changes in Spanish banks' lending standards



Notes: The Figure shows the change in banks' conditions for housing loans to households over the past three months (frequency of tightened minus eased lending standards). We obtain the data from the ECB's bank lending survey, which is available since 2003.

the ratio of residential investment to GDP almost doubled from 1995 to 2006—motivate our second prominent pull hypothesis, the housing bubble shock, which is innate to the housing market. A housing bubble, according to Shiller (2005, 2007), is best described by a social pandemic, fueled by the belief of ever-increasing house prices that thereby raise the willingness to pay higher prices. The surge in prices, in turn, spurs housing demand because of the general perception that a property, if not needed, can be sold in any case with a profit at a higher price. As a side effect, property owners, who face positive wealth effects with the price increases, spend some of their new wealth on non-durable goods, increasing domestic demand even further. Consequently, as the domestic demand expansion in the durable and non-durable sectors triggered by the bubble shock partly draws on foreign goods, it is also a candidate to generate the observed negative correlation between housing and the current account. For instance, Laibson and Mollerstrom (2010), Adam et al. (2012), and In't Veld et al. (2014) argue that housing bubble shocks cause current account deficits and thus capital inflows. According to these studies, the domestic demand expansion triggered by a housing bubble induces imports, generating current account deficits. For the US, asset prices have been identified as a major driver of the current account (see Fratzscher et al., 2010); with housing occupying one of the largest positions in households' asset portfolios, the housing bubble hypothesis is, consequently, a relevant factor to explain current account swings.

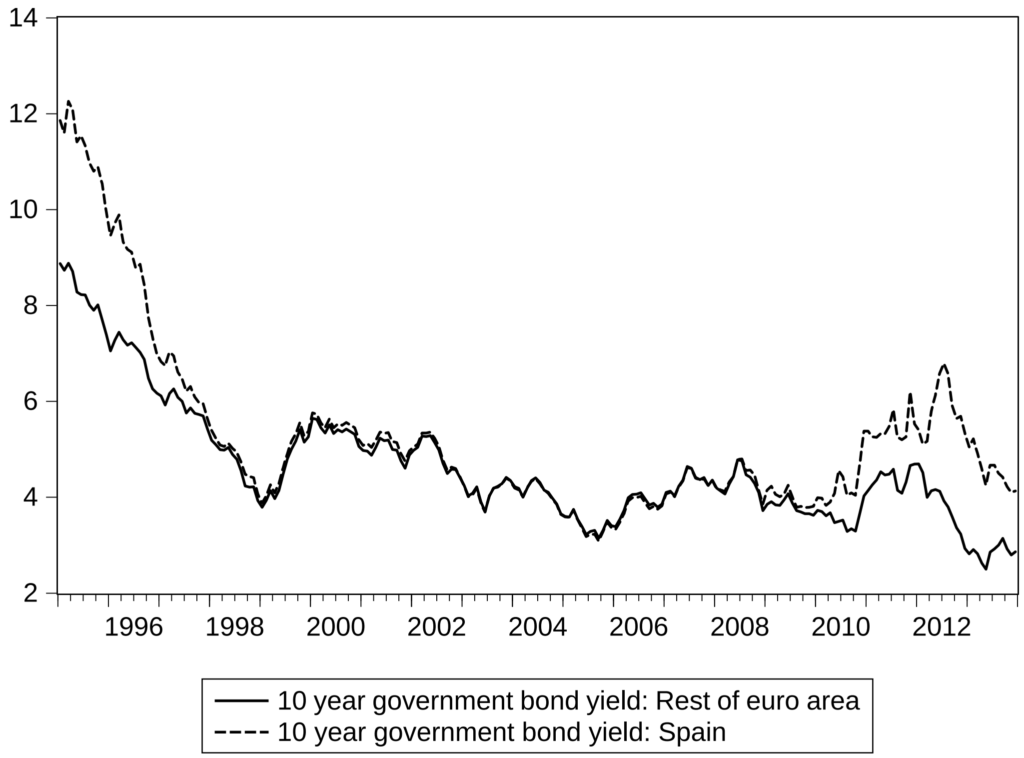
When comparing the two pull factors, the housing bubble shock is much more specific to the residential sector than the financial easing shock, which operates at a much broader level of the economy. Crucially, this observation is decisive to differentiating between the two shocks. Zooming in on the aggregate demand components, we would expect that the demand expansion is much more oriented towards investment than towards consumption in the case of the housing bubble shock. Likewise, the financial easing shock should expand more into consumptive expenditures. Even more severely, Justiniano et al. (2014) show in a theoretical model that financial easing shocks may be unable to explain the coincidence of increasing house prices and strong residential investment. Therefore, the two shocks should be separable by comparing consumption-to-investment ratios, with the financial easing shock increasing the consumption-to-investment ratio. We show in Section 3.3 that this feature can indeed be used to theoretically and empirically disentangle both pull disturbances.[7]

Next, we discuss the competing push hypothesis. The push view, for instance, underlies the so-called risk premium shock (In't Veld et al., 2014). Due to a plethora of institutional changes and the associated financial market reactions, this narrative proposes that rest of Eurozone investors increasingly perceived the Spanish economy as an attractive investment opportunity and began to allocate funds to Spain, thereby impacting the current account. As a consequence, the additional supply of capital lowered Spanish long-term interest rates and thus may have stimulated activity particularly in interest-rate-sensitive sectors such as the housing market. Some major drivers of this narrative can be summarized as follows: beginning with

[7]Overall, as increasing house prices loosen collateral constraints, the overall transmission of housing bubble shocks to the broader economy, however, is similar to financial easing shocks. Nevertheless, policy implications of both pull disturbances are different as the source of the housing bubble shock relates to the demand side, whereas the financial easing shock originates at the supply side of the housing market.

the Madrid Summit in 1995, Spanish risk-free rates started to converge to the level of German bond rates, thereby loosening overall financial conditions in Spain (see Figure 3.3).

Figure 3.3: 10-year government bond yields



Notes: The Figure depicts the development of 10-year government bond yields for Spain and the rest of the Euro Area. We obtain the data from Eurostat.

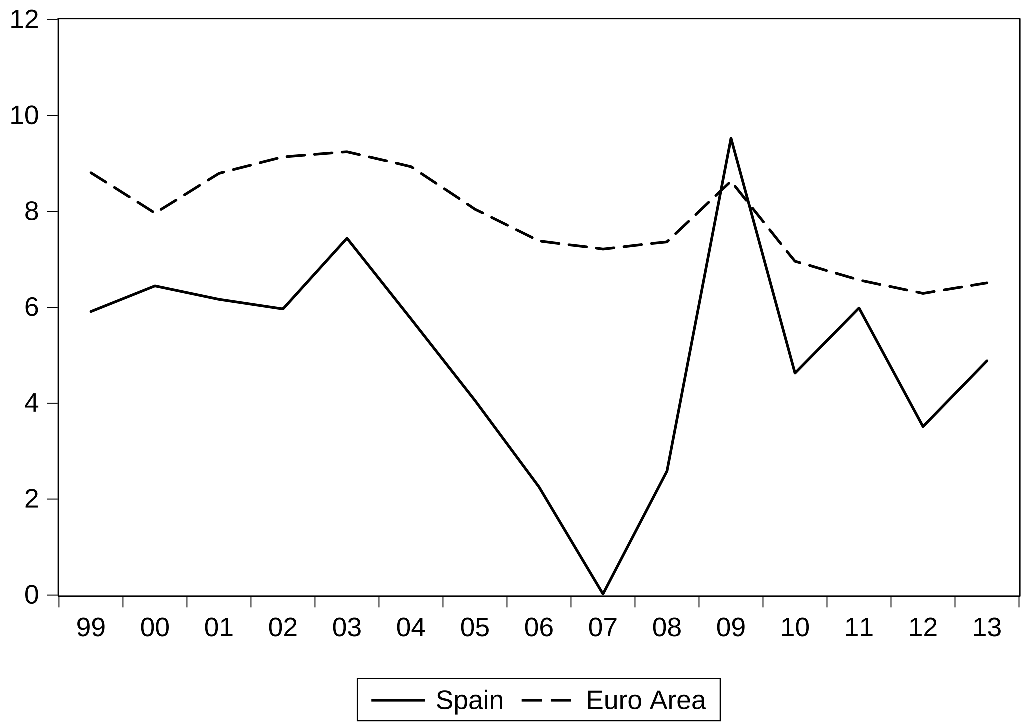
According to the risk premium narrative, the introduction of the common European currency, created an overall institutional environment that encouraged portfolio investors and banks to expand portfolio investment and lending to the periphery because, e.g., Spanish assets were paying higher yields. First and foremost, the creation of the Euro eliminated currency risks and might even have made investors believe in possible bailouts, thus decreasing the perception of political risks. Additionally, as pointed out in Hale and Obstfeld (2014), the ECB's refinancing policy did not discriminate between Spanish and, e.g., German sovereign bonds, despite their different credit ratings. The same applies to capital requirements that attached zero risk weights to all Euro Area government debt obligations. The introduction of an efficient payment settlement system (TARGET), in addition, eliminated transaction cost. In general, this unfolding may have contributed to capital inflows to Spain and, by compressing risk premiums over Spanish risk-free, corporate sector, or mortgage rates may have heated up the Spanish residential sector. The risk premium shock narrative can also explain the turnaround of the current account and housing cycle in Spain because, with the financial crisis that hit in 2008, risk spreads re-emerged, the current account reverted, and housing markets collapsed.

Another push factor conveys a European variant of the "savings glut" (Bernanke, 2005; Mendoza et al., 2009) shock operative for Spain. Clearly, the savings glut hypothesis cannot be applied literally to Spain. The idea of "uphill" flowing money, in particular, from China to the US, due to an underdeveloped Chinese financial system with a limited amount of financial instruments, is specific to the US. Instead, we argue for the case of Spain as follows. In the course of the housing boom, Spanish GDP and HICP growth rates were roughly one percentage point higher than those in the rest of the Euro Area. Thus monetary conditions, measured against a Taylor rate, were excessively expansionary for Spain and provide another rationale for the current account deficits because low real interest rates, on the one hand, discouraged saving and, on the other hand, fostered investment in housing.[8] Figure 3.4 depicts net saving rates for Spain and the Euro Area from 1999 to 2013. Since 2003, Spanish net saving rates dropped from 7 to 0 percent before sharply reverting at the onset of the Great Recession, while the Euro Area counterpart series fluctuated modestly around 8 percent.

This setting is reminiscent of the savings glut idea, as savings from the core Eurozone sought profitable investment opportunities in the periphery. Slack in core economies depressed Spanish exports, while the booming Spanish economy attracted imports and triggered current account deficits. In part, the capital inflows from core Eurozone countries may have found their way into the Spanish housing market, a sector that temporarily augured the most profitable returns on investment. Compared to the risk premium narrative, the savings glut shock constitutes a slack shock,

[8] See also Adam et al. (2012) for the interaction of real interest rate dynamics and beliefs in fueling house price booms.

Figure 3.4: Net household saving as percentage of net disposable income



Notes: The Figure portrays net household saving as a percentage of net disposable income for Spain and the rest of the Euro Area. We obtain the data from the OECD.

i.e., an excess saving and thus recessionary shock in core Eurozone countries, which distinguishes both shocks. In contrast to the risk premium shock, the savings glut shock is thus characterized by disinflation (in relative terms) in the rest of Eurozone vis-à-vis Spain and consequently also yields lower policy rates by the ECB, reflecting the slack environment in the majority of countries in the union. Additionally, both push shocks drive down long-term bond rates in Spain, whereas the demand-boosting Spanish pull shocks imply increasing bond yields, which further orthogonalizes the push from the pull hypotheses. In the following Section 3.3, we provide theoretical justification that these different features are robust and can be used to give the different developments an interpretation as structural shocks.

3.3 DSGE model sign restrictions

In this section, we develop a New Keynesian DSGE model by building on Rabanal (2009), Iacoviello and Neri (2010), and Aspachs-Bracons and Rabanal (2011).[9] We use the model's predictions to derive robust sign restrictions of impulse response functions, which we employ for identification in the empirical analysis.

3.3.1 Motivation

We construct a DSGE model tailored to permit a meaningful role for and a joint analysis of the two objects of investigation—the Spanish housing market and the current account—as follows: to analyze the interplay of shocks, frictions, and endogenous propagation mechanisms that characterize housing markets and that spill over to the macroeconomy, the heart of the economy consists of a workhorse business cycle model structure that is well-known to correctly capture business cycle moments, as in, e.g., Smets and Wouters (2003) and Christiano et al. (2005); we enrich the model to capture key features of the housing market as in Iacoviello (2005) or Iacoviello and Neri (2010). On the demand side, households derive utility from housing and use their housing wealth to borrow against—the housing collateral channel—and also as a vehicle to save. On the supply side, sectoral production heterogeneity induces endogenous fluctuations in residential investment and property prices. Moreover, the model's international dimension of a currency union setup accounts for the fact that investment versus saving balances do not need to clear each period in the country. We thus account for free international markets for capital within the Euro area. This implies, inter alia, that capital from the rest of the Eurozone may seek attractive investment opportunities in Spain or that extra loan demand in Spain may be met through funds coming from the rest of the Eurozone giving rise to endogenous current account flows as in, among others, Rabanal (2009) or Sá and Wieladek (2015). While studies such as In't Veld et al. (2014) rely on a detailed modeling of the home country, and model the foreign country block in a

[9] Mayer and Gareis (2013) estimate a model similar to ours with Bayesian techniques to study the housing boom and bust cycle in Ireland.

more stylized form, we account for a fully specified block for the rest of the Eurozone as well, thereby ex ante allowing for a level playing field for foreign push and domestic pull shocks in explaining the negative co-movement under consideration.

The rich specification of our large-scale monetary union model, however, comes at the cost of abstracting from other features in the data.[10] For instance, we abstract from modeling unemployment explicitly, which, of course, should affect Spanish households' budget constraints and saving rates. It is important to note, however, that we base our *quantitative* empirical analysis and inferences on a structural VAR model by using the DSGE model predictions only *qualitatively*. That is, while the theoretical model here abstracts from, inter alia, unemployment, these missing ingredients should only affect our model quantitatively, and should not change the sign restrictions, we are interested in (see, e.g., Sá and Wieladek, 2015). Our empirical analysis, however, can implicitly capture these amplification mechanisms in the data (see Section 3.4). The lack of these building blocks is therefore more critical in studies that estimate DSGE models directly and derive quantitative conclusions from the potentially misspecified structure of these models, as in Pariès and Notarpietro (2008) and In't Veld et al. (2014).

3.3.2 Model

The model features two economies in a closed monetary union, i.e., a domestic (Spain of size n) and a foreign country (rest of Eurozone of size $1 - n$). In both economies, households are composed of two types, i.e., borrowers and savers, where the latter have a higher discount factor, as in Kiyotaki and Moore (1997). Firms consist of monopolistically competitive intermediate goods producers and perfectly competitive final goods bundlers and are partitioned into two sectors. By employing capital and labor services, firms in the first sector produce non-durable consumption

[10]Our model, e.g., can capture the bond spread and housing bubble narratives proposed in Fernández-Villaverde et al. (2013), but is not able to, e.g., zoom into microeconomic details, such as corporate governance problems in the Spanish banking system, with badly governed banks characterized by excessively soft lending standards as in Akin et al. (2014). Nor can our model speak to political economy issues and their interaction with the self-reinforcing triangle of regional legislation, developers, and Spanish savings banks (so-called *cajas*) also discussed in Fernández-Villaverde et al. (2013). Finally, while we also stress the consequences of domestic pull factors, we leave other pull factors such as migration, as in Gonzalez and Ortega (2013), for future research.

and investment goods, which are traded across countries. Firms in the second sector produce housing by employing land in addition to using capital and labor as input factors, with savers owning the stocks of capital and land. Households maximize lifetime utility subject to a budget constraint, where utility concavely increases in consumption of non-durables and housing, and convexly decreases in labor. Optimizing borrowers and savers allocate resources among each other, which results in equilibrium debt. As in Iacoviello (2005), debtors borrow against housing. The expected present value of housing multiplied by a LTV ratio, as a consequence, determines borrowers' collateral constraints and thus their leverage (see also Kiyotaki and Moore, 1997). Following Smets and Wouters (2003) and Christiano et al. (2005), the model considers several real and nominal frictions.

We derive sign restrictions from the DSGE model exclusively for shocks that are necessary for identification in the empirical analysis and that ensure orthogonality to other macroeconomic disturbances. We restrict the presentation to the optimization problems of home country households and firms because there exists symmetry across the home country and the rest of the single currency area.

Borrowers' program

We denote the continuum of borrowing households (see Monacelli, 2009) with $b \in [0, \omega]$. b represents a borrower, and the share of borrowers in the economy is $\omega < 1$, and

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \zeta_{\beta,t} \tilde{\beta}^t \left(\alpha \log(\tilde{C}_t(b) - h\tilde{C}_{t-1}) + (1-\alpha) \log(\tilde{D}_t(b)) - \frac{\tilde{L}_t(b)^{1+\eta}}{1+\eta} \right) \right\} \tag{3.1}$$

is the intertemporal utility function. $\tilde{\beta}$ is the discount factor of borrowers (indicated with $\tilde{}$), where borrowers are less patient than savers, i.e., $\tilde{\beta} < \beta$. $\zeta_{\beta,t}$ is an exogenous shock disturbing the discount factor and logarithmically follows $\log(\zeta_{\beta,t}) = \rho_\beta \log(\zeta_{\beta,t-1}) + \epsilon_{\beta,t}$, with $\epsilon_{\beta,t} \sim \mathcal{N}(0, \sigma_\beta)$ and $\rho_\beta > 0$. $\mathbb{E}_t$ represents expectations formation at time t. Consumption of dwellings, $\tilde{D}_t(b)$, i.e., the stock of housing, increases borrowers' utility, whereas an index of labor supply, $\tilde{L}_t(b)$, negatively affects utility. η stands for the inverse Frisch elasticity. Consumption of a composite index comprising domestic and foreign non-durables, $\tilde{C}_t(b)$, is subject to external habits, with h determining the degree of habit formation.

The basket of non-durables is $\tilde{C}_t(b) = (\tau^{\frac{1}{\iota}} \tilde{C}_{H,t}(b)^{\frac{\iota-1}{\iota}} + (1-\tau)^{\frac{1}{\iota}} \tilde{C}_{F,t}(b)^{\frac{\iota-1}{\iota}})^{\frac{\iota}{\iota-1}}$, where subscripts indicate whether the non-durable is produced in the home, H, or foreign country, F. ι is the substitution elasticity between both non-durable goods, and τ defines the fraction of goods produced in the home country. Reallocating labor services from the non-durable consumption goods sector, $\tilde{L}_{C,t}(b)$, to the housing sector, $\tilde{L}_{D,t}(b)$, is subject to frictions as in Iacoviello and Neri (2010) and Aspachs-Bracons and Rabanal (2011). $\iota_L \geq 0$ measures cost associated with labor reallocation, and ϱ is the size of the housing sector, where the index of labor services is $\tilde{L}_t(b) = ((1-\varrho)^{-\iota_L} \tilde{L}_{C,t}(b)^{1+\iota_L} + \varrho^{-\iota_L} \tilde{L}_{D,t}(b)^{1+\iota_L})^{\frac{1}{1+\iota_L}}$. Borrowers are constrained by the following sequence of budget restrictions

$$P_{C,t}\tilde{C}_t(b) + P_{D,t}\tilde{X}_t(b) + R_{t-1}\tilde{S}_{t-1}(b) = \sum_j^{C,D} \frac{W_{j,t}}{\mathcal{M}_{j,t}} \tilde{L}_{j,t}(b) + \tilde{S}_t(b) + \Pi_t'(b). \tag{3.2}$$

$P_{j,t}, W_{j,t}$, and $\mathcal{M}_{j,t}$ denote prices, wages, and nominal wage markups in sector $j = C, D$, with C denoting the non-durable consumption goods sector and D indicating the durable consumption goods sector. The markups result from monopolistic competition that drives a wedge between wages paid by producers and those earned by borrowing households. $\tilde{X}_t(b)$ is borrowers' investment in residential property, and $\tilde{S}_t(b)$ represents one-period debt that borrowers hold against domestic savers for a gross interest rate of $R_t > 1$. Ultimately, labor unions pay dividends, $\Pi_t'(b)$.

Indebted households borrow against the expected present value of their dwellings, which serve as collateral (see Iacoviello, 2005). The nominal collateral constraint holds in every period and reads

$$R_t\tilde{S}_t(b) \leq \zeta_{LTV,t}(1-\chi)(1-\delta)\mathbb{E}_t \left\{ P_{D,t+1}\tilde{D}_t(b) \right\}, \tag{3.3}$$

where χ is the rate of down payment, i.e., $1-\chi$ the LTV ratio, respectively. $\zeta_{LTV,t}$ represents an exogenous AR(1) shock to the loan-to-value ratio with an unconditional mean of zero, which eases or tightens lending standards for borrowers. Furthermore, the housing stock depreciates with rate δ and has the accumulation equation $\tilde{D}_t(b) = (1-\delta)\tilde{D}_{t-1}(b) + \tilde{X}_t(b)$. To ensure a well-defined steady state of nominal debt (Schmitt-Grohé and Uribe, 2003), borrowers in the home country pay a risk premium on the union-wide risk-free bond rate, which inversely relates to deviations of the net foreign asset position from its non-stochastic steady state, as in Aspachs-Bracons and Rabanal (2011)

$$\frac{R_t}{R_t^*} = \exp\left[-\kappa\left(b_t' - b'\right) + \zeta_{RP,t}\right]. \tag{3.4}$$

b_t' is the net-foreign-asset-to-nominal-GDP ratio and b' the respective steady state. $\kappa \geq 0$ measures how sensitively the risk premium, R_t/R_t^*, reacts to fluctuations in b_t', where the union-wide (indicated with *) risk-free bond rate is R_t^*. $\zeta_{RP,t}$ is an exogenous disturbance that stochastically manipulates the risk premium, with $\zeta_{RP,t} = \rho_{RP}\zeta_{RP,t-1} + \epsilon_{RP,t}$ and $\epsilon_{RP,t} \sim \mathcal{N}(0, \sigma_{RP})$.

Borrowers optimally choose non-durable consumption and debt holdings to maximize (3.1) subject to (3.2), which gives

$$\tilde{U}_{C,t} = P_{C,t}\tilde{\lambda}_t \quad \text{and} \quad R_t^{-1} = \tilde{\beta}\mathbb{E}_t\left\{\frac{P_{C,t}}{P_{C,t+1}}\frac{\tilde{U}_{C,t+1}}{\tilde{U}_{C,t}}\right\} + \tilde{\psi}_t. \tag{3.5}$$

$\tilde{U}_{C,t}$ denotes the marginal increase in utility associated with the consumption of one extra unit of the non-durable good. $\tilde{\lambda}_t$ and $\tilde{\lambda}_t\tilde{\psi}_t$ are multipliers on the budget and collateral constraint, respectively. The optimal choice of the housing stock yields

$$\zeta_{B,t}\frac{\tilde{U}_{D,t}}{\tilde{U}_{C,t}} = \frac{P_{D,t}}{P_{C,t}} - (1-\delta)\left(\tilde{\psi}_t\zeta_{LTV,t}(1-\chi)\mathbb{E}_t\left\{\frac{P_{D,t+1}}{P_{C,t}}\right\} - \tilde{\beta}\mathbb{E}_t\left\{\frac{\tilde{U}_{C,t+1}}{\tilde{U}_{C,t}}\frac{P_{D,t+1}}{P_{C,t+1}}\right\}\right), \tag{3.6}$$

where $\tilde{U}_{D,t}$ denotes the marginal increase in utility from an extra unit of dwellings.

$\zeta_{B,t}$ is a stationary AR(1) shock representing a near rational bubble process in housing prices as in In't Veld et al. (2011). In the spirit of Bernanke et al. (1999), this disturbance temporarily shocks the housing Euler equation—which is the relevant asset equation—and drives a wedge between the expected house price and the counterpart value under fully rational expectations. Hence, for housing investors, this bubble is similar to a risk premium that is unrelated to fundamentals. By allowing only for small deviations from rational expectations on future fundamentals, we can introduce this stationary, non-fundamental disturbance and still solve for the unique rational expectations equilibrium. Overall, $\zeta_{B,t}$ captures the ideas promoted, inter alia, in Shiller (2005, 2007), who calls for explanations of housing cycles beyond fundamentals and describes housing bubbles as periods of optimism followed by panic reactions, i.e., pessimism regarding future housing market conditions.

Finally, the demand for domestic and foreign produced non-durables read $\tilde{C}_{H,t} = \tau(P_{C,t}/P_{H,t})^{\iota}\tilde{C}_t$ and $\tilde{C}_{F,t} = (1-\tau)(P_{C,t}/P_{F,t})^{\iota}\tilde{C}_t$, with $P_{H,t}$ and $P_{F,t}$ denoting the price of consumption goods produced in country $i = H, F$. Thus domestic consumers' price index is a composite, i.e., $P_{C,t} = (\tau P_{H,t}^{1-\iota} + (1-\tau){P_{F,t}}^{1-\iota})^{\frac{1}{1-\iota}}$.

Savers' program

The continuum of saving households is $s \in [\omega, 1]$, where each saver (s) has the lifetime utility function

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \zeta_{\beta,t}\beta^t \left(\alpha \log(C_t(s) - hC_{t-1}) + (1-\alpha)\log D_t(s) - \frac{L_t(s)^{1+\eta}}{1+\eta} \right) \right\}, \tag{3.7}$$

and maximizes it subject to the following sequence of nominal budget constraints

$$\begin{aligned} &P_{C,t}C_t(s) + P_{D,t}X_t(s) + P_{I,t}\sum_{j}^{C,D} I_{j,t}(s) + S_t(s) + B_t(s) = \sum_{j}^{C,D} \frac{W_{j,t}}{\mathcal{M}_{j,t}} L_{j,t}(s) \\ &+ \sum_{j}^{C,D} R_{j,t}Z_{j,t}(s)K_{j,t-1}(s) - P_{I,t}\sum_{j}^{C,D} a\left(Z_{j,t}(s)\right)K_{j,t-1}(s) + R_{l,t}l(s) + R_{t-1}S_{t-1}(s) \\ &+ R_{t-1}B_{t-1}(s) + \Pi_t''(s) + \Pi_t'''(s). \end{aligned} \tag{3.8}$$

Savers have access to international bond markets, $B_t(s)$, which is not the case for domestic, borrowing households. $R_{l,t}l(s)$ are revenues from renting out land, $l(s)$, to producers in the construction sector at rate $R_{l,t}$. $\Pi_t''(s)$ and $\Pi_t'''(s)$ denote dividends obtained from intermediate goods firms and labor unions, respectively.[11] Moreover, savers invest in non-residential capital, $K_{j,t}(s)$, of sector $j = C, D$, where $I_{j,t}(s)$ is a composite of home and foreign non-durable investment goods defined as $I_{j,t}(s) = (\tau^{\frac{1}{\iota}} I_{H,t}^{j}(s)^{\frac{\iota-1}{\iota}} + (1-\tau)^{\frac{1}{\iota}} I_{F,t}^{j}(s)^{\frac{\iota-1}{\iota}})^{\frac{\iota}{\iota-1}}$. As the home country's weight, τ, is the same as in the counterpart index for consumption goods, it holds that $P_{I,t} = P_{C,t}$. Building on, e.g., Christiano et al. (2005) and Smets and Wouters (2007), saving households optimally decide on the capital utilization rate, $Z_{j,t}(s)$. Adjusting this intensive

[11] Definitions of non-durable consumption goods and labor supply indices and consumption demand are analogous to those of borrowing households.

margin of capital is subject to cost, $a\left(Z_{j,t}(s)\right)$, where the cost function has the properties as in Pariès and Notarpietro (2008). $R_{j,t}$ is the rental price of capital in nominal terms, which determines savers' income from supplying the effectively used capital stock, $Z_{j,t}(s)K_{j,t-1}(s)$, to producers in sector $j = C, D$. Sector-specific capital accumulates over time as follows

$$K_{j,t}(s) = (1-\delta_j)K_{j,t-1}(s) + \left[1 - S\left(\frac{I_{j,t}(s)}{I_{j,t-1}(s)}\right)\right] I_{j,t}(s), \tag{3.9}$$

and depreciates with rate δ_j. Following Christiano et al. (2005), varying investment is costly, where $S(\cdot)$ is a cost function with $S(1) = S'(1) = 0$ and $S''(1) = \rho > 0$.

The solution to savers' decision problems with respect to their optimal choices of non-durable consumption and bond holdings results in the following FOCs

$$U_{C,t} = P_{C,t}\lambda_t \quad \text{and} \quad R_t^{-1} = \beta\mathbb{E}_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\right\}. \tag{3.10}$$

Optimal consumption of the housing good implies

$$\zeta_{B,t}\frac{U_{D,t}}{U_{C,t}} = \frac{P_{D,t}}{P_{C,t}} - \beta(1-\delta)\mathbb{E}_t\left\{\frac{U_{C,t+1}}{U_{C,t}}\frac{P_{D,t+1}}{P_{C,t+1}}\right\}. \tag{3.11}$$

Furthermore, savers optimize the stock of capital and its utilization rate as well as investment into sector-specific capital, which amounts to the following FOCs

$$Q_{j,t} = \beta\mathbb{E}_t\left\{\frac{U_{C,t+1}}{U_{C,t}}\left[(1-\delta_j)Q_{j,t+1} + \left(\frac{R_{j,t+1}}{P_{C,t+1}}Z_{j,t+1} - a(Z_{j,t+1})\right)\right]\right\}, \tag{3.12}$$

$$Q_{j,t}\left[1 - S\left(\frac{I_{j,t}}{I_{j,t-1}}\right) - S'\left(\frac{I_{j,t}}{I_{j,t-1}}\right)\left(\frac{I_{j,t}}{I_{j,t-1}}\right)\right] =$$

$$1 - \beta\mathbb{E}_t\left\{Q_{j,t+1}\frac{U_{C,t+1}}{U_{C,t}}S'\left(\frac{I_{j,t+1}}{I_{j,t}}\right)\left(\frac{I_{j,t+1}}{I_{j,t}}\right)^2\right\}, \text{ and } \frac{R_{j,t}}{P_{C,t}} = a'(Z_{j,t}) \tag{3.13}$$

where the real value of the existing capital stock, namely, Tobin's Q is $Q_{j,t}$.

Labor market

Households supply homogeneous labor that monopolistically competitive unions differentiate as in Smets and Wouters (2007) and Iacoviello and Neri (2010). There is one union for each sector and country, where savers govern the unions as in Quint and Rabanal (2014). Unions sell labor services to wholesale labor packers that ultimately supply composite labor services to intermediate firms. Building on Erceg et al. (2000), unions face nominal wage rigidities in the form of a Calvo (1983)-style lottery, where the fraction of unions receiving a wage setting signal is $\theta_{W,j}$, for $j = C, D$. Moreover, unions partially index wages to the previous period's price inflation of non-durable consumption goods as in Smets and Wouters (2003), with $\gamma_{W,j}$ measuring the sector-specific degree of indexation.

Unions' wage setting yields the following sectoral wage Phillips curve

$$\log\left(\frac{\omega_{j,t}}{\Pi_{C,t-1}^{\gamma_{W,j}}}\right) = \beta\mathbb{E}_t\left\{\log\left(\frac{\omega_{j,t+1}}{\Pi_{C,t}^{\gamma_{W,j}}}\right)\right\} - \frac{(1-\theta_{W,j})(1-\beta\theta_{W,j})}{\theta_{W,j}}\log\left(\frac{\mathcal{M}_{j,t}}{\mathcal{M}_j}\right). \quad (3.14)$$

$\Pi_{C,t} = P_{C,t}/P_{C,t-1}$ and $\omega_{j,t} = W_{j,t}/W_{j,t-1}$ are the price inflation of non-durable consumption goods and gross wage inflation in sector $j = C, D$, respectively. Nominal, sectoral wages, $W_{j,t}$, include non-competitive wage markups, $\mathcal{M}_{j,t}$, which result from unions' monopoly power over wage setting and read for savers

$$\mathcal{M}_{C,t} = \frac{W_{C,t}}{P_{C,t}}\frac{U_{C,t}}{(1-\varrho)^{-\iota_L}L_t^{\eta-\iota_L}L_{C,t}^{\iota_L}} \quad \text{and} \quad \mathcal{M}_{D,t} = \frac{W_{D,t}}{P_{C,t}}\frac{U_{C,t}}{\varrho^{-\iota_L}L_t^{\eta-\iota_L}L_{D,t}^{\iota_L}}. \quad (3.15)$$

Thus the markups represent deviations of savers' marginal rate of substitution from sector-wide real wages.

By contrast, borrowing households are merely members of unions with no governing power. Therefore, they only adjust the amount of supplied labor services to the prescribed wage. Their sectoral optimality conditions read

$$\mathcal{M}_{C,t} = \frac{W_{C,t}}{P_{C,t}}\frac{\tilde{U}_{C,t}}{(1-\varrho)^{-\iota_L}\tilde{L}_t^{\eta-\iota_L}\tilde{L}_{C,t}^{\iota_L}} \quad \text{and} \quad \mathcal{M}_{D,t} = \frac{W_{D,t}}{P_{C,t}}\frac{\tilde{U}_{C,t}}{\varrho^{-\iota_L}\tilde{L}_t^{\eta-\iota_L}\tilde{L}_{D,t}^{\iota_L}}. \quad (3.16)$$

Final goods firms

Final goods bundlers operate under perfect competition with fully flexible prices. They buy intermediate goods $i \in [0, n]$ from firms of sector $j = C, D$ and combine them according to the aggregator function

$$Y_{j,t} = \left(\frac{1}{n}\right)^{\lambda}\left(\int_0^n Y_{j,t}(i)^{\frac{1}{1+\lambda}}di\right)^{1+\lambda}. \quad (3.17)$$

$Y_{j,t}(i)$ represents type i intermediate goods, which bundlers employ for the production of the final goods, $Y_{j,t}$. λ is the net price markup (see, e.g., Smets and Wouters, 2003). Cost minimization of bundling firms yields the following sector-specific demand equations

$$Y_{C,t}(i) = \frac{1}{n}\left(\frac{P_{H,t}}{P_{H,t}(i)}\right)^{\frac{(1+\lambda)}{\lambda}} Y_{C,t} \quad \text{and} \quad Y_{D,t}(i) = \frac{1}{n}\left(\frac{P_{D,t}}{P_{D,t}(i)}\right)^{\frac{(1+\lambda)}{\lambda}} Y_{D,t}. \tag{3.18}$$

$P_{j',t}(i)$ and $P_{j',t}$, for $j' = H, D$, are domestic prices of sectoral intermediate and final products, respectively. Under zero profits in the final goods market the latter read

$$P_{j',t} = \left(\frac{1}{n}\right)^{-\lambda} (\int_0^n P_{j',t}(i)^{-\frac{1}{\lambda}} di)^{-\lambda}. \tag{3.19}$$

Intermediate goods firms

Building on Davis and Heathcote (2005) and Iacoviello and Neri (2010), we allow for sectoral heterogeneity of intermediate goods firms, which operate under monopolistic competition. The model introduces endogenous sectoral dynamics as a result of sector-specific production technologies

$$Y_{C,t}(i) = K'_{C,t}(i)^{\mu_C} L_{C,t}(i)^{1-\mu_C},\ Y_{D,t}(i) = \zeta_{AD,t} l(i)^{\mu_l} K'_{D,t}(i)^{\mu_D} L_{D,t}(i)^{1-\mu_l-\mu_D}. \tag{3.20}$$

$K'_{j,t}(i) = Z_{j,t}(i) K_{j,t-1}(i)$ denotes sectoral capital, effectively used in production, i.e., the accumulated stock of productive capital adjusted for time-varying capital utilization (see Smets and Wouters, 2007). μ_j, for $j = C, D$, are sectoral capital shares, and μ_l is the land share in the housing sector. $\zeta_{AD,t}$ is an AR(1) housing technology shock.

Firms in the intermediate goods sector solve a standard cost-minimization problem, which results in the following sectoral marginal cost equations

$$MC_{C,t}(i) = \frac{{R_{C,t}}^{\mu_C} {W_{C,t}}^{1-\mu_C}}{\mu_C^{\mu_C}(1-\mu_C)^{1-\mu_C}},\ MC_{D,t}(i) = \frac{{R_{l,t}}^{\mu_l} {R_{D,t}}^{\mu_D} {W_{D,t}}^{1-\mu_l-\mu_D}}{\mu_l^{\mu_l} \mu_D^{\mu_D} (1-\mu_l-\mu_D)^{1-\mu_l-\mu_D} \zeta_{AD,t}}. \tag{3.21}$$

The stock of land is fixed, i.e., $l_t = l$, and the interest for renting out land, $R_{l,t}$, is

$$R_{l,t} = \frac{\mu_l}{1-\mu_l-\mu_D} \frac{W_{D,t} L_{D,t}(i)}{l}, \tag{3.22}$$

where we choose l to yield equal sectoral wages as in Aspachs-Bracons and Rabanal (2011). Firms in the intermediate products sector earn subsequent profits

$$\Pi_{C,t}(i) = (P_{H,t}(i) - MC_{C,t}(i)) \left(\frac{1}{n}\right) \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\frac{1+\lambda}{\lambda}} Y_{C,t} \text{ and} \tag{3.23}$$

$$\Pi_{D,t}(i) = (P_{D,t}(i) - MC_{D,t}(i)) \left(\frac{1}{n}\right) \left(\frac{P_{D,t}(i)}{P_{D,t}}\right)^{-\frac{1+\lambda}{\lambda}} Y_{D,t}, \tag{3.24}$$

where they maximize the expected value of these profits. Analogously to unions' wage-setting process, intermediate firms face nominal rigidities. Thus, in each sector, a fraction of firms, $\theta_{P,j}$, is not able to set the profit-maximizing price, $\dot{P}_{H,t}(i)$, as in Calvo (1983), but is allowed to partially index prices to sectoral price inflation as in Smets and Wouters (2003). The solution to non-durable sector firms' program is

$$\mathbb{E}_t \left\{ \sum_{k=0}^{\infty} \Lambda_{t,t+k} \theta_{P,C} Y_{C,t+k}(i) \left(\frac{\dot{P}_{H,t}(i)}{P_{H,t}} \frac{P_{H,t-1+k}^{\gamma_{P,C}}}{P_{H,t-1}^{\gamma_{P,C}}} \frac{P_{H,t}}{P_{H,t+k}} - (1+\lambda) \frac{MC_{C,t+k}(i)}{P_{H,t+k}} \right) \right\} = 0, \tag{3.25}$$

where firms discount future profits with factor $\Lambda_{t,t+k} = \beta^k(\lambda_{t+k}/\lambda_t)$, and $\gamma_{P,C}$ denotes the intensity of price indexation. The counterpart optimality condition for housing sector firms is analogous and reads

$$\mathbb{E}_t \left\{ \sum_{k=0}^{\infty} \Lambda_{t,t+k} \theta_{P,D} Y_{D,t+k}(i) \left(\frac{\dot{P}_{D,t}(i)}{P_{D,t}} \frac{P_{D,t-1+k}^{\gamma_{P,D}}}{P_{D,t-1}^{\gamma_{P,D}}} \frac{P_{D,t}}{P_{D,t+k}} - (1+\lambda) \frac{MC_{D,t+k}(i)}{P_{D,t+k}} \right) \right\} = 0. \tag{3.26}$$

Finally, we obtain the law of motion for domestic prices in the non-durable sector

$$P_{H,t}{}^{-\frac{1}{\lambda}} = \theta_{P,C} \left[P_{H,t-1} \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^{\gamma_{P,C}} \right]^{-\frac{1}{\lambda}} + (1-\theta_{P,C}) \dot{P}_{H,t}(i)^{-\frac{1}{\lambda}}, \tag{3.27}$$

and the housing sector

$$P_{D,t}{}^{-\frac{1}{\lambda}} = \theta_{P,D} \left[P_{D,t-1} \left(\frac{P_{D,t-1}}{P_{D,t-2}} \right)^{\gamma_{P,D}} \right]^{-\frac{1}{\lambda}} + (1-\theta_{P,D}) \dot{P}_{D,t}(i)^{-\frac{1}{\lambda}}. \tag{3.28}$$

Market equilibrium

In equilibrium, the home country production of non-durables equals borrowers' consumption demand and savers' consumption and investment demand

$$\begin{aligned} Y_{C,t} &= n(\omega \tilde{C}_{H,t} + (1-\omega)(C_{H,t} + I_{H,t}^{C} + I_{H,t}^{D})) \\ &+ (1-n)(\omega^* \tilde{C}_{H,t}^* + (1-\omega^*)(C_{H,t}^* + I_{H,t}^{C*} + I_{H,t}^{D*})) + \Omega_t, \end{aligned} \tag{3.29}$$

with Ω_t denoting resource cost that result from the time-varying utilization of the capital stock. The housing market clears under the following condition

$$Y_{D,t} = n(\omega \tilde{X}_t + (1-\omega)X_t). \tag{3.30}$$

With the definitions of housing and non-housing supply at hand, we obtain domestic GDP in real terms, i.e., $Y_t = Y_{C,t} + Y_{D,t}$. Sectoral labor markets clear as follows

$$\omega \tilde{L}_{j,t} + (1-\omega)L_{j,t} = \int_0^n L_{j,t}(i)di, \text{ for } j = C, D, \tag{3.31}$$

and the equilibrium conditions of domestic and international debt markets are

$$\omega \tilde{S}_t = (1-\omega)S_t \text{ and } n(1-\omega)B_t + (1-n)(1-\omega^*)B_t^* = 0. \tag{3.32}$$

Ultimately, the evolution of the domestic country's net foreign assets is

$$\begin{aligned} n(1-\omega)B_t &= n(1-\omega)R_{t-1}B_{t-1} \\ &- nP_{F,t}[\omega \tilde{C}_{F,t}(1-\omega)(C_{F,t} + I_{F,t}^C + I_{F,t}^D)] \\ &+ (1-n)P_{H,t}[\omega^* \tilde{C}_{H,t}^* + (1-\omega^*)(C_{H,t}^* + I_{H,t}^{C*} + I_{H,t}^{D*})]. \end{aligned} \tag{3.33}$$

Monetary policy

The monetary authority perfectly controls the riskless bond rate in the monetary union, R_t^*, and follows an empirically motivated Taylor (1993) type instrument rule

$$\frac{R_t^*}{R^*} = \left(\frac{R_{t-1}^*}{R^*}\right)^{\mu_R} \left(\frac{\Pi_t^*}{\Pi^*}\right)^{\mu_\Pi(1-\mu_R)} \left(\frac{Y_t^*}{Y_{t-1}^*}\right)^{\mu_{\Delta Y}} \left(\frac{\Pi_t^*}{\Pi_{t-1}^*}\right)^{\mu_{\Delta \Pi}} \exp\left(\epsilon_{R,t}^*\right). \tag{3.34}$$

The central bank engages in interest rate smoothing, where μ_R measures the smoothness of interest rate policy. Moreover, the policy instrument reacts to deviations of the union-wide consumer price inflation, from its steady state, Π_t^*/Π^*, and to changes in output and the inflation rate, as in Christoffel et al. (2008). μ_π, $\mu_{\Delta\pi}$, and $\mu_{\Delta Y}$ are the reaction coefficients. $\epsilon_{R,t}^*$ is a white noise monetary policy shock.

3.3.3 Deriving restrictions

As in Peersman and Straub (2009), we simulate the DSGE model 10,000 times by drawing uniformly distributed, random values for the structural parameters within specified intervals (Table 3.1).[12] Then, we present median impulse responses together with 10 and 90 percent percentiles from all draws.

For a pairwise comparison of shocks, finding at least one common and one opposed endogenous response that is robustly predicted by the different structural models yields mutually exclusive restrictions, i.e., orthogonal shocks.

Exogenous processes

We implement the four shocks from Section 3.2 in the DSGE model as follows.

Savings glut shock in the rest of the Eurozone. Households in the rest of the union become more patient than home country households. As in Sá and Wieladek (2015), we model the savings glut shock as a positive discount factor shock, $\zeta_{\beta,t}$, in equations (3.1) and (3.7), describing the lifetime utility of borrowers and savers, respectively.

Risk premium shock in the rest of the Eurozone. This disturbance increases preferences of rest of union investors for home country bonds. It corresponds to a negative risk premium shock, $\zeta_{RP,t}$, in the net foreign asset equation (3.4).

Financial easing shock in Spain. This shock enhances credit availability against housing collateral of domestic borrowers and equals a positive shock, $\zeta_{LTV,t}$, in the collateral constraint equation (3.3) and the housing Euler equation (3.6).

Housing bubble shock in Spain. As in In't Veld et al. (2011), this is a shock disturbing the risk premium on housing values and appears as $\zeta_{B,t}$ in domestic borrowers' and savers' housing Euler equations (3.6) and (3.11).

[12] We draw on empirical DSGE models like, e.g., Smets and Wouters (2003), Aspachs-Bracons and Rabanal (2011), In't Veld et al. (2014), and Coenen et al. (2008) to specify parameter ranges.

Table 3.1: Parameter intervals

Parameter	Description	Range
$\theta_{W,C}$	Wage stickiness: non-durable sector	[0.60, 0.90]
$\theta_{W,D}$	Wage stickiness: durable sector	[0.00, 0.30]
$\gamma_{W,C}$	Wage indexation: non-durable sector	[0.50, 0.90]
$\gamma_{W,D}$	Wage indexation: durable sector	[0.00, 0.40]
$\mathcal{M}_C$	Wage markup in steady state: non-durable sector	[1.10, 1.50]
$\mathcal{M}_D$	Wage markup in steady state: durable sector	[1.10, 1.50]
$1+\lambda$	Price markup in steady state	[1.10, 1.50]
h	Habit parameter	[0.40, 0.80]
η	Inverse Frisch elasticity	[1.50, 2.50]
ρ	Adjustment cost: investment	[1.00, 7.00]
υ	Degree of capital utilization	[0.10, 0.50]
$\theta_{P,C}$	Price stickiness: non-durable sector	[0.60, 0.90]
$\theta_{P,D}$	Price stickiness: durable sector	[0.00, 0.30]
$\gamma_{P,C}$	Price indexation: non-durable sector	[0.30, 0.90]
$\gamma_{P,D}$	Price indexation: durable sector	[0.00, 0.40]
μ_{Π}	Reaction coefficient: inflation	[1.15, 3.00]
μ_R	Interest rate smoothing	[0.50, 0.90]
$\mu_{\Delta Y}$	Reaction coefficient: change in output	[0.00, 0.30]
$\mu_{\Delta\Pi}$	Reaction coefficient: change in inflation	[0.00, 0.25]
ρ_B	Persistence: housing bubble shock	[0.95, 0.99]
ρ_{LTV}	Persistence: financial easing shock	[0.95, 0.99]
ρ_β	Persistence: savings glut shock	[0.40, 0.60]
ρ_{RP}	Persistence: risk premium shock	[0.95, 0.99]
ρ_{AD}	Persistence: housing technology shock	[0.95, 0.99]

Notes: The Table displays the parameter ranges employed to simulate the model.

Calibration strategy

For parameters governing nominal rigidities in goods and labor markets, we draw on the 90 percent posterior intervals of Smets and Wouters (2003). Calvo parameters, $\theta_{W,C}$ and $\theta_{P,C}$, range from 0.6 to 0.9.[13] Parameters capturing wage and price indexation, $\gamma_{W,C}$ and $\gamma_{P,C}$, vary from 0.5 to 0.9 and 0.3 to 0.9, respectively (see Aspachs-Bracons and Rabanal, 2011). We draw wage and price markups from 1.1 to 1.5, corresponding to elasticities of substitutions for differentiated goods and labor services ranging from 3 to 11 (Coenen et al., 2008). Following Sá and Wieladek (2015), Calvo housing parameters, $\theta_{P,D}$ and $\theta_{W,D}$, vary from 0 to 0.3 and indexation parameters, $\gamma_{P,D}$ and $\gamma_{W,D}$, from 0 to 0.4, implying a more flexible housing compared to the non-durables sector. The degree of habit formation, h, ranges from 0.4 to 0.8 (see Smets and Wouters, 2003; In't Veld et al., 2014). For the inverse Frisch elasticity, η, we allow for variations from 1.5 to 2.5 (Coenen et al., 2008), while we set discount factors of savers, β, to 0.99 and borrowers, $\tilde{\beta}$, to 0.98. We rely on Smets and Wouters (2003) and Aspachs-Bracons and Rabanal (2011) for the capital bloc. Investment and capital utilization adjustment cost coefficients, ρ and ν, range from 1 to 7 and 0.1 to 0.5, respectively. The annual depreciation rate in the housing sector is 1 percent, and 10 percent in the non-durables sector. The capital share is 30 percent in the non-durables and 20 percent in the housing sector, while the land share is 10 percent in the housing sector. As in Aspachs-Bracons and Rabanal (2011), the cost coefficient of labor reallocation, ι, is 1.28, and the construction sector accounts for 10 percent of GDP in the steady state. The LTV ratio, $1-\chi$, is 0.8 (Akin et al., 2014) and the share of borrowing households, ω, is 0.4 (Hristov et al., 2012). The GDP weight of Spain in the Eurozone, n, is 0.1. Consistently, the fraction of Eurozone imports, $1-\tau$, is 0.15, while the fraction of imports from Spain, τ^*, is 0.0167. Domestic bonds' risk premium elasticity with respect to the net foreign asset position, κ, varies from 0.002 to 0.007 (Quint and Rabanal, 2014), and the Taylor coefficient intervals encompass 90 percent of the posterior distributions from the ECB's New Area-Wide Model (Christoffel et al., 2008). As in Sá and

[13] We expand the lower bound to 0.6, as the posterior intervals in Smets and Wouters (2003) do not include the popular values of $\theta_{W,C} = \theta_{P,C} = 0.75$.

Wieladek (2015), AR shock coefficients vary in persistent regions (Table 3.1), with standard deviations as in Aspachs-Bracons and Rabanal (2011).

Shock propagation

Figure 3.5 displays a financial easing shock.[14] A shock to the collateral constraint allows home country borrowers to increase credit against the expected value of housing, which raises borrowers' demand. Additionally, a relaxation of borrowing constraints fuels domestic absorption, in particular, in the non-durables sector.[15] Thus imports from the union increase, while exports shrink due to adverse terms of trade effects, i.e., the current account turns negative. A financial easing shock does not predict a boom in residential investment as enhanced borrowing capacities, predominantly, cause purchases of non-durables. Additionally, savers invest in housing when prices are low. Because house prices increase at short horizons due to the enhanced housing demand by borrowers, savers' residential investment drops, which overcompensates borrowers' investment in housing and, ultimately, also the house price increase. Furthermore, the central bank reacts to the financial easing shock by raising the policy rate, which translates into an increase of long-term bond rates in the home country.

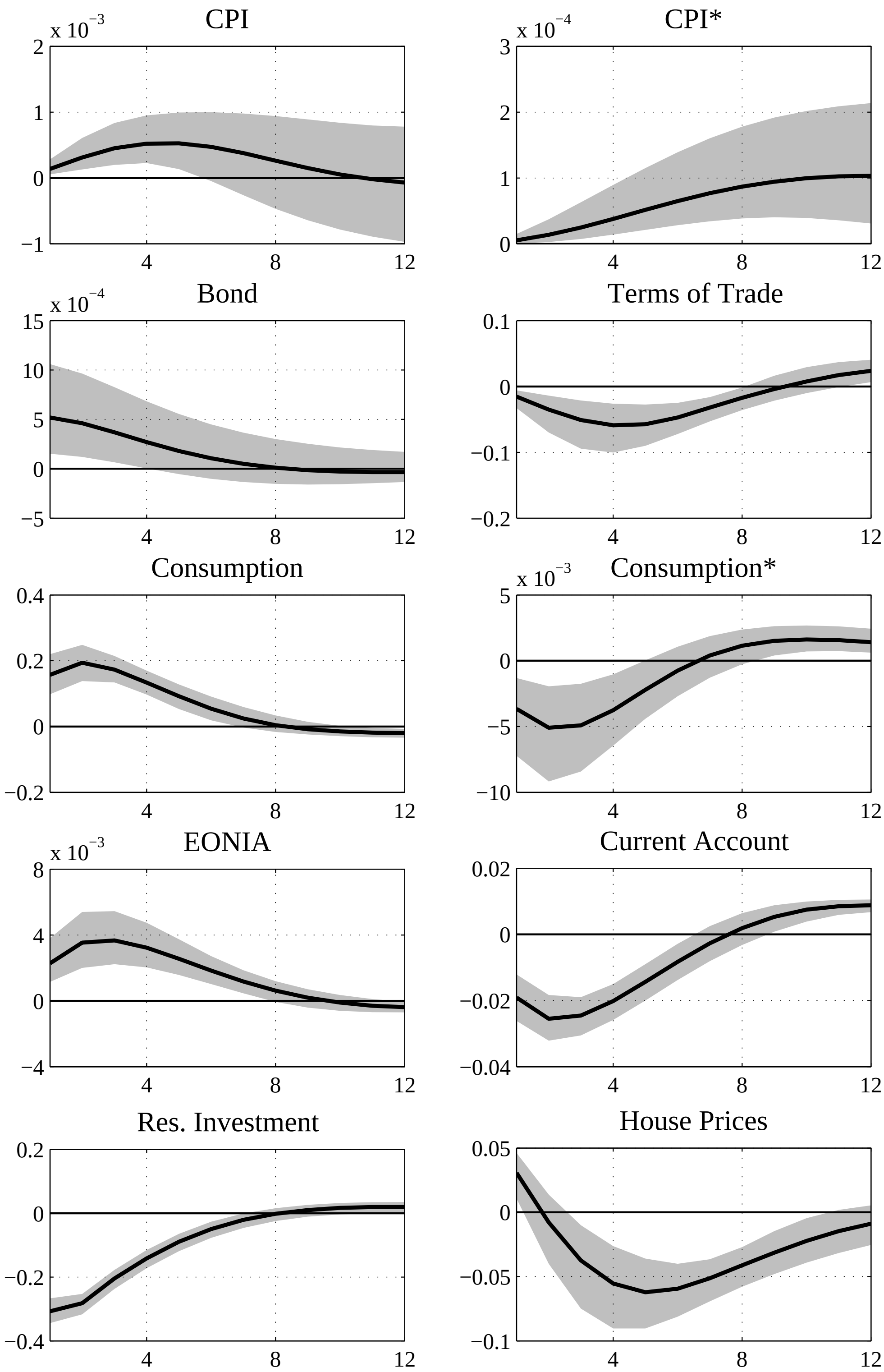
In contrast, a housing bubble shock can account for a positive co-movement of residential investment and real house prices (see Figure 3.6). Furthermore, while the ratio of consumption to residential investment increases following a financial easing shock, it decreases after a housing bubble shock. We use this feature to disentangle the two shocks.[16] Overall, both pull shocks imply an increase in consumer price inflation and, accordingly, an increase in the policy instrument, which depresses consumption demand in the rest of the monetary union.

[14] We calculate home country bond rates as a geometric average of short-term interest rates over a 10-year horizon as in Sá and Wieladek (2015).

[15] We analyze the dynamics for consumption instead of GDP, which allows us to isolate the impact on net exports—reflected by the current account—and on domestic absorption.

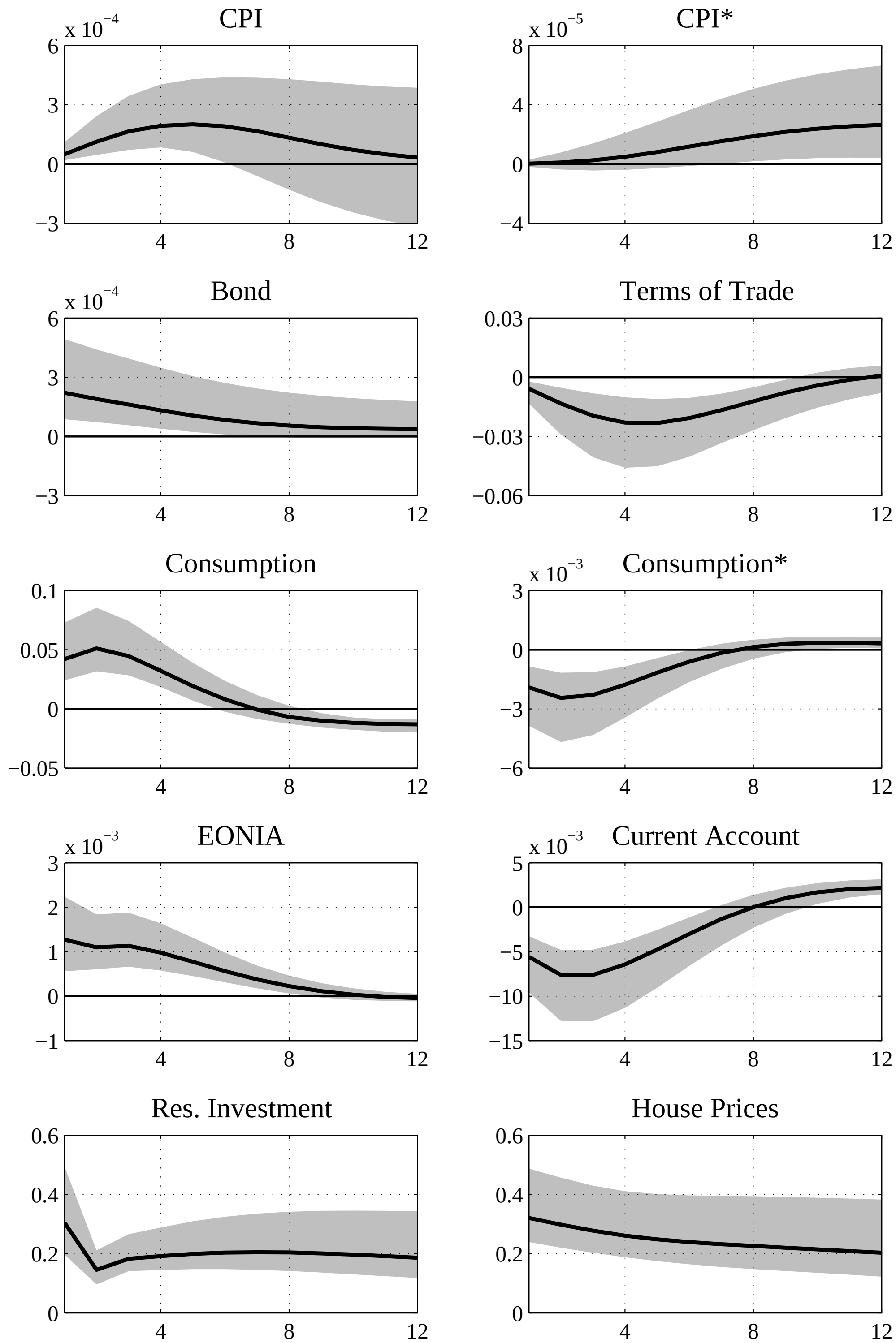
[16] This different prediction for the consumption-to-residential-investment ratio following both pull shocks is robust for the considered models over a horizon of seven quarters. Results are available upon request.

Figure 3.5: Financial easing shock



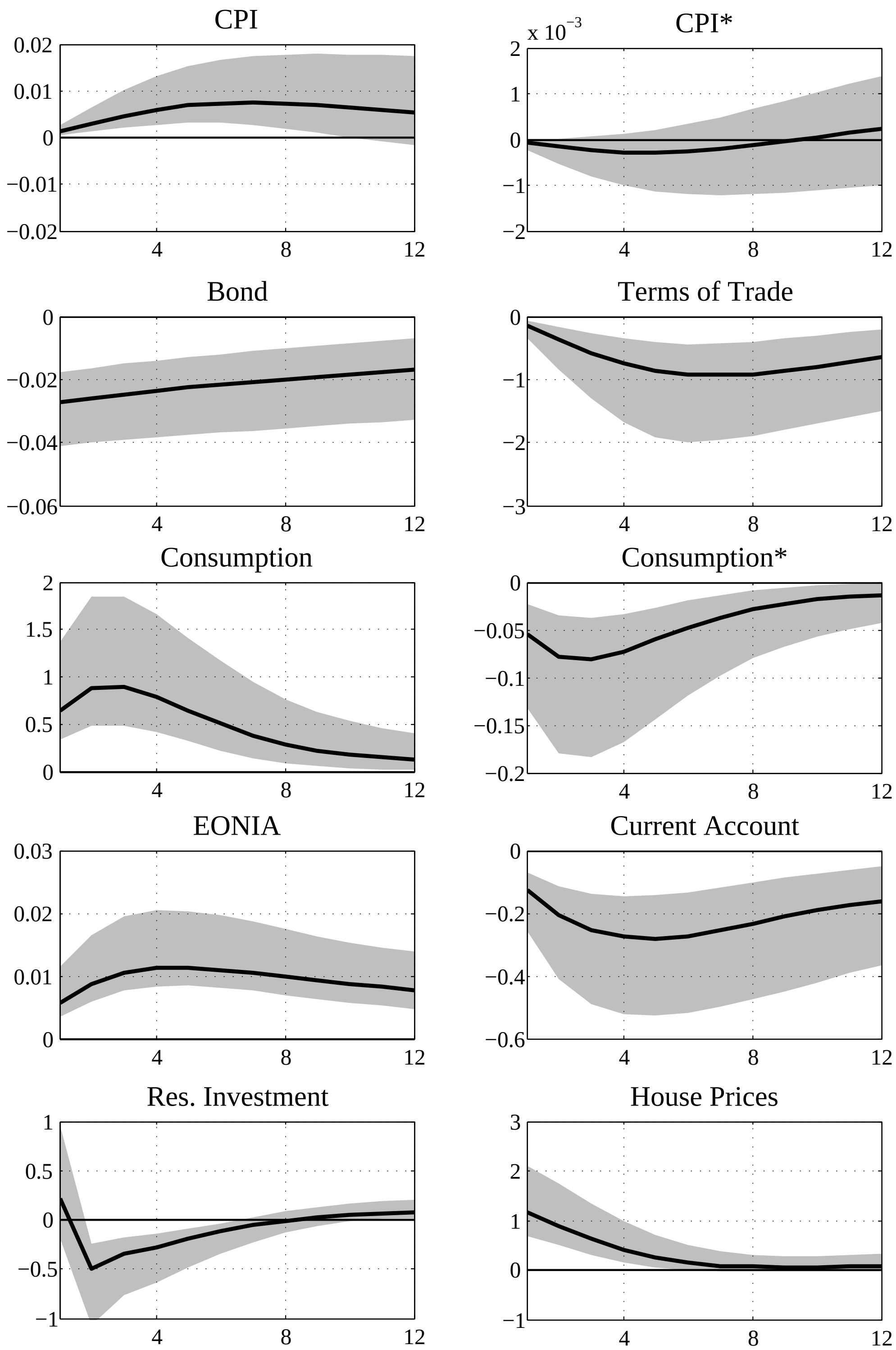
Notes: The x-axis is in quarters. The y-axis measures percent deviations from steady state. The solid line represents the median impulse response. Shaded areas display 10% and 90% percentiles of the simulated impulse responses.

Figure 3.6: Housing bubble shock



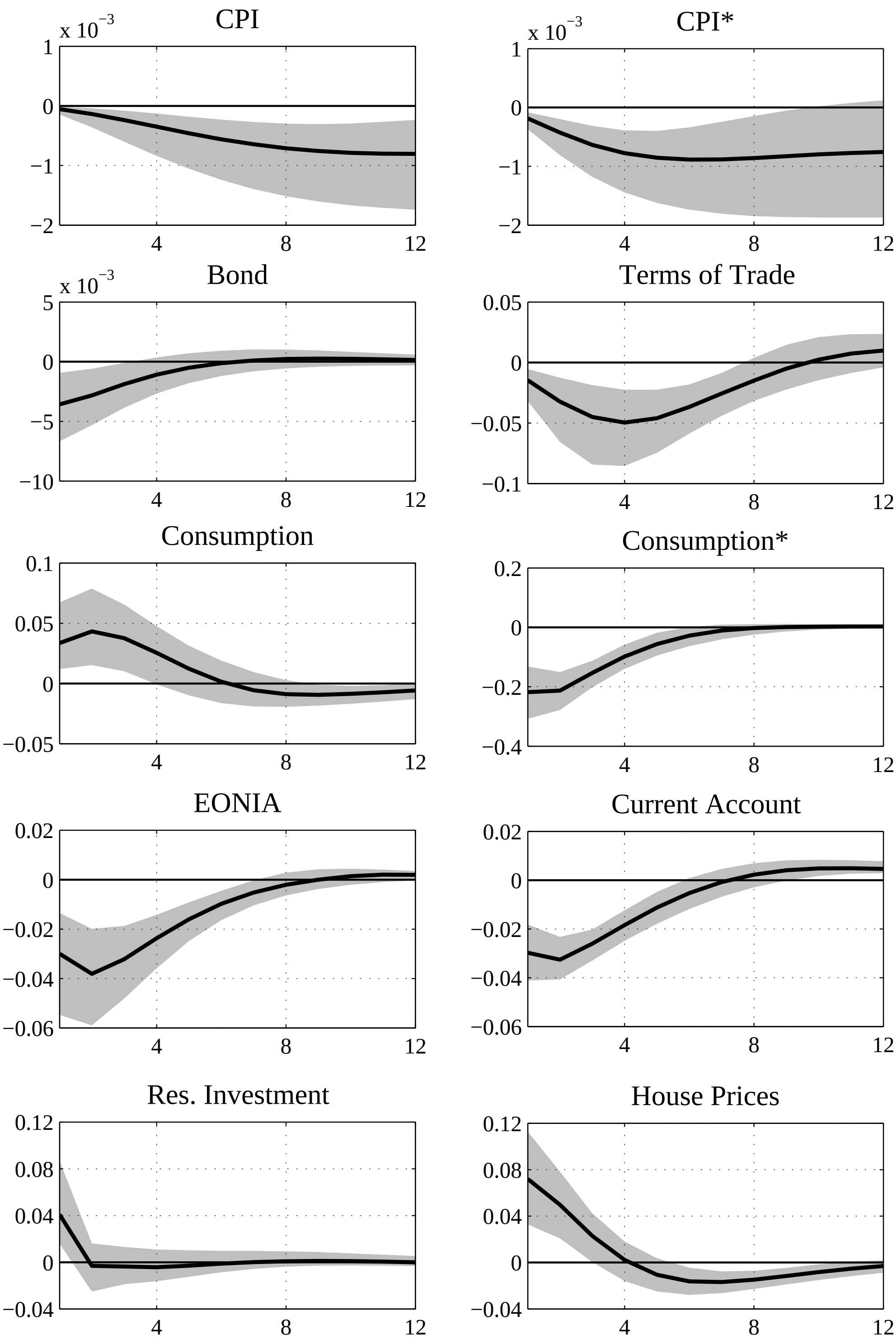
Notes: The x-axis is in quarters. The y-axis measures percent deviations from steady state. The solid line represents the median impulse response. Shaded areas display 10% and 90% percentiles of the simulated impulse responses.

Figure 3.7: Risk premium shock



Notes: The x-axis is in quarters. The y-axis measures percent deviations from steady state. The solid line represents the median impulse response. Shaded areas display 10% and 90% percentiles of the simulated impulse responses.

Figure 3.8: Savings glut shock



Notes: The x-axis is in quarters. The y-axis measures percent deviations from steady state. The solid line represents the median impulse response. Shaded areas display 10% and 90% percentiles of the simulated impulse responses.

Figure 3.7 traces the adjustment patterns following a risk premium shock. Investors in the rest of the union have greater preferences for home country assets and invest in these bonds to a larger extent. Capital inflows cause bond rates to fall, which distinguishes the risk premium shock from the alternative pull disturbances. In turn, lower interest rates increase domestic absorption as savers and borrowers increase consumption and housing demand. The central bank responds to the home country boom with higher interest rates, which mildly depresses consumption in the rest of the union.

Closely related to the risk premium shock is the savings glut shock (see Figure 3.8). However, in contrast to the risk premium shock, the simulations robustly predict a decline of short-term interest rates in the face of a savings glut shock. The surge of the discount factor in the rest of the union implies higher saving rates that in turn depress current economic activity, i.e., the savings glut shock represents a recessionary shock in the rest of the monetary union associated with a significant fall in consumer prices, and thus calls upon the central bank to decrease the policy instrument. As a consequence of the recession in the rest of the union with pronounced dis-inflationary effects, the CPI in the home country falls due to lower prices of imported goods – a facet of the savings glut shock, which further distinguishes this shock from the risk premium shock. Overall, due to asymmetric business cycles in the union, domestic interest rates are 'too low', triggering a boom in this economy. Lower interest rates, in addition, decrease borrowers' cost of financial services and relax borrowing constraints. This effect supports domestic absorption and reinforces a deterioration of the home country's current account.

To ensure orthogonality to other shocks, we also simulate a monetary policy shock and a housing technology shock.[17] Both shocks predict a rise in domestic and foreign consumption, which makes them orthogonal to our disturbances. Table 3.2 summarizes the set of robust sign restrictions that ensure orthogonality between the considered shocks and that we employ in the empirical analysis.

[17]The monetary policy shock is implemented as a negative $\epsilon^*_{R,t}$ shock in the Taylor rule equation (3.34). The housing technology shock is pinned down as an increase in home country's housing sector-specific technology, $\zeta_{AD,t}$, in equation (3.20). Results are available from the authors upon request.

Table 3.2: Benchmark sign restrictions

	Savings Glut	Financ. Easing	Risk Premium	Housing Bubble
Real Consumption	↑	↑	↑	↑
Real Consumption*	↓	↓	↓	↓
Prices	↓	↑	↑	↑
EONIA	↓	↑	↑	↑
Bond Rate	↓	↑	↓	↑
Bond Rate*				
Loans				
Current Account/GDP	↓	↓	↓	↓
Real House Prices				
Real Res. Investment				
Cons.-to-Investm.		↑		↓

Notes: Except for the current account, where we only restrict the impact quarter, we impose the restrictions for three quarters, i.e., 9 months as ≤ 0 or ≥ 0 (see, e.g., Sá and Wieladek, 2015).

As in Sá and Wieladek (2015), among others, we impose the restrictions for three quarters and do not impose restrictions on both housing market variables. For the current account, we only restrict the impact quarter in line with the DSGE model predictions to ensure that we isolate shocks that coincide with a current account deterioration. In Section 3.5, we relax the restriction on the current account and test how our results are affected by this identification assumption.

3.4 Empirical methodology

In this section, we empirically analyze the effects of savings glut, risk premium, financial easing, and housing bubble shocks on the current account and the housing market in Spain. We begin with a description of the data and the estimation strategy. Using a Gibbs sampler, we estimate a mixed-frequency VAR and draw efficient likelihood inferences as in Eraker et al. (2015). In particular, the mixed-frequency VAR approach is helpful, given the short period of the housing cycle in Spain. Then we present the identification of structural shocks via sign restrictions as proposed in Uhlig (2005) and summarize the empirical findings.

3.4.1 Estimation, data, and inference

The analysis builds on the following reduced-form open-economy VAR model

$$\boldsymbol{y}_t = \boldsymbol{c} + \sum_{l=1}^{p} \boldsymbol{\Phi}_l \boldsymbol{y}_{t-l} + \boldsymbol{\varepsilon}_t, \text{ where } \mathbb{E}[\boldsymbol{\varepsilon}_t] = 0 \text{ and } \mathbb{E}[\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t{}'] = \boldsymbol{\Sigma}_\varepsilon. \tag{3.35}$$

$\boldsymbol{c}$ is a vector of intercepts, $\boldsymbol{\Phi}_l$ is a $n \times n$ matrix including AR coefficients at lag $l = 1, ..., p$, and $\boldsymbol{\Sigma}_\varepsilon$ is a $n \times n$ variance-covariance-matrix. $\boldsymbol{\varepsilon}_t$ represents one step ahead forecasting errors, and $\boldsymbol{y}_t$ comprises the following n endogenous variables

$$\boldsymbol{y}_t = [\ \mathtt{C}_t\ \mathtt{C}^*_t\ \mathtt{CPI}_t\ \mathtt{EONIA}_t\ \mathtt{BOND}_t\ \mathtt{BOND}^*_t\ \mathtt{LOANS}_t\ \mathtt{CA}_t\ \mathtt{RINV}_t\ \mathtt{CPIH}_t\ ]'. \tag{3.36}$$

The open-economy VAR framework is increasingly employed to study spillover effects from domestic shocks into foreign country aggregates, and vice versa (see, e.g., Fratzscher et al., 2010; Sá and Wieladek, 2015). Accordingly, we include Spanish data and time series for the rest of the Euro Area in $\boldsymbol{y}_t$.[18] $\mathtt{CPI}_t$ is the log level of the Harmonized Index of Consumer Prices (HICP). $\mathtt{C}_t$ denotes the $\mathtt{CPI}_t$ deflated log level of private consumption expenditures, and $\mathtt{BOND}_t$ measures nominal 10-year sovereign bond yields in percent. To calculate rest of Euro Area counterparts (indicated with *), we apply the household expenditure weights used by the HICP. These weights are updated annually and range from a share of 8.8 percent to 12.7 percent for Spain at Euro Area expenditures.[19] $\mathtt{EONIA}_t$ represents interest rates in percent for unsecured, overnight lending in Euro Area interbank markets. As in Ciccarelli et al. (2015), we use $\mathtt{EONIA}_t$ instead of the interest rate on the ECB's main refinancing operations as proxy for the monetary policy stance. Following the financial turmoil of 2008, the ECB adopted various credit-enhancing policies for banks, e.g., liquidity provisions with fixed interest rates and full allotment, as well as longer-term refinancing operations, which temporarily pushed $\mathtt{EONIA}_t$ toward the ECB's deposit facility interest rate (see Lenza et al., 2010). Therefore, $\mathtt{EONIA}_t$, in contrast to the official policy rate, implicitly accounts for these liquidity management

[18] An alternative is to specify data as country differentials by assuming symmetry across countries.

[19] See, e.g., Dees et al. (2007), who compare fix country weights with continuously varying weighting schemes in a GVAR analysis.

programs making it a reasonable policy measure especially since the financial crisis (Ciccarelli et al., 2015). As a measure of bank lending by Spanish banks, we include $\texttt{LOANS}_t$, which represents the outstanding stock of Euro-denominated bank loans to the non-financial private sector in real terms. $\texttt{CA}_t$ stands for the Spanish current-account-to-GDP ratio in percent. $\texttt{RINV}_t$ and $\texttt{CPIH}_t$ are log levels of real residential investment and a real house price index measuring residential property prices of all Spanish dwellings, respectively. Except for $\texttt{CPIH}_t$, which we obtain from the BIS, all data come from Eurostat, the Bank of Spain, or the ECB.[20] Consumption, prices, and interest rate series primarily enter the VAR due to the identification of shocks, while we include the current account, loan volume, and housing variables to study the effects of capital inflows on the Spanish housing market. To pick up the EMU convergence period, we start the sample in 1995 M1 (see Crespo-Cuaresma and Fernández-Amador, 2013). We confine the estimation to 2013 M12 to avoid non-linearities caused by the zero lower bound on the nominal interest rate and provide robustness for the sample choice in Section 3.5.

Since the data sample is small, we employ a Bayesian mixed-frequency approach for estimation and inference. In particular, for the case of short samples, Eraker et al. (2015) demonstrate that combining high-frequency with low-frequency time series yields efficiency gains compared to an estimator that discards high-frequency information by relying on the coarsest data frequency for all variables. Thus we use n_z quarterly series, $\boldsymbol{z}_t$, and, provided that they are available, n_x monthly series, $\boldsymbol{x}_t$, where $n_z + n_x = n$. Concretely, the subsets of $\boldsymbol{y}_t$ read $\boldsymbol{x}_t = [\ \texttt{CPI}_t\ \texttt{EONIA}_t\ \texttt{BOND}_t\ \texttt{BOND}^*_t\ \texttt{LOANS}_t\ ]'$ and $\boldsymbol{z}_t = [\ \texttt{C}_t\ \texttt{C}^*_t\ \texttt{CA}_t\ \texttt{RINV}_t\ \texttt{CPIH}_t\ ]'$. Following the Bayesian mixed-frequency approach, we assume high-frequency elements in $\boldsymbol{z}_t$ to be latent and hence consider them as missing realizations.[21] Using Markov-Chain-Monte-Carlo methods, the estimator alternately samples from latent obser-

[20] In Table 3.3, we summarize the data sources and the data transformations for the VAR model. Note that $\texttt{RINV}_t$ corresponds to National Account data and $\texttt{CPIH}_t$ is based on a nominal price index from the BIS, which entails residential property prices including *all types of dwellings*, such as, e.g., owner-occupied dwellings, single-family and multi-family houses, first-time homeowner properties, etc.

[21] See Ghysels (2016) for an alternative method of estimating mixed-frequency VAR models within the mixed-data-sampling-regression framework. In addition, Foroni et al. (2013) offer a survey of mixed-frequency data methods, in general.

Table 3.3: Description of variables

Abbr.	Variable	Source	Transf.
$\texttt{C}_t$	Real Domestic Consumption	Eurostat	1
$\texttt{C}^*_t$	Real RoE Consumption	Eurostat	1
$\texttt{CPI}_t$	Domestic HICP	Eurostat	1
$\texttt{EONIA}_t$	Euro Over Night Index Average (%)	Banco de Esp.	0
$\texttt{BOND}_t$	10-Year Gov. Bond Rate (%)	ECB	0
$\texttt{BOND}^*_t$	RoE 10-Year Gov. Bond Rate (%)	ECB	0
$\texttt{LOANS}_t$	Real Loans: Non-Fin. Private Sector	Banco de Esp.	1
$\texttt{CA}_t$	Current Account as % of GDP	Eurostat	0
$\texttt{RINV}_t$	Real Residential Investment	Eurostat	1
$\texttt{CPIH}_t$	Real Price Index of All Dwellings	BIS	1

Notes: Data are transformed as follows: 0: levels, 1: log-levels. Variables are deflated with CPI and seasonally adjusted with the Census X-12 filter.
Link to house price index: `http://www.bis.org/statistics/pp_long.htm`.
Residential investment is retrieved from: `http://ec.europa.eu/eurostat/web/products-datasets/-/namq_pi6_c`.

vations and model parameters. Let $\widehat{\boldsymbol{z}}^i$ include low-frequency data—both observed and latent—for Markov-Chain-Monte-Carlo iteration i, where the sampled data are $\widehat{z}^i_1, \widehat{z}^i_2, \widehat{z}^i_4$ ... $\widehat{z}^i_{T-1}$. Furthermore, let $\widehat{\boldsymbol{z}}^i_{-t}$ represent the complete vector $\widehat{\boldsymbol{z}}^i$ except for element $\widehat{z}^i_t$. As in Eraker et al. (2015), we proceed as follows. First, given initial values and using a conjugate Normal-Inverse-Wishart prior for the parameters, we draw $\widehat{z}^i_t$ from a multivariate Normal density, while conditioning on $\boldsymbol{x}_t$, $\widehat{\boldsymbol{z}}^{i-1}_{-t}$, $\boldsymbol{c}^{i-1}$, $\boldsymbol{\Phi}^{i-1}_l$, and $\boldsymbol{\Sigma}^{i-1}_\varepsilon$. Second, we draw $\boldsymbol{c}^i$ and $\boldsymbol{\Phi}^i_l$ for given $\boldsymbol{x}_t$, $\widehat{\boldsymbol{z}}^i$, and $\boldsymbol{\Sigma}^{i-1}_\varepsilon$, and third, we obtain $\boldsymbol{\Sigma}^i_\varepsilon$ by conditioning on $\boldsymbol{x}_t$, $\widehat{\boldsymbol{z}}^i$, $\boldsymbol{c}^i$, and $\boldsymbol{\Phi}^i_l$. Taking the temporal aggregation structure of low-frequency variables in the VAR(p) into account, we computationally follow Qian (2013) and draw blocks of latent observations (aggregation cycle). We estimate the VAR with $p = 6$ lags, i.e., 2 quarters after linearly detrending all series and provide robustness on the VAR specification in Section 3.5.[22] Note that the detrending is motivated by the mixed-frequency approach, which requires non-trending data. We experimented with different detrending procedures, where the results are robust to the concrete choice of methods.

[22]We analyzed the sensitivity of the results with respect to the choice of the lag length by running the estimation for $p = 3, 9$, and 12 lags. For these specifications, the qualitative behavior of the key variables is not markedly affected. The results of these exercises are available upon request.

3.4.2 Identification

From the VAR model in equation (3.35), we derive impulse response functions to structural shocks by imposing sign restrictions (see, e.g., Faust, 1998; Canova and De Nicolo, 2002; Uhlig, 2005). Reduced-form forecasting errors, $\boldsymbol{\varepsilon}_t$, linearly map structural shocks, $\boldsymbol{\eta}_t$, through $\widetilde{\boldsymbol{P}}\boldsymbol{\eta}_t = \boldsymbol{\varepsilon}_t$, with $\mathbb{E}[\boldsymbol{\eta}_t] = 0$ and $\mathbb{E}[\boldsymbol{\eta}_t\boldsymbol{\eta}_t'] = \boldsymbol{\Sigma}_\eta$. $\boldsymbol{\Sigma}_\eta$ is diagonal, ensuring the orthogonality of the structural shocks. Furthermore, $\widetilde{\boldsymbol{P}} = \boldsymbol{PQ}$, where $\boldsymbol{P}$ represents one Cholesky factor from the Bayesian estimation. Hence, we can rewrite the variance-covariance matrix of the reduced-form model as $\mathbb{E}[\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t'] = \boldsymbol{\Sigma}_\varepsilon = \boldsymbol{PQQ'P'}$, where $\boldsymbol{Q}$ is an orthonormal matrix, i.e., $\boldsymbol{QQ'} = \boldsymbol{I}$. We obtain $\boldsymbol{Q}$ by applying the QR decomposition to a matrix $\boldsymbol{Z}$, which is sampled from a $\mathcal{N}(0,1)$ density. Each $\boldsymbol{Q}$ determines a different structural model and thus different impulse response functions. According to the sign restrictions approach, we derive impulse response functions for various structural models saving only those draws that are consistent with the imposed restrictions. As summary statistics, we then present the 16th, 50th, and 84th percentiles of all accepted draws as in, e.g., Peersman (2005), Uhlig (2005), and Fratzscher et al. (2010).

We simultaneously identify four types of macroeconomic shocks by imposing sign restrictions as summarized in Table 3.2 for nine months, i.e., three quarters (see, e.g., Sá and Wieladek, 2015). A broad class of open-economy DSGE models robustly predicts these restrictions, which are sufficient to disentangle the four shocks, and ensure orthogonality to other disturbances (Section 3.3). As demonstrated in Paustian (2007) and Canova and Paustian (2011), we sharpen the identification by imposing more than the minimum set of sign restrictions, which increases the probability of isolating the shocks of interest. However, by leaving the responses of the housing market variables unrestricted, we remain agnostic about their dynamics.

3.4.3 Results

Figures 3.9 to 3.12 trace the propagation of the identified shocks through the variables in $\boldsymbol{y}_t$. The shaded area denotes the 68-percent credible set from the Bayesian estimation, and the solid line represents the median impulse response function. We report the dynamics for 48 months, i.e., for four years. We define all monthly shocks to reduce consumption in the rest of the Euro Area, i.e., $\mathtt{C}_t^*$ falls, and to incur a Spanish consumption boom, i.e., $\mathtt{C}_t$ increases.

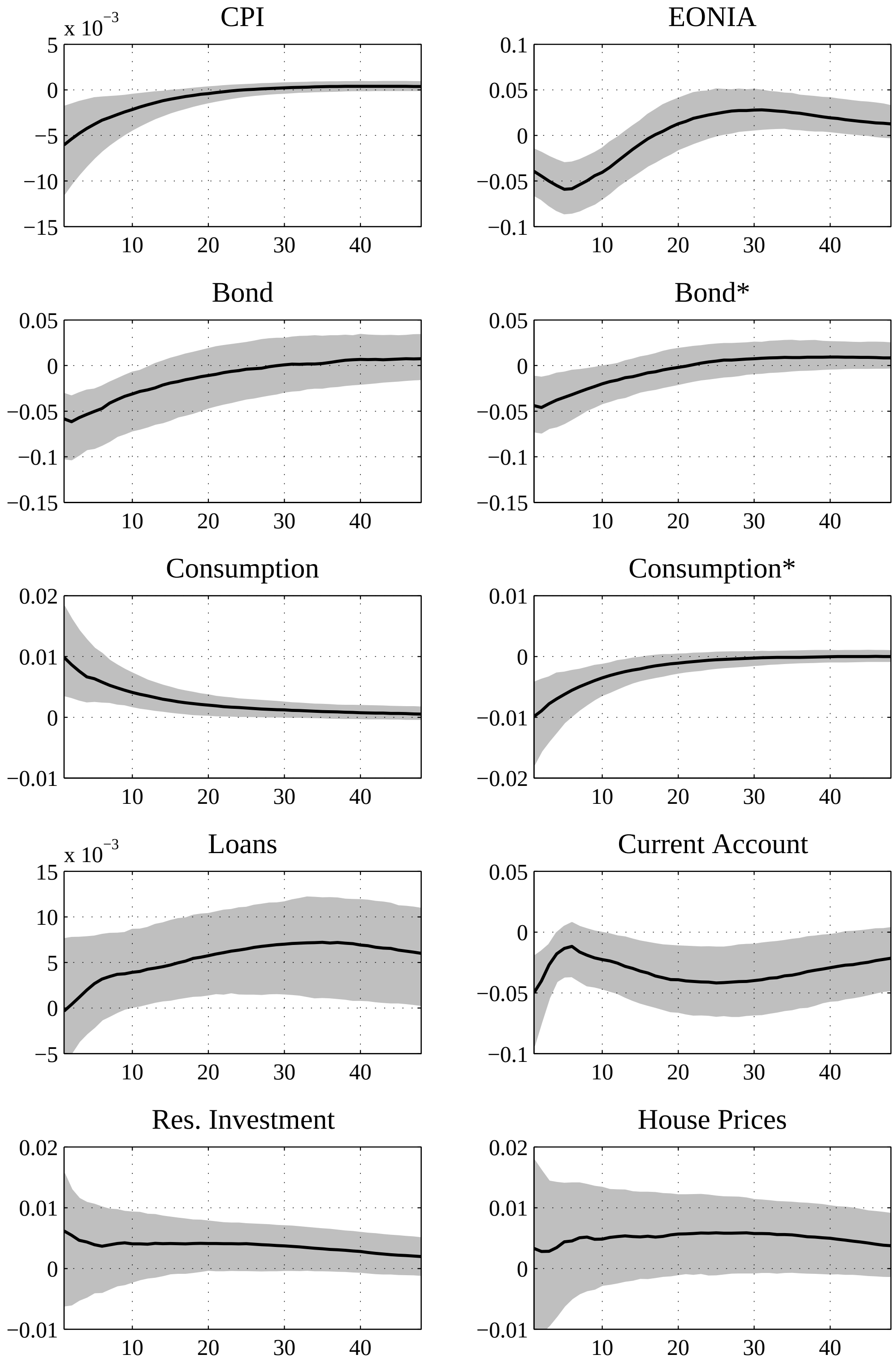
After a savings glut shock, the current account is significantly negative in the impact quarter in line with the imposed restriction (see Figure 3.9). Then, the response is insignificant for four months before significantly falling again for three and a half years. The unrestricted housing variables follow a sluggish increase, with median impulse responses being positive over the whole forecast horizon. Residential investment and house prices are, however, significant only at the margin. Furthermore, the unrestricted bank loans feature a slowly building rise, which remains significant from the second year onwards. Figure 3.10 displays adjustment patterns after a risk premium shock on Spanish bonds. This macroeconomic disturbance produces housing market and current account dynamics that are quantitatively similar to the savings glut shock. However, this shock reveals more inertia with respect to the current account, which remains significantly different from zero over the entire forecast horizon. Additionally, the risk premium shock predicts significant increments for both housing variables after one and a half years. The bank loan response largely mirrors the dynamics after a savings glut shock, i.e., loans slowly build up and remain significantly positive after a year. The financial easing shock from Figure 3.11 only forces the current account into negative territory as long as we impose the sign restrictions, i.e., for three months. Then, the current account response is insignificant, with the median impulse response even overshooting the pre-shock level after one and a half years. Interestingly, the shock does not predict a boom with respect to both housing variables. While house prices are insignificant over the entire impulse horizon, residential investment even falls significantly in the first year after the shock and bank loans do not exhibit a significant reaction.

Nevertheless, the DSGE model predicts this impact on housing markets (see Figure 3.5). From a theoretical perspective, financial easing shocks generally need not entail a housing boom because savers consume less housing, whereas borrowers increase the demand for housing. The overall impact on housing markets thus crucially hinges on the composition of households and their discount factors (see Justiniano et al., 2015). Altogether, the negative impulse response dynamics of residential investment together with the negative reaction of house prices (albeit insignificant) after a financial easing shock are difficult to reconcile with the Spanish housing boom. As opposed to the financial easing shock, the housing bubble shock is capable of generating a negative correlation between the current account and all housing market variables in the VAR (see Figure 3.12). Most notably, residential investment immediately builds up in a statistically significant fashion for 20 months after the shock, and house prices also increase at short horizons. Bank loans feature a hump-shaped increase that, however, is statistically insignificant.

Finally, we evaluate the importance of each shock with a forecast error variance decomposition, which indicates how much of the error variance in each variable can be attributed to the respective shock over a specified time horizon (see Table 3.4).[23] Concerning the explanatory power of each shock, we obtain a homogenous picture for the variables of interest, i.e., housing market variables and current account. Quantitatively, our results relate to the findings of Sá and Wieladek (2015) for the US, who apply a similar identification scheme. In relative terms, we find an important role for push factor representatives with regard to the housing market variables. On impact, the savings glut shock is strongest for house prices, whereas the explanatory power of the risk premium shock kicks in at later horizons and persists in both housing variables. As a pull factor representative, the financial easing shock is more relevant for explaining variations in the current account. Finally, the housing bubble shock explains least of the variation overall; however, its impact effect on residential investment prevails over the other shocks.

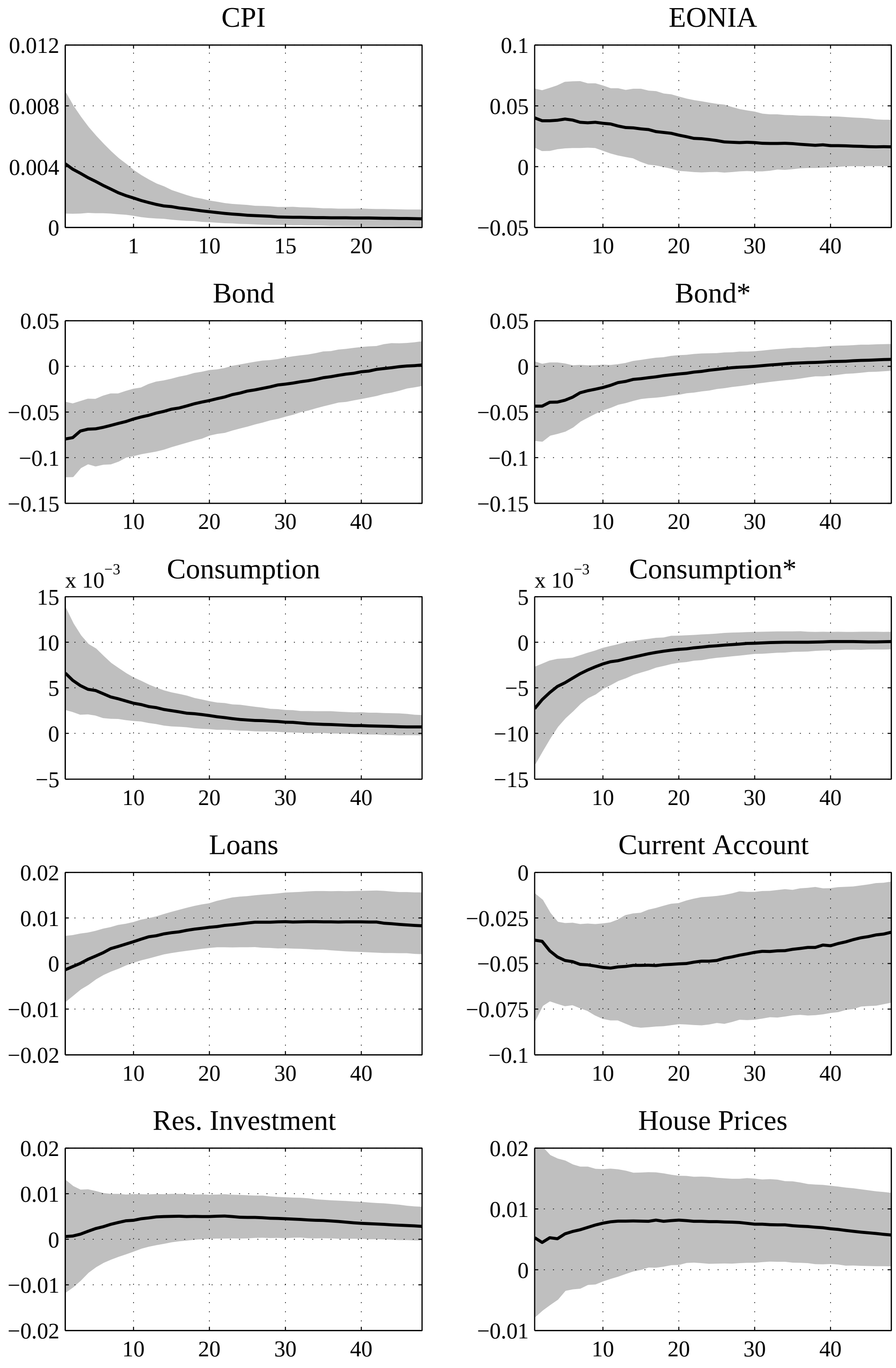
[23]All k-step-ahead forecast revisions are based on the median draw with 68 percent credible sets.

Figure 3.9: VAR: Savings glut shock



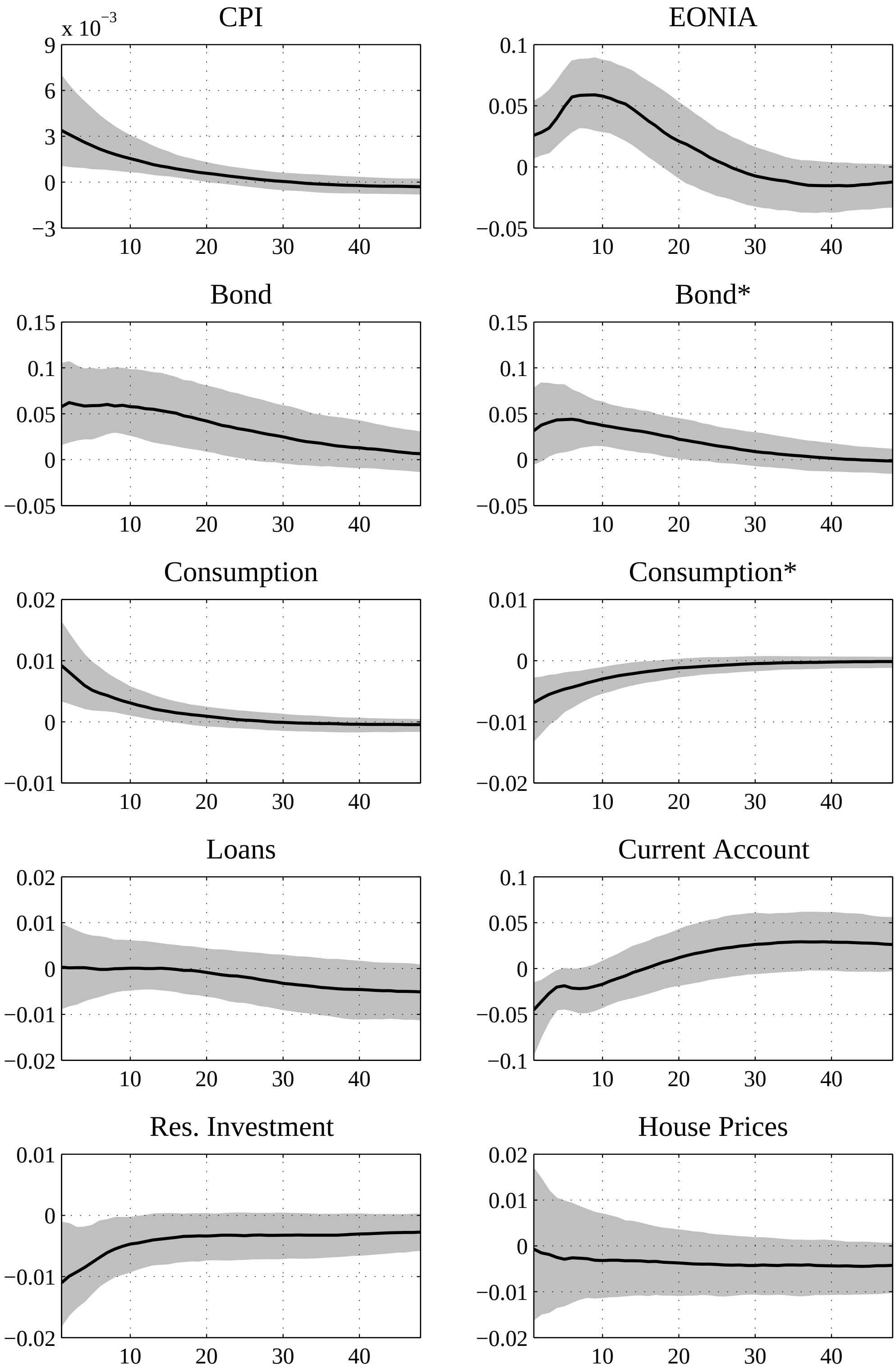
Notes: The x-axis is in months. The solid line represents the median impulse response functions from the BVAR. Shaded areas display 16% and 84% percentiles of the posterior distribution.

Figure 3.10: VAR: Risk premium shock



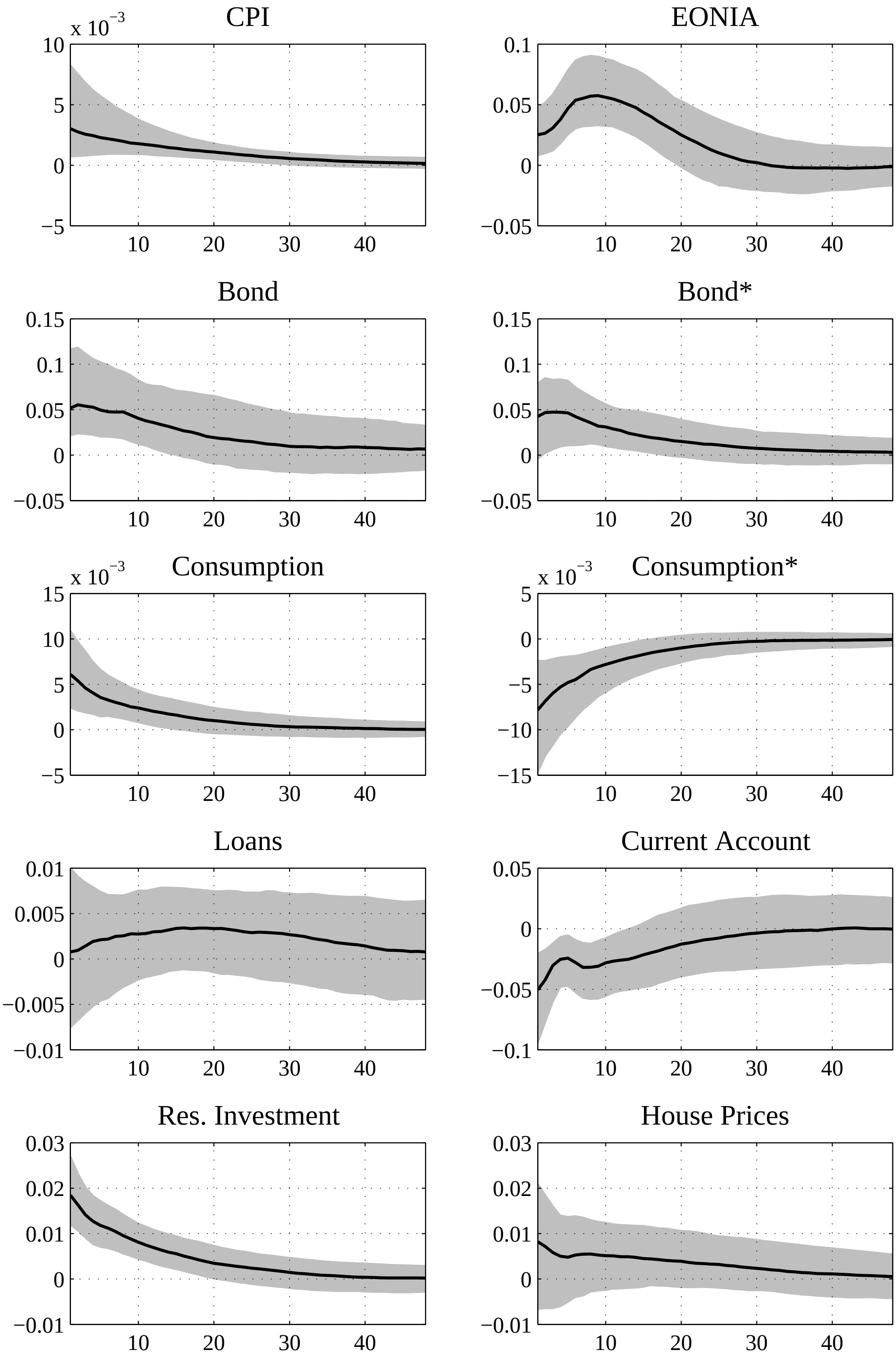
Notes: The x-axis is in months. The solid line represents the median impulse response functions from the BVAR. Shaded areas display 16% and 84% percentiles of the posterior distribution.

Figure 3.11: VAR: Financial easing shock



Notes: The x-axis is in months. The solid line represents the median impulse response functions from the BVAR. Shaded areas display 16% and 84% percentiles of the posterior distribution.

Figure 3.12: VAR: Housing bubble shock



Notes: The x-axis is in months. The solid line represents the median impulse response functions from the BVAR. Shaded areas display 16% and 84% percentiles of the posterior distribution.

Table 3.4: Forecast error variance decomposition

	Horizon	Current Account	House Prices	Res. Investment
Savings Glut Shock	Impact	3.88	7.49	5.00
		(0.34, 17.60)	(0.79, 26.54)	(0.37, 21.8)
	6 Months	6.34	5.35	4.39
		(1.91, 16.68)	(1.27, 15.14)	(0.87, 18.90)
	12 Months	6.01	5.04	4.69
		(1.51, 18.17)	(1.22, 16.38)	(0.94, 18.73)
	24 Months	5.61	5.28	4.88
		(1.19, 17.34)	(1.18, 16.47)	(1.16, 18.32)
	48 Months	5.05	4.97	5.07
		(1.18, 16.40)	(1.30, 16.17)	(1.28, 17.62)
Risk Premium Shock	Impact	5.63	4.79	5.84
		(0.69, 22.49)	(0.55, 19.92)	(0.52, 21.65)
	6 Months	7.78	5.97	7.98
		(2.51, 19.57)	(1.05, 24.67)	(1.56, 22.65)
	12 Months	7.50	6.48	7.63
		(1.98, 19.89)	(1.16, 23.76)	(1.76, 22.80)
	24 Months	6.63	6.76	8.16
		(1.42, 21.53)	(1.16, 22.56)	(2.13, 22.43)
	48 Months	6.76	7.04	8.53
		(1.53, 21.54)	(1.37, 21.04)	(2.31, 21.94)
Financial Easing Shock	Impact	6.72	6.23	3.40
		(0.53, 18.59)	(0.61, 21.77)	(0.29, 16.63)
	6 Months	7.84	6.09	7.44
		(1.98, 28.52)	(1.04, 20.36)	(1.45, 25.48)
	12 Months	7.88	6.19	7.52
		(2.04, 17.88)	(1.08, 20.29)	(1.40, 24.94)
	24 Months	7.02	6.65	7.93
		(1.81, 19.00)	(1.25, 20.62)	(1.75, 23.14)
	48 Months	7.29	7.35	7.79
		(1.72, 20.90)	(1.32, 20.96)	(2.16, 22.59)
Housing Bubble Shock	Impact	3.84	4.98	6.21
		(0.31, 17.35)	(0.54, 19.68)	(0.76, 23.17)
	6 Months	5.92	5.76	4.72
		(1.66, 15.04)	(1.34, 19.91)	(0.81, 18.97)
	12 Months	5.88	5.61	4.83
		(1.70, 16.11)	(1.55, 18.82)	(0.82, 18.14)
	24 Months	5.79	5.65	5.23
		(1.29, 17.63)	(1.37, 18.70)	(1.07, 17.74)
	48 Months	5.88	6.07	5.33
		(1.19, 18.56)	(1.64, 18.93)	(1.41, 17.95)

Notes: Results are in percent for the median draw and we report the 68 percent credible sets in brackets.

In general, the analysis leaves substantial fractions of the forecast revisions in the key variables open, i.e., explained by structural shocks that we do not identify. Our analysis, for instance, is orthogonal to macroeconomic disturbances emerging from, e.g., asymmetric housing technology dynamics or monetary policy shocks (see Section 3.3).[24]

3.5 Robustness

Until this point, we rely on the median of all accepted impulse responses in the VAR to draw inferences. However, since the impulse responses of these pointwise posterior statistics need not necessarily be generated by the same structural model, we now calculate the median target solution as in Fry and Pagan (2011) and study the dynamics for this particular model. The median target hereby refers to a single model that produces impulses, which minimize the weighted distance to the median. Consequently, this model renders an interpretation feasible from a structural perspective. The impulse response functions of the median target model resemble the dynamics of the posterior median fairly closely.[25] Therefore, we conclude that our inferences and main findings are not materially affected by considering the median instead of the median target solution.

Furthermore, we impose a different set of sign restrictions. The benchmark set of sign restrictions from Table 3.2 places restrictions on the current account while leaving both housing market variables unrestricted. As a consequence, only the magnitude of the response is informative for the current account in the restricted impact quarter. In line with the DSGE model simulations from Figures 3.5 to 3.8, we can allow for an alternative identification strategy, which leaves the current account unrestricted over the whole forecast horizon. Instead, we impose a positive reaction on real house prices for all shocks in the impact quarter. We refrain from

[24] Furthermore, our modeling device of, e.g., the financial easing shock as an LTV shock in the DSGE model represents a lending shock in terms of quantities and thus excludes an also-conceivable relaxation of bank lending standards in terms of prices, i.e., mortgage rates. Therefore, the easing shock cannot explicitly capture all facets of eased lending standards emerging from, e.g., stronger competition within the banking sector.

[25] We do not present all the robustness exercises to conserve space. They are available upon request.

restricting higher impulse response horizons because such a restriction does not hold for the financial easing shock. The results we obtain from the alternative identification approach do not differ substantially from the baseline results, reinforcing their robustness.

Ultimately, we test the extent to which our results are affected by modifying the data sample. We exclude all sample observations after Mario Draghi held his influential speech in July 2012 and re-run the regressions. The Draghi speech stands out as being a game changer within the crisis and might have an impact on the results. However, no notable differences compared to the benchmark sample emerge.

3.6 Conclusion and policy implications

Since the late 1990s, two macroeconomic cycles, which hampered policy makers and attracted great interest by academics and the news media, have characterized the Spanish economy: The persistent build-up of a housing bubble and the pronounced deterioration of the current account. With the onset of the Great Recession, both developments reverted sharply. To our knowledge, we are the first to put different hypotheses to a test by quantitatively studying this joint co-movement in the data through the lens of an open-economy VAR that explicitly takes into account the specifics of a monetary union by deriving robust sign restrictions from a DSGE model for a single currency area. Savings glut, risk premium, and housing bubble shocks can generate the imbalances of Spain vis-à-vis the rest of the Eurozone and, at the same time, a housing boom in Spain. In contrast, financial easing shocks are capable neither of generating a distinct deterioration of the Spanish current account nor of triggering a housing boom in Spain. In contrast, financial easing shocks are counterfactual to the housing boom, as a loosening of lending standards coincides with the housing markets cooling down in our structural VAR analysis.

The circumstance that the ECB only partially targets economic conditions of its member countries—Spain in this case—constitutes a potential policy lesson to take away from this paper. For both the domestic pull and foreign push shocks, the common conduct of monetary policy constitutes an amplification mechanism. In contrast to the monetary union setup, an independent national central bank may decide to lean against the wind, thereby curbing national housing market repercussions. A country-specific central bank may, e.g., decide to raise interest rates following a compression of relative cross-country sovereign bond yields caused by a risk premium shock, thereby counteracting a decline in long-term interest rates; further, a national central bank may choose to actively burst an unfolding housing bubble due to not fundamentally anchored house price appreciation expectations again by raising the policy instrument. In the Euro area's institutional setting, which we explicitly account for, these policies are not available, at least not to the full extent as for a national central bank. The lack of a tailored monetary policy thus makes the case for alternative policies to alleviate the impact of the analyzed shocks. One could, for instance, consider the implementation or enhancement of microprudential and/or macroprudential instruments designed to take into account individual countries' housing market characteristics. Considering such measures may be particularly relevant in the current situation, with the IMF's average of real house prices for 57 countries being back to pre-crisis level and with the European Systemic Risk Board warning of vulnerable residential sectors in countries such as Austria, Belgium, Finland, or the Netherlands. Even more severe, given the binding zero-lower-bound, the interest rate externality becomes even more rigid, making the case for alternative instruments as, e.g., microprudential and/or macroprudential policy tools.

Apart from that, our results may be of particular interest for countries that envisage forming a monetary union at some point in the future. In this respect, unions of, e.g., Latin American countries immediately come to mind. Against the backdrop of the experience of the European Monetary Union and the findings of our paper, the member states of future monetary unions can infer from our results that additional microprudential and/or macroprudential policies may be put in place to prevent the build-up of financial and macroeconomic imbalances among the member countries of such a union.

Chapter 4

A Model of the Market for Bank Credit: The Case of Germany

4.1 Introduction[1]

We present a basic model that illustrates the process of credit creation in a monetary economy. In our model, credit is determined by the interaction of three sectors: banks, non-banks, and the central bank. The model features two markets: the market for bank credit and, connected by a multiplier relation, the market for high-powered money. In a first step, the credit volume is determined by supply and demand in the market for bank credit and, in a second step, banks demand a fraction of the credit volume in form of high-powered money from the central bank. This modeling design of banks adequately describes the daily business practice of banks. As a matter of fact, banks do not need a specific amount of reserves or pre-collected savings beforehand in order to extend credit. When a bank makes a loan, it simply credits the customer's account with a bank deposit equal to the size of the loan

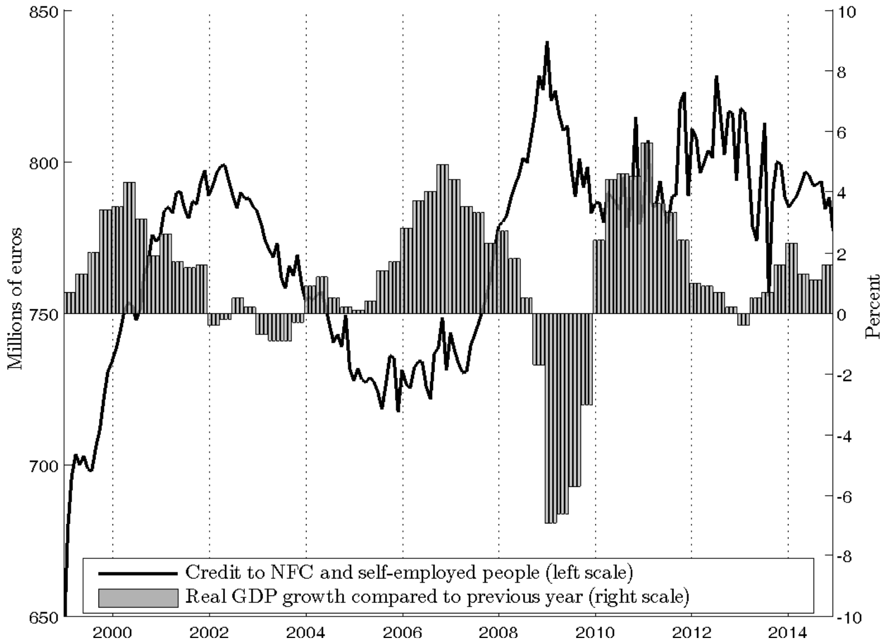
[1] This Chapter is based on joint work with Peter Bofinger and Mathias Ries. An earlier version appeared as Bofinger et al. (2017).

(McLeay et al., 2014). This introduces, in contrast to the predominant view of banks as intermediaries, the idea of banks as creators of credit.

In addition to presenting our model, we push our analysis further and verify the veracity of our model by estimating a credit market. More precisely, we estimate the German market for firm credit from January 1999 until December 2014, where demand and supply factors are chosen on the basis of our theoretic model. On account of information imperfections in credit markets (Stiglitz and Weiss, 1981) and disturbances emanating from other sectors of the economy, it is unlikely that supply and demand in the market for bank loans are equal at every point in time. We take this feature into account by analyzing the credit market in a disequilibrium framework estimated with Bayesian methods. Beyond evaluating our theoretic model, the disequilibrium framework also allows us to identify episodes in the German credit market that were characterized by demand or supply overhang.

Figure 4.1 displays the evolution of the credit to non-financial firms and self-employed people and real GDP growth during our sample period. Unsurprisingly, the evolution of credit is closely linked to the business cycle, where GDP growth seems to lead movements in credit. Focusing on the evolution of real GDP growth, Germany experienced a short recovery at the beginning of our sample, between 1999 and 2001, before entering a recessionary phase that lasted until 2004. Then, for a short period, the German economy accelerated until the financial crisis erupted in 2007/2008. Whereas other European countries struggled to recover from the financial crisis, Germany bounced back relatively quickly and regained its pre-crisis GDP level from the first quarter of 2008 in the first quarter of 2011. Moving on to the development of credit, the short economic recovery around 1999 and 2000 is reflected by an increase in credit. Credit peaked locally in the first quarter of 2002 with a credit volume of approximately 800 million euros, before a decline set in that went on until late 2005. The negative credit growth fell in a period where Germany performed poorly in economic terms, which led the incumbent government to reform the welfare system and the labor market (Agenda 2010).

Figure 4.1: Bank credit to non-financial corporations and self-employed people and real GDP growth



Source: Bundesbank and OECD.

From 2006 until the crisis, credit exploded and increased from 730 million to 840 million euros in the first quarter of 2009. Then, in 2009, Germany's bank credit market for firms experienced a strong drop in credit growth. The financial crisis, which had started in the U.S., finally spilled over to Europe. The crisis increased the uncertainty about counter-party risks among banks, which resulted into a freeze of the interbank market. The fear of a melt-down of the financial system, with devastating consequences for the real economy, led the ECB to take, in addition to standard monetary easing measures, non-standard measures to protect the functioning of the financial system. As liquidity dried up in funding markets, the ECB introduced liquidity and funding measures like the long-term refinancing operations (LTROs) and purchased assets in malfunctioning market segments, e.g., Covered Bonds Purchase Program (CBPP). On the national level, the German government ensured the banks' solvency with guarantees and supported aggregate demand with an economic stimulus plan in 2009.

Applying the disequilibrium model to the German market for firm credit, we are able to capture the economic episodes in Germany fairly well. Our model predicts that at the beginning of the millennium credit demand by the firm sector was lagging behind credit supply, which coincides with the recessionary environment of the German economy at the time. Thereafter, during the run-up to the crisis and afterwards, credit supply was the constraining market side and prevented a stronger credit expansion. Our results are supported on a microeconomic level. The *Kredithürde* of the ifo-institute, which reflects the borrowing conditions of German firms, indicates worsening credit conditions after the financial crisis. This result is confirmed by Rottmann and Wollmershäuser (2013). They develop a bank credit supply indicator, based on the responses by firms from the Ifo Business Survey, which suggests a tightening of credit supply after the crisis.

Furthermore, the regression results confirm the relevance of our model's main determinants. Our model motivates a role for economic activity and for various funding costs of banks and firms, which includes lending rates, bond rates, and the refinancing rate. Quantitatively and qualitatively, we find plausible and significant results for the factors determining credit supply and demand.

Our contribution aligns with the following dimensions. First, we present an aggregate model of the market for bank loans, in which banks back their credit business with a variety of refinancing instruments. This includes, in addition to refinancing via the central bank and deposits, the bond market and equity market. Second, banks' credit business is placed before refinancing operations, which is the adequate description of banking today. Third, we estimate a market for German firm credit in a disequilibrium framework and, in addition to testing our model, identify episodes of excess demand and supply in the loan market. And fourth, we show that the evolution of bank credit can be well captured with prices, which gives support to the price-theoretic approach of our model.[2]

The paper is organized as follows. Section 2 contains an overview of related literature. Section 3 illustrates the theoretic model for the banking sector. Section 4 discusses our econometric approach and section 5 provides the estimation results. Section 6 concludes.

[2]Price-theoretic means that it is not quantities, such as deposits and equity, that play the leading role in extending credit, but rather differentials in prices.

4.2 Literature review

Our theoretic model builds on the work by Bofinger and Schächter (1995). Close to this model design is the work of Winker (1996), who also models an aggregate market for bank loans, in which banks behave as profit-maximizing firms (Freixas and Rochet, 2008). Most importantly, our model design is consistent with the view of banks as creators of credit, opposed to the mainstream view of banks as intermediaries of credit. In short, the mainstream view assumes that intermediary banks lend out funds that they collected before making the loan.[3] This assumes that some entity in the economy has put funds, which can be lent out, to disposition by, e.g., saving more. In contrast, viewing banks as creators of credit reverses causality: making a loan creates, as a balance sheet reflex, deposits on the bank's liability side. Therefore, the extension of credit depends on the willingness of banks to loan money and not on the abstinence of some household epitomized by saving more. The misconception of seeing saving as the source or prerequisite for expenses of any sort is further strengthened by a misinterpretation of the savings-investment identity. The identity is interpreted causally, with causality running from saving to investment. However, it is not higher saving that is needed for funding new investments, but rather additional financing possibilities. A deeper digression into the difference between saving and financing is provided by Borio and Disyatat (2011, 2015) and Lindner (2012). Therefore, since banks are able to make loans by "pure will", their credit business is not constrained or relaxed by pre-collected savings or reserves.[4] On the contrary: in a first step, the bank makes a loan and, in a second step, the necessary reserves are procured after credit business has taken place. Our model describes this process accurately by placing credit business in first place. Werner (2014) actually proves that this is the way banks do business, by carrying out a field experiment that documents this practice. Making a distinction between the two models of banking is not only of mere academic interest. Disyatat (2008, 2011) underlines that the understanding of how banks function and how they are

[3]This is the correct description, of course, for financial institutions other than banks.

[4]This does not mean that banks serve every demand for credit. Banks operate in a competitive environment, in which bad decisions push them out of business.

modeled in theory impacts policy implications in an important way. Finally, Jakab and Kumhof (2015) contribute to this area of research by developing a state-of-the-art DSGE model that includes banks as creators of credit, instead of intermediaries, and illustrate the implications of the modeling choice of banks in the framework of a DSGE model. As an aside, it is stunning that these insights were well known among economists and central bankers from the early 20th century, but did not get incorporated into mainstream economics.[5]

The empirical study and estimation of markets for bank loans started in the early 1970s. In the beginning, markets were estimated by assuming them to be in equilibrium, but as evidence on the possibility of credit rationing accumulated, economists developed the disequilibrium framework. In this framework, demand and supply do not balance each other out at every instant of time and one market force is constrained. Therefore, both sides of the market, demand and supply, are analyzed separately. An early work is the paper by Laffont and Garcia (1977), who estimate a disequilibrium model for the supply and demand of chartered banks' loans to business firms in Canada. Building on their work and on others, the disequilibrium approach became a standard tool for answering questions relating to the credit market, which resulted into a broad body of work.[6] Among recent studies that apply the disequilibrium framework is Everaert et al. (2015). They study countries in Central, Eastern, and Southeastern Europe that experienced a credit boom-bust cycle in the last decade. Their goal is to find out whether demand or supply factors were the more important driving forces during this period. For Latvia, Poland, and Romania, they find constraints on the credit demand side for the period from 2003 to 2012. In contrast, Lithuania and Montenegro seem to be the object of changing demand and supply regimes. Especially after crisis events, scholars studied the question whether economic conditions are further aggravated by a shortage in credit supply, which is denoted a credit crunch. In particular, the financial crisis of 2007 put

[5] Jakab and Kumhof (2015) list many statements from central bankers and economists of the early 20th century that describe banks as creators of credit. In academia, this view was pursued vigorously only outside of mainstream. See, e.g., Lavoie (1984); Asimakopulos (1986); Davidson (1986); Palley (1996).

[6] A non-exhaustive list is: Ito and Ueda (1981); King (1986); Kugler (1987); Martin (1990), and Pazarbasioglu (1997).

heavy strains on banking sectors that probably led banks to curb the supply of credit. Reznakova and Kapounek (2014), for example, test for a credit crunch of the Czech credit market after the financial crisis. They conclude that the decrease in credit after the crisis can be related to low economic and investment activity, which rejects the hypothesis of a credit crunch. Vouldis (2015) analyzes the Greek credit market on a disaggregated level (short- and long-term business loans, consumer loans, and mortgages) between 2003 and 2011. He finds that credit demand exceeded supply during the boom-phase. Thereafter, as the debt crisis intensified, constraints on the supply side led to a contraction in credit.

Turning to Germany, several authors studied the German credit market for episodes of disequilibrium and credit crunches. Nehls and Schmidt (2003) study the market for loans to enterprises and self-employed workers during the period from 1980 until 2002. On the supply side they distinguish between an aggregated banking sector and different banking groups. The authors find evidence for excess credit demand in 2002. Especially the behavior of big banks contributed to supply constraints of aggregate credit. Boysen-Hogrefe et al. (2010) modify the model of Nehls and Schmidt (2003) and estimate a coefficient-varying disequilibrium model for loan supply and demand of non-financial corporations between 1970 and 2009. In addition, they evaluate the effects of a hypothetical change in equity regulations on the development of credit. Furthermore, they examine the effect of credit growth on economic growth. Contributing to research on supply side shortages of credit during the financial crisis, Erdogan (2010) analyzes the German market for bank credit from 1991 until 2009 for non-financial corporations. She finds that a liquidity injection into the German banking system at the end of 2008 helped overcome supply constraints in Germany. Schmidt and Zwick (2012) support her findings. Additionally, Schmidt and Zwick (2012) update their earlier model (Nehls and Schmidt (2003)) for different banking groups between 1990 and 2011, with the result that banks with high impairments during the financial crisis cut their supply more than the others.

4.3 A simple model for the banking market

We introduce a model for the credit market that builds on Bofinger and Schächter (1995). The model provides a framework to analyze the process of credit creation in a bank-based economy. The model features two markets, the market for bank loans and the market for high-powered money, which are linked by a multiplier relation. On the market for bank loans, banks provide credit that the non-banking sector uses for finance. By setting the refinancing rate for banks, the central bank influences the banks' funding costs and, therefore, has an effect on the supply of credit. The interaction of credit demand and supply in the market for bank loans yields the equilibrium quantity of credit and price, i.e., the market rate for credit. Banks then need to acquire a fraction of their granted credit, pinned down by the multiplier, in form of central bank money in the market for high-powered money. In the market for high-powered money, the central bank acts as the sole supplier of base money and meets the banks' demand for central bank money at a fixed price (refinancing rate).

Extending the model in Bofinger and Schächter (1995), banks have a richer set of refinancing instruments at their disposal to fund their credit business. This includes, in addition to deposits and credit from the central bank, the issuance of bonds and holdings of equity. Expanding the set of financial instruments makes a distinction between the two monetary aggregates, money and credit, reasonable. The defining characteristic between the two is their maturity structure as bank liabilities. Whereas money is short-term debt and held in form of deposits in bank accounts, credit includes also longer-term debt such as equity and bonds.

The next steps include a presentation of each market and their participants.

4.3.1 The credit market

Supply of bank loans

The model follows an industrial-organization approach, which is characterized by profit maximization of each bank. Banks do so by choosing the amount of credit that maximizes their profit. The asset side of the bank's balance sheet reveals the revenues from credit business and the liability side, which consists of the refinancing sources of banks (equity, bonds, deposits and central bank credit), exposes the refinancing costs (see Table 4.1).[7] Taking into account all revenues and costs, the profit function for one representative bank j is equal to:

$$\pi_B^j = i_B Cr_{B/NB}^j - i_D D^j - i_R(Cr_{CB/B}^j - R^j) - i_E E^j - i_{NB} B^j - O^j - V_B^j,$$
$$\text{with } V_B^j = c_B \times (Cr_{B/NB}^j)^2.$$

The revenue $i_B Cr_{B/NB}^j$ stems from the credit business. $Cr_{B/NB}^j$ denotes the credit from banks to non-banks, which is provided at the bank interest rate of i_B. The costs associated with the credit business are the sum of the interest paid on deposits $i_D D$, the net refinancing from the Central bank $i_R(Cr_{CB/B} - R)$, equity costs $i_E E$, refinancing at the bond market $i_{NB} B$, operational costs O and credit risk costs V_B.[8] According to Fuhrmann (1987); Cosimano (1988); Freixas and Rochet (2008), we assume that the credit risk costs increase disproportionately in the amount of credit. The component c_B depends positively on the credit default probability and negatively on income. The operational costs consist of, among others, screening and monitoring costs. The balance sheet of one representative bank is illustrated in Table 4.1.

Banks refinance their business via equity, bonds, deposits, and credit from the central bank. They use these funds for granting credit and holding minimum reserves at the central bank. To simplify the profit function, we take the balance sheet identity of a bank and substitute:

$$Cr_{CB/B}^j - R^j = Cr_{B/NB}^j - D^j - E^j - B^j. \tag{4.1}$$

[7] The balance sheets of all sectors are presented in Appendix Tables 4.3 - 4.5.
[8] The characteristics of V_B ensure a concave profit function with a unique optimum.

Table 4.1: Bank's balance sheet

Assets	Liabilites
Credit from banks to non-banks $Cr_{B/NB}$	Equity E
Reserves R	Bonds B
	Deposits D
	Credit from Central bank to banks $Cr_{CB/B}$

Furthermore, we assume that a fixed proportion of bank credit to the non-banking sector is backed by equity, as it is required in the Basel Regulations. An additional fraction of credit is held in form of bonds, which allows a reduction of interest rate risk. Interest rate risk emanates from the maturity mismatch between assets and liabilities on the bank's balance sheet. We set:

$$\begin{aligned} \eta^E &= \frac{E^j}{Cr^j_{B/NB}} \quad \text{and} \\ \eta^B &= \frac{B^j}{Cr^j_{B/NB}}. \end{aligned}$$

Substituting η^E, η^B, and Equation (4.1) into the profit function, we get:

$$\begin{aligned} \pi^j_B = (i_B - i_R &- \eta^E(i_E - i_R) - \eta^B(i_{NB} - i_R))Cr^j_{B/NB} \\ &- (i_D - i_R)D^j - O^j - c_B(Cr^j_{B/NB})^2. \end{aligned}$$

For deriving the optimal credit supply of one representative bank, we take the first-order condition of the profit function with respect to the credit volume, $Cr^j_{B/NB}$, which yields:

$$Cr^j_{B/NB} = \frac{(i_B - i_R) - \eta^E(i_E - i_R) - \eta^B(i_{NB} - i_R)}{2c_B}.$$

Assuming that there are n identical banks, total credit supply is equal to:

$$Cr^S_{B/NB} = \sum_{j=1}^{n} Cr^j_{B/NB} = \frac{[(i_B - i_R) - \eta^E(i_E - i_R) - \eta^B(i_{NB} - i_R)]n}{2c_B}. \qquad (4.2)$$

Demand for bank loans

Each sector (public and private) demands credit in order to invest or consume. We model income and the cost for credit as key determinants of our credit demand.

Additionally, the possibility to choose between different types of financing affects credit demand. This might not be the case for households and small and medium-sized enterprises which obtain their financing only via banks, but larger enterprises might choose the type of financing that suits their needs best. This possibly includes financing via the bond market.[9] Hence, we introduce substitutability between different sources of financing according to Singh and Vives (1984), Wied-Nebbeling (1997), Ledvina and Sircar (2011). These considerations motivate the following form for the demand of bank loans:

$$Cr_B^D = a - bi_B + d(i_{NB} - i_B), \qquad (4.3)$$
$$\text{with } a = \mu + \gamma Y.$$

The demand for bank credit depends negatively on the interest rate for bank credit, i_B, and positively on income, Y, and on the price differential of the two credit categories, bonds and bank credit, $(i_{NB} - i_B)$.

According to Ledvina and Sircar (2011), the substitutability implies three different relationships between the market for bank credit and bonds:

- independent loans $d = 0$: The price differential between bank credit and bonds does not influence the demand for bank credit.
- differentiated loans $d \in (0, \infty)$: The price differential between bank credit and bonds does influence the demand for bank credit.
- homogeneous loans/perfect substitutes $d \to \infty$: The two types of financing are perfect substitutes. Hence, if there is a price difference between the two credit categories, the sector which offers the lowest price serves the whole demand.

In an institutional sense, the banking sector is a key driver of economic activity due to the function as the supplier of money. The bond market operates on top of the banking sector by intermediating financial claims that the banking sector has created before. Therefore, in a sense, the bank credit market is a prerequisite for the bond market.

[9] We assume a homogeneous bond market and therefore banks and non-banks face the same bond rate.

Equilibrium

The market for bank loans is in equilibrium if the supply of bank loans (Equation (4.2)) is equal to the demand for bank loans (Equation (4.3)).[10] Hence, we get the following equilibrium credit volume and interest rate:

$$Cr^*_{B/NB} = \frac{a - (b+d)(i_R + \eta^E(i_E - i_R) + \eta^B(i_{NB} - i_R))}{1 + 2c_B(b+d)},$$
$$i^*_B = \frac{2c_B(a + di_{NB}) + (i_R + \eta^E(i_E - i_R) + \eta^B(i_{NB} - i_R))}{1 + 2c_B(b+d)}.$$

4.3.2 Bank credit multiplier

After the derivation of the equilibrium amount of credit in the banking market, we are interested in the amount of high-powered money that corresponds to this credit volume.

In economic textbooks, the relation of money to high-powered money is called the money multiplier. However, the multiplier in our model is not to be confounded with the common textbook money multiplier. Here, the bank credit multiplier, m_B, which extends beyond the standard money multiplier by including a wider array of refinancing instruments, is defined as the ratio of credit from banks to non-banks, $Cr_{B/NB}$, to high-powered money, H:

$$m_B = \frac{Cr_{B/NB}}{H}.$$

By making use of the following equality:

$$Cr_{B/NB} = \frac{M}{1 - \eta^E - \eta^B},$$

and the fact that money, M, consists of cash, C, and deposits, D:

$$M = C + D,$$

as well as that high-powered money, H, includes cash, C, and reserves, R:

$$H = C + R,$$

[10]Here, for simplifying matters, we set the number of banks, n, equal to one.

the bank credit multiplier can be written as:

$$m_B = \frac{Cr_{B/NB}}{H} = \left(\frac{C+D}{C+R}\right)\left(\frac{1}{1-\eta^E-\eta^B}\right).$$

Additionally, we suppose that the public holds a fixed proportion of deposits in cash:

$$C = h \times D,$$

where h is the cash holding coefficient of the public.

Furthermore, the banking sector is obliged to hold reserves as a fraction of deposits:

$$R = r \times D,$$

where r is the minimum reserve requirements determined by the central bank. Including all these facts in the bank credit multiplier equation, we get:

$$m_B = \frac{Cr_{B/NB}}{H} = \underbrace{\left(\frac{1+h}{h+r}\right)}_{\text{(A)}}\underbrace{\left(\frac{1}{1-\eta^E-\eta^B}\right)}_{\text{(B)}}.$$

The first ratio, (A), is the standard money multiplier, which is larger than one. The second ratio, (B), is also larger than one, because $\eta^E + \eta^B < 1$, resulting in a bank credit multiplier larger than one. If the banking system increases the ratio of leverage from the non-banking system, η^B, or the equity financing, η^E, the bank credit multiplier increases. Hence, for the same amount of bank credit less high-powered money is required.

Given the bank credit multiplier, m_B, and the equilibrium amount of credit, $Cr^*_{B/NB}$, we derive the optimum amount of high-powered money demanded by banks as:

$$H^* = \frac{Cr^*_{B/NB}}{m_B}. \tag{4.4}$$

At this point, we would like to emphasize an important distinction. The interpretation of our multiplier is diametrically opposed to the interpretation of the multiplier in standard economic textbooks. Therein, the money supply process starts with the central bank injecting a specific amount of high-powered money into the banking system which then, by the multiplier process, generates a quantity of money that surpasses the initial base money injection by a factor larger than one. However, this modeling approach does not capture adequately the mechanism of endogenous money creation by the banking sector (Werner, 2014; McLeay et al., 2014). Consistent with the endogenous money theory, our model incorporates this feature where causality runs from money to high-powered money. That means, it is the banking sector that acts first by extending credit and, in a second step, the central bank provides the high-powered money, determined by the multiplier relation, that the banking sector demands. This order of causation is expressed in Equation (4.4), where the equilibrium amount of high-powered money is a function of credit and the multiplier.

4.3.3 The market for high-powered money

The role of the central bank is two-fold in this model. It sets the refinancing rate and provides high-powered money as a monopolistic supplier. The central bank provides as much high-powered money as the banking sector demands at the fixed price (refinancing interest rate, i_R).

The demand for high-powered money can be considered as a function of bank credit. If the interplay of demand and supply produces no positive amount of credit, banks have no incentive to demand high-powered money. Assuming a linear demand function for high-powered money, H^D, we derive its slope by connecting two points on the demand schedule (saturation quantity and quantity at reservation price).

Thus, we obtain the following demand function for high-powered money:

$$H^D = \frac{Cr^*_{B/NB}}{m_B} - \frac{Cr^*_{B/NB}}{m_B \times e} i_R, \tag{4.5}$$

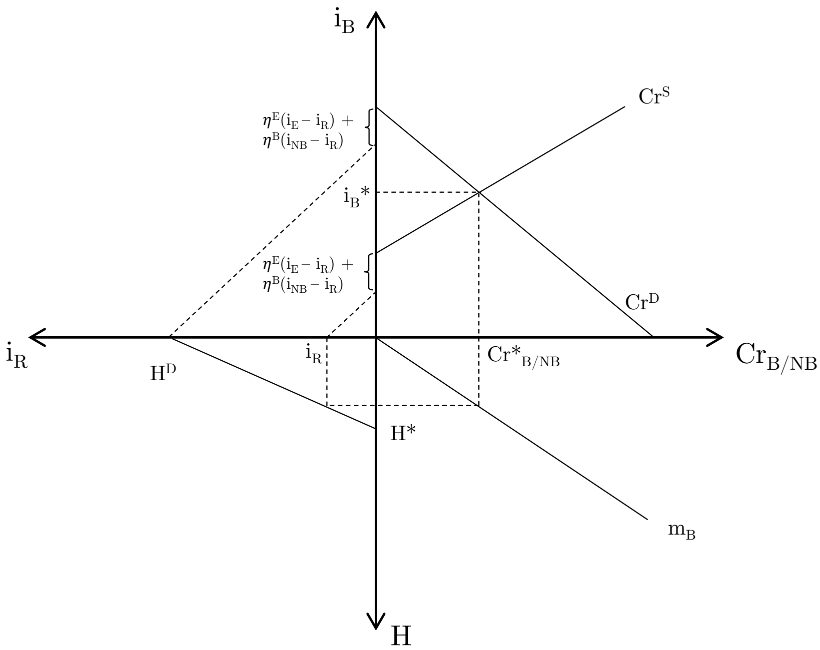
$$\text{with } e = \left(\frac{a + d i_{NB}}{b + d} \right) - \eta^E (i_E - i_R) - \eta^B (i_{NB} - i_R). \tag{4.6}$$

Banks' demand for high-powered money depends on the optimal credit volume, the multiplier relation, the prohibitive price of credit (e), and the refinancing rate. This determination is in line with causality running from credit to high-powered money.

4.3.4 Graphical illustration

Figure 4.2 shows a graphical representation of the model, which also highlights the connection between the credit market and the market for high-powered money. By choosing the refinancing rate, the central bank sets the intercept of the credit supply curve. The refinancing costs at the equity market as well as at the bond market shift the supply curve upwards by increasing the intercept. The intersection between credit demand and supply determines the interest rate and amount of bank credit in equilibrium. Via the bank credit multiplier, we obtain the amount of high-powered money at a fixed refinancing rate.

Figure 4.2: Complete model of the credit market with all sectors: banks, non-banks and central bank



4.4 Empirical methodology

We estimate a model of the credit market in which the explanatory variables chosen on the basis of our theoretic model. To take into account the specifics of a credit market, like the information structure (Stiglitz and Weiss, 1981), we estimate a disequilibrium model. Stiglitz and Weiss (1981) motivated the case for disequilibria in the credit market where non-clearing lending rates are based on information-theoretic arguments. Financial contracts are especially subject to information asymmetries such that banks might set interest rates below the clearing market rate. The reason for this is that increasing the market rate has two effects. First, good borrowers drop out of the market (adverse selection) and, second, borrowers are likely to undertake riskier projects (moral hazard), thereby increasing default costs. As a consequence, market rates are not consistent with the market-clearing rate, which leaves the demand side constrained.

The empirical model for estimating a disequilibrium model takes the following form:

$$d_t = x'_{1t}\beta_1 + u_{1t}, \tag{4.7a}$$

$$s_t = x'_{2t}\beta_2 + u_{2t}, \tag{4.7b}$$

$$q_t = \min(x'_{1t}\beta_1 + u_{1t}, x'_{2t}\beta_2 + u_{2t}). \tag{4.7c}$$

d_t and s_t represent the notional demand and supply for credit. β_1 and β_2 are the slope parameters for demand and supply, respectively. x_{1t} is a $(k_1 \times 1)$ vector and x_{2t} is a $(k_2 \times 1)$ vector of explanatory variables for d_t and s_t, respectively. Obviously, identification is only possible if the two explanatory vectors differ in at least one co-variate.

$u_{1t} \sim N(0, \sigma_1)$ and $u_{2t} \sim N(0, \sigma_2)$ are independent error terms, which allows for different supply and demand variances. The observed credit volume, q_t, is set equal to the minimum of the two market sides, and the other side of the market remains unobserved.

The model consists of the demand equation, (4.7a), supply equation, (4.7b), and one minimum condition, (4.7c), which allocates observed credit, q_t, to the demand or the supply side. The specification in Equation (4.7c) includes demand and supply disturbances inside the minimum condition and, therefore, introduces a stochastic regime selection. Alternatively, it is possible to leave out the error terms and obtain a deterministic regime selection, where an error term is added outside the minimum condition to capture observational errors. We retain the model with stochastic regime selection because from an economic perspective it is more reasonable that demand and supply shocks determine, by including them into the minimum condition, which market side is constrained. Ultimately, the minimum condition implements the crucial disequilibrium assumption. Which market side we truly observe is unknown. Given the parameter estimates and data, we can only assign a probability to each observation of belonging to the demand or the supply side and set the market side that is likely to be smaller equal to the observed market volume. The other market side is unobserved and treated as a latent variable.

4.4.1 Estimation

Historically, disequilibrium models have been estimated by means of classical methods, i.e., maximum likelihood estimation. In this context, Maddala and Nelson (1974) made a significant contribution by deriving general likelihood functions for this class of models. However, in this scenario, maximum likelihood estimation runs quickly into problems. The complexity of disequilibrium models leads to non-monotonic and non-smooth likelihood functions where numerical optimization techniques prove to be indispensable. Nevertheless, it is likely that optimization algorithms get stuck in local optima and do not converge to the global optimum.

An alternative approach, which avoids numerical optimization, is to resort to Bayesian estimation techniques. In particular, Bauwens and Lubrano (2007) paved the way by proposing an elegant way to estimate dynamic disequilibrium models with Bayesian methods. They use a dynamic version of the disequilibrium model and apply the data augmentation principle, by Tanner and Wong (1987), to treat the unobservable data problem. Finally, they obtain posterior distributions of the model parameters via Gibbs sampling. The method by Tanner and Wong proposes to draw the latent variable and the model parameters iteratively via Gibbs sampling. More specifically, first, the latent variable is sampled conditionally on the model parameters and the observed variables. Then, second, the model parameters are updated conditionally on the simulated latent variable and the observed variables. This poses no problem since the conditional distributions are known (see Section 4.4.2). We follow closely their estimation procedure and apply it to our static disequilibrium model.

The estimation procedure can be separated into two stages. First, we determine for each point in time which regime, demand or supply, conditional on the data and parameter estimates, is observed. Second, given the sample separation, we draw parameters from conditional distributions. These steps are iterated until parameter estimates have converged. By averaging the sampled parameters we obtain posterior means and distributions.

4.4.2 Bayesian inference

We apply a Normal linear regression model and estimate it with Bayesian methods to derive posterior estimates. We use a natural conjugate prior that has the same distributional form as the likelihood.[11] We elicit priors of the following form:

$$\pi(h_i) \sim \mathcal{G}(\underline{s_i}^{-2}, \underline{\nu_i}) \quad \text{and} \quad \pi(\beta_i|h_i) \sim \mathcal{N}(\underline{\beta_i}, h_i^{-1}\underline{V_i}).$$

h_i is the error precision, i.e., $h_i = \sigma_i^{-2}$. Their joint prior distribution is called a Normal Gamma distribution:

$$\pi(\beta_i, h_i) = \pi(\beta_i|h_i) \times \pi(h_i) \sim \mathcal{NG}(\beta_i, h_i|\underline{\nu_i}, \underline{s_i}^{-2}, \underline{\beta_i}, \underline{V_i})$$

for $i = 1$ (demand) and 2 (supply). $\mathcal{G}(\cdot,\cdot)$ represents a Gamma distribution, $\mathcal{N}(\cdot,\cdot)$ a Normal distribution, and $\mathcal{NG}(\cdot,\cdot,\cdot,\cdot)$ a Normal Gamma distribution. In general, the hyperparameters are defined as follows:

$$\begin{aligned}
\underline{\nu_i} &= T - k_i, \\
\underline{\beta_i} &= \beta_{i,OLS}, \\
\underline{s_i}^2 &= \frac{(y_i - x_i\underline{\beta_i})'(y_i - x_i\underline{\beta_i})}{\underline{\nu_i}}, \\
\underline{V_i} &= diag(Var(\beta_{i,OLS})),
\end{aligned}$$

where $\underline{\nu_i}$ is the degree of freedom with T equal to the number of observations and k_i equal to the number of co-variates. $\underline{\beta_i}$ is the OLS estimator and $\underline{s_i}^2$ is defined as the error variance. Finally, $\underline{V_i}$ represents the covariance matrix of the OLS estimator, where all off-diagonal entries are zero. The prior hyperparameters allow

[11] Notation draws on the book by Koop (2003). Variables with underscores are normally prior values, and variables with bars denote posterior values.

the econometrician to introduce prior information that he has about the economic problem. We take a neutral standpoint and do not impose any external information. This means that we choose non-informative priors, which amounts to setting $\underline{\nu_i}$ and $\underline{V_i}^{-1}$ equal to zero. Since we use a natural conjugate prior, it follows that the posterior belongs to the same family of distributions, i.e.:

$$p(\beta_i, h_i|y_i) \sim \mathcal{NG}(\bar{\nu}_i, \bar{s}_i^{-2}, \bar{\beta}_i, \bar{V}_i).$$

Note that posterior quantities depend on sampled values, y_i, of the dependent variable. The posterior parameters read as follows:

$$\begin{aligned}
\bar{\nu}_i &= \underline{\nu}_i + T, \\
\bar{V}_i &= (\underline{V_i}^{-1} + x_i' x_i)^{-1}, \\
\bar{\beta}_i &= \bar{V}_i(\underline{V_i}^{-1}\underline{\beta}_i + x_i' x_i \beta_{i,OLS}), \\
\bar{\nu}_i \bar{s}_i^2 &= \underline{\nu}_i \underline{s}_i^2 + \nu_i s_i^2 + (\beta_{i,OLS} - \underline{\beta}_i)' [\underline{V_i} + (x_i' x_i)^{-1}]^{-1} (\beta_{i,OLS} - \underline{\beta}_i).
\end{aligned}$$

Finally, the marginal posterior for the error precision and the conditional posterior for the parameter vector of explanatory variables are:

$$p(h_i|y_i) \sim G(\bar{s}_i^{-2}, \bar{\nu}_i) \quad \text{and} \quad p(\beta_i|h_i, y_i) \sim N(\bar{\beta}_i, \bar{V}_i).$$

Now, the following two equations represent the demand and supply equation for credit:

$$d_t^{(j)} = x_{1t}' \beta_1^{(j)} + u_{1t}^{(j)} \text{ and} \tag{4.8a}$$

$$s_t^{(j)} = x_{2t}' \beta_2^{(j)} + u_{2t}^{(j)}, \tag{4.8b}$$

where the superscript j indicates the j-th draw in our Bayesian estimation cycle. The first iteration, $j = 1$, is initialized with OLS estimates, assuming that the market is in equilibrium, i.e., $q_t = d_t = s_t$.[12] These values are used in turn to determine which regime is operative. We now draw a value $U_t^{(j)}$ for each observation from a Uniform distribution. Given the estimates, we can calculate the probability, $\lambda_t^{(j)}$, of the notional demand being shorter than the notional supply:

$$\lambda_t^{(j)} := \mathbb{P}(d_t^{(j)} < s_t^{(j)}) = \Phi\left(\frac{x_{2t}'\beta_2^{(j)} - x_{1t}'\beta_1^{(j)}}{\sqrt{\sigma_2^{2(j)} + \sigma_1^{2(j)}}}\right). \tag{4.9}$$

[12] Taking OLS estimates to initialize the procedure is unproblematic because the influence of starting values on the results diminishes along the iteration process.

Φ designates the standard Normal distribution function and $\sigma_1^{2(j)}$ and $\sigma_2^{2(j)}$ are the variances of the notional demand and supply equations, respectively. We now assign the observed credit variable in the following way:

$$\text{If } U_t^{(j)} < \lambda_t^{(j)} \text{ then } y_{1t}^{(j+1)} := q_t \text{ and draw } y_{2t}^{(j+1)} \sim \mathcal{TN}_{d_t^{(j)} < s_t^{(j)}}(x'_{2t}\beta_2^{(j)}, \sigma_2^{2(j)}), \quad (4.10)$$

$$\text{If } U_t^{(j)} > \lambda_t^{(j)} \text{ then } y_{2t}^{(j+1)} := q_t \text{ and draw } y_{1t}^{(j+1)} \sim \mathcal{TN}_{s_t^{(j)} < d_t^{(j)}}(x'_{1t}\beta_1^{(j)}, \sigma_1^{2(j)}), \quad (4.11)$$

where $y_1^{(j)}$ and $y_2^{(j)}$ represent vectors of demand and supply, respectively. Both vectors consist of the sampled and observed values of the dependent variable. $\mathcal{TN}$ denotes a truncated Normal probability distribution. At this stage, the market side that is more likely to be shorter is set equal to the observed credit variable, and the other market side, which is likely to be larger and is not observed, is sampled from a truncated Normal probability distribution.

The estimation procedure can be summarized by the following pseudo-code:

1. $(\beta_1^{(j)}, \beta_2^{(j)}, \sigma_1^{2(j)}, \sigma_2^{2(j)}) = (\beta_1^{(j-1)}, \beta_2^{(j-1)}, \sigma_1^{2(j-1)}, \sigma_2^{2(j-1)})$, where $j = 1$ corresponds to OLS estimates.

2. For $t = 1, ..., T$:

   Calculate $\lambda_t^{(j)}$ as in (4.9) and draw $U_t^{(j)}$ from a Uniform distribution.

   If $U_t^{(j)} < \lambda_t^{(j)}$, set $y_{dt}^{(j+1)}$ equal to q_t and sample $y_{st}^{(j+1)}$ as in (4.10).

   If $U_t^{(j)} > \lambda_t^{(j)}$, set $y_{st}^{(j+1)}$ equal to q_t and sample $y_{dt}^{(j+1)}$ as in (4.11).

3. Draw $(\beta_1^{(j+1)}, \beta_2^{(j+1)}, \sigma_1^{2(j+1)}, \sigma_2^{2(j+1)})$ from conditional posterior distributions.

4.4.3 Model specification

In the empirical analysis, we focus on the German credit market for firms. We use monthly data from January 1999 up to December 2014. We draw our data mainly from the Deutsche Bundesbank. Our explained variable represents an aggregate credit variable that contains loans to enterprises and self-employed working people, comprising different maturities.[13] The selection of the variables that we include in our model is largely based on the theoretic model in section 4.3. We map every

[13]for more details see Appendix Table 4.6.

variable from our model to an empirical counterpart, except for equity costs due to data constraints. In the credit demand equation we include industrial production (Y), the bank lending rate (i_B), and the corporate bond rate (i_{NB2}). On the supply side equation we introduce industrial production, the bank lending rate, a spread between the bank lending rate and the refinancing rate (Spread 1, $i_B - i_R$), a spread between the bank bond rate and the refinancing rate (Spread 2, $i_{NB1} - i_R$) weighted with the share of bonds (η_B), and the percentage of non-performing loans (npl) in Germany.[14] We include industrial production with a lag of 12 months to capture the fact that it leads the credit variable. Accordingly, our baseline reads as follows:

$$
\begin{aligned}
\log(Cr_t^D) &= c_1 + \beta_{11}\log(\mathrm{Y}_{t-12}) + \beta_{12} i_{B,t} + \beta_{13} i_{NB2,t} + u_{1,t}, \\
\log(Cr_t^S) &= c_2 + \beta_{21}\log(\mathrm{Y}_{t-12}) + \beta_{22} i_{B,t} + \beta_{23}(i_B - i_R)_t + \beta_{24}[\eta_B(i_{NB1} - i_R)]_t \ldots \\
&\quad + \beta_{25}\mathrm{npl}_t + u_{2,t}.
\end{aligned}
$$

We estimate the model in levels. All variables, except interest rates and spreads, are expressed in logs. We take 100.000 Bayesian draws and discard the first 25.000 draws as burn-in. To ensure convergence of the parameters, we apply Geweke-statistics (Geweke et al., 1991) and inspect the convergence of the model parameters visually.

4.5 Results

The estimation results of the German market for firm credit are illustrated in Table 4.2. Since disequilibrium models are possibly prone to instability, we test for their robustness by applying different estimation methods. The first column depicts Bayesian estimates, the second column maximum likelihood estimates, and the third column OLS estimates. For inference, we adjust for autocorrelated residuals. Closer inspection reveals that the estimates are of similar magnitude, quantitatively and qualitatively, irrespective of the estimation method.

[14] In contrast to the theoretic model, we apply the actual bond rates for banks and non-financial corporations.

Table 4.2: Baseline estimation results of the German market for firm credit

	Model 1 Bayesian	Model 2 Maximum Likelihood	Model 3 OLS
Credit Demand			
Constant, c_1	5.945	5.936	6.254
	(0.347)	(0.151)	(0.302)
Industrial production[1], Y	0.157	0.159	0.087
	(0.073)	(0.031)	(0.063)
Lending rate, i_B	-0.021	-0.006	-0.024
	(0.01)	(0.004)	(0.009)
Corporate bond rate, i_{NB2}	0.027	0.01	0.028
	(0.011)	(0.003)	(0.007)
Credit Supply			
Constant, c_2	5.839	5.64	5.486
	(0.466)	(0.664)	(0.592)
Industrial production[1], Y	0.13	0.146	0.232
	(0.095)	(0.138)	(0.121)
Lending rate, i_B	0.047	0.078	0.019
	(0.016)	(0.013)	(0.008)
Spread 1, $(i_B - i_R)$	0.097	0.143	0.042
	(0.023)	(0.024)	(0.012)
Spread 2, $\eta_B(i_{NB1} - i_R)$	-0.039	-0.03	-0.017
	(0.05)	(0.047)	(0.034)
Non-performing loans, npl	-0.057	-0.099	-0.021
	(0.018)	(0.021)	(0.015)

Dependent variable: Credit to non-financial firms and self-employed persons.

[1] Industrial production enters with its 12^{th} lag.

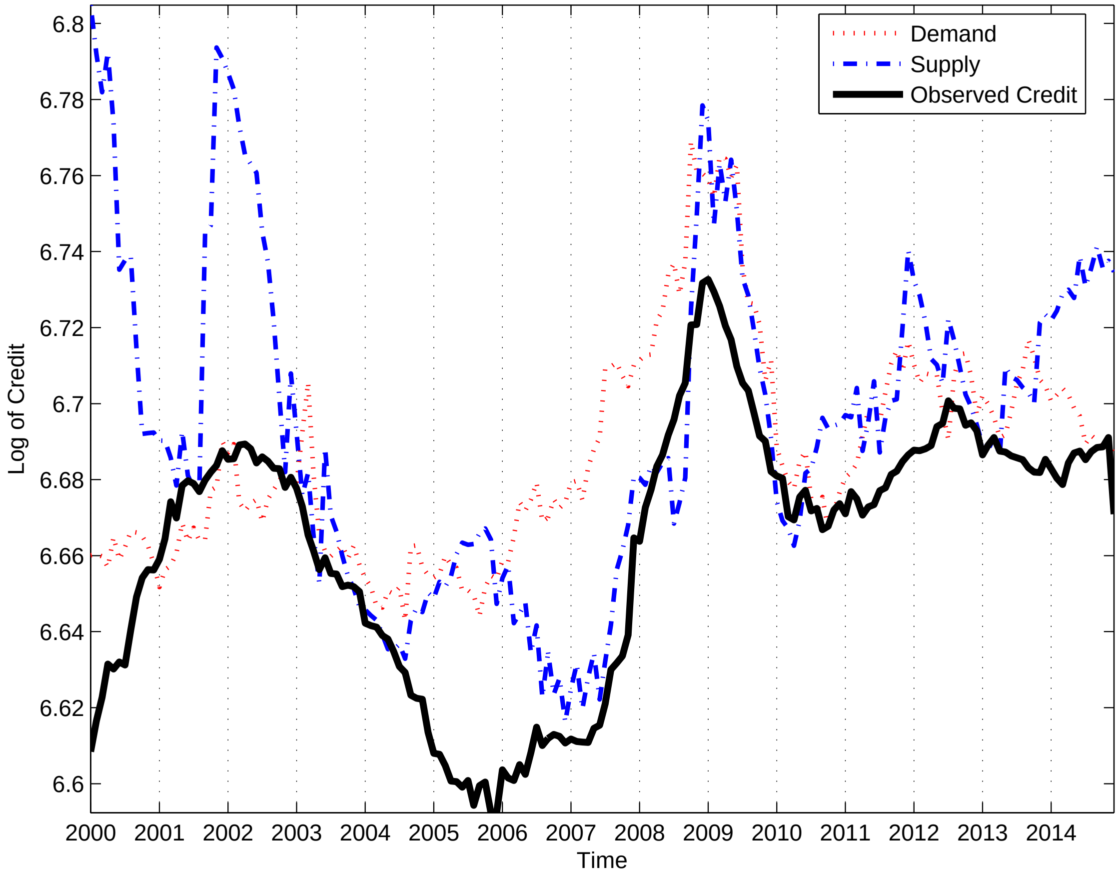
Standard errors are in parenthesis.

Starting with the credit demand equation, we find significant effects at the 5 percent level for industrial production, the lending rate and the corporate bond rate. Industrial production and the corporate bond rate affect credit demand positively.

A one percent increase in industrial production leads to a 0.16 percent increase in credit demanded, and a rise in the corporate bond rate by one percentage point increases credit demand by 0.03 percent. The lending rate, however, factors in negatively with a coefficient of around 0.02. Qualitatively, the estimates are consistent with theory. Increases in industrial production need credit for financing labor and capital services that flow into the production of goods. A higher lending rate, which represents the cost of credit, has the tendency to reduce credit demand. Finally, higher corporate bond rates imply that funding via the bond market becomes more expensive for firms. Consequently, firms are more willing to finance their expenses with bank credit.

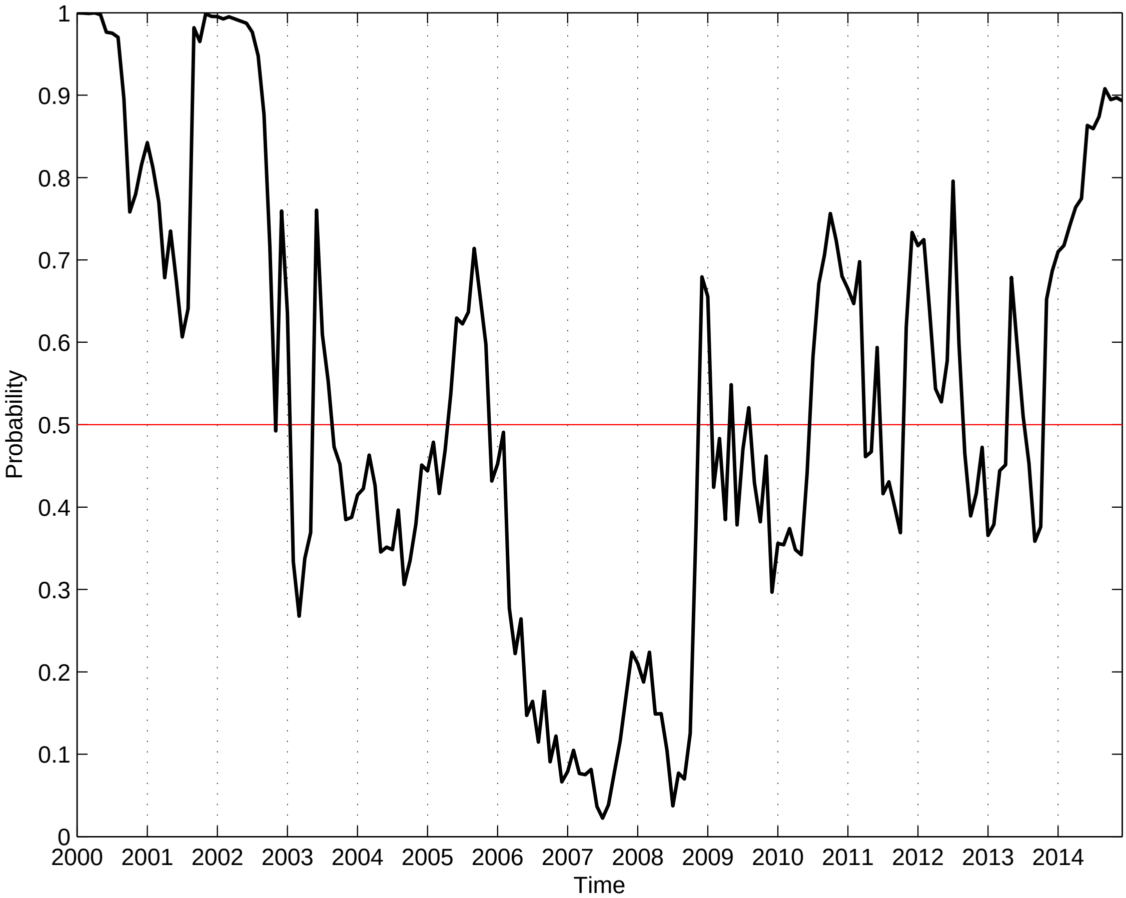
Turning to the credit supply equation, we do not detect a significant effect of industrial production on credit supply. Apart from that, the remaining estimates prove to be significant at the 1 percent level. We find a positive estimate for the lending rate, which represents higher bank revenues for a given volume of credit, and for spread 1 (the spread between lending rate and refinancing rate), which expresses a profit margin that incentivizes banks to supply more credit. Compared with the lending rate estimate, it is even more important quantitatively. The only variable that factors in negatively is spread 2 (the spread between the bank bond rate and the refinancing rate). Spread 2 can be given the interpretation of a cost, representing maturity transformation, which makes it reasonable to find a negative coefficient. In summary, the regression results indicate that prices play a significant role in the determination of credit. On the supply side, we find a significant and positive effect of price variables on credit that influences the banks' revenue. In contrast to other studies, we do not include variables like deposits into the credit supply equation because this would be in conflict with our earlier discussion of the banks' ability to create credit by "pure will". It would be problematic to explain credit causally with deposits, when the act of extending credit creates simultaneously deposits. On the demand side, we introduce substitutability for firms between bank and non-bank financing, where the possibility of arbitrage between the two forms of finance seems to play a significant role. Altogether, our findings support the price-theoretic modeling approach of bank credit. Figure 4.3 illustrates observed bank credit to firms and self-employed people (black line), notional credit demand (dashed red line), and notional credit supply (dashed-dotted blue line). This representation indicates which market side was likely to be the restricting market side for every point in our sample. In the period before the financial crisis in 2007, we identify two sub-periods with excess supply.

Figure 4.3: Observed bank credit to firms and self-employed people and notional credit demand and supply



The first excess supply period occurs around 2000 to 2003, which is in line with the economic malaise in Germany at the time. During this period, Germany was characterized by low economic growth, low inflation, and high unemployment rates. On account of the large weight of Germany in the Eurozone, its low inflation rates forced the ECB to keep interest rates at a relatively low level in order to meet its mandate of price stability for the Eurozone. As a consequence, the loose monetary policy was one factor for the boom in southern European countries. Especially in Greece and Spain, in which low nominal rates and high inflation rates translated into low real rates, which led to economic expansions in both countries. In Germany, the low growth rates eventually led the German government to undertake far-reaching reform measures (Agenda 2010). The second excess supply period, in 2005, was described by a more stable environment with constant inflation and moderate growth rates. Due to the announcement of the Basel II regulations in 2004, which were finally adopted in 2007, firms were obliged to reach better balance sheet figures in order to fulfill the new regulations. Furthermore, firms increased their share of internal financing that made up almost the entire volume of finance during the years 2004 and 2005 (Deutsche Bundesbank, 2012). Both factors contributed to a credit supply overhang. Following this excess supply period, the most distinct period extends from 2006 until the end of 2008. Until 2009 we observe a sharp increase in bank credit. With the outbreak of the financial crisis, the credit expansion came to a halt and we observe a decline in credit until 2010. During the increase, our model suggests an excess demand regime. Hence, the uptrend in credit before 2008 could have been stronger if the banks had been willing to lend more. In the aftermath of the financial crisis, no clear demand or supply regime can be identified. The safety programs for banks from the ECB and the German Bund (Soffin) as well as the stimulus package of the German Bund contributed to a fast recovery of the credit market after the crisis. In 2014, the EBA-stress testing constrained the banks' willingness to grant credit due to the high uncertainty surrounding the test results. After the publication of the positive results for German banks in November 2014, notional credit supply started to exceed notional credit demand. Since 2014, the demand for bank credit decreases. This could hint at the influence of geopolitical risks and reflect the slow growth environment in the Eurozone. Figure 4.4 provides an alternative presentation of our results. The graph shows the estimated probability of observing a demand regime for every observation in the sample. The sequence of probabilities represents a probabilistic counterpart to Figure 4.3. Computing the probability of a demand or supply regime, complements the analysis in terms of providing the likelihood of a specific regime. At the beginning of the millennium, until 2003, and in 2005, we observe an elevated likelihood of a demand regime, which is greater than 0.7. In between, we have changing patterns with equally likely regimes.

Figure 4.4: Probability of a demand regime (demand is restricting force)



Following this, we identify the most characteristic period of our sample. From 2006 to 2009, our model suggests a supply restricting regime with a probability of approximately 0.9. This is consistent with an acceleration of the German economy before the crisis. After 2010, we have, again, alternating regime probabilities marked by occasional spikes.

An important caveat to this type of analysis is that it is not possible to structurally identify the exact reasons for an eventual shortage in demand or supply. The model design only allows to analyze whether a demand or supply schedule is more likely. Nevertheless, we checked the plausibility of the model by relating the results to developments that took place outside of the model at the same time.

4.6 Conclusion

We present a model of the bank credit market and apply it to the German credit market for firms and self-employed persons. Banks operate as profit-maximizing firms and serve the credit demand by non-banks. The model integrates the central bank, banks, and non-banks into the determination of credit. The central bank sets the refinancing rate for base money, which influences the supply of bank credit. Bank supply and firm demand for bank loans determine the equilibrium market rate and credit volume. Banks then demand a fraction of their credit business, determined by the bank credit multiplier, in form of base money in the market for central bank credit. In our model, credit business precedes the banks' refinancing operations, which is a better description of how banks operate in reality. Besides base money from the central bank and deposits as a source of refinancing, the banks also have the possibility to back their credit business via holdings of equity and the issuance of bonds. Finally, we put our model to a test and estimate a market for German firm credit. This empirical exercise shows that the determinants of credit supply and demand, which have been selected on the basis of our theoretic model, play a significant role. In addition to that, our empirical framework of a disequilibrium model allows to identify periods of credit supply or credit demand overhang between 1999 and the end of 2014.

4.7 Appendix to Chapter 4

Table 4.3: Central bank's balance sheet

Assets	Liabilites
Credit from central bank to banks $Cr_{CB/B}$	Reserves R Cash C

Table 4.4: Bank's balance sheet

Assets	Liabilites
Credit from banks to non-banks $Cr_{B/NB}$ Reserves R	Equity E Bonds B Deposits D Credit from central bank to banks $Cr_{CB/B}$

Table 4.5: Non-bank's balance sheet

Assets	Liabilites
Deposits D Cash C Bonds B Equity E	Credit from banks to non-banks $Cr_{B/NB}$

Table 4.6: Description of variables

Variable	Transformation	Source
Credit to non-financial firms	SA, log-level	Bundesbank
Industrial production	SA, log-level	Destatis
Bank lending rate	Level, %	Bundesbank
Corporate bond rate	Level, %	Bundesbank
Bank bond rate	Level, %	Bundesbank
Refinancing rate	Level, %	Bundesbank
Non-performing loans	Level, %, interpolated (cubic)	Worldbank

Figure 4.5: Credit to non-financial corporations and self-employed people (in logs)

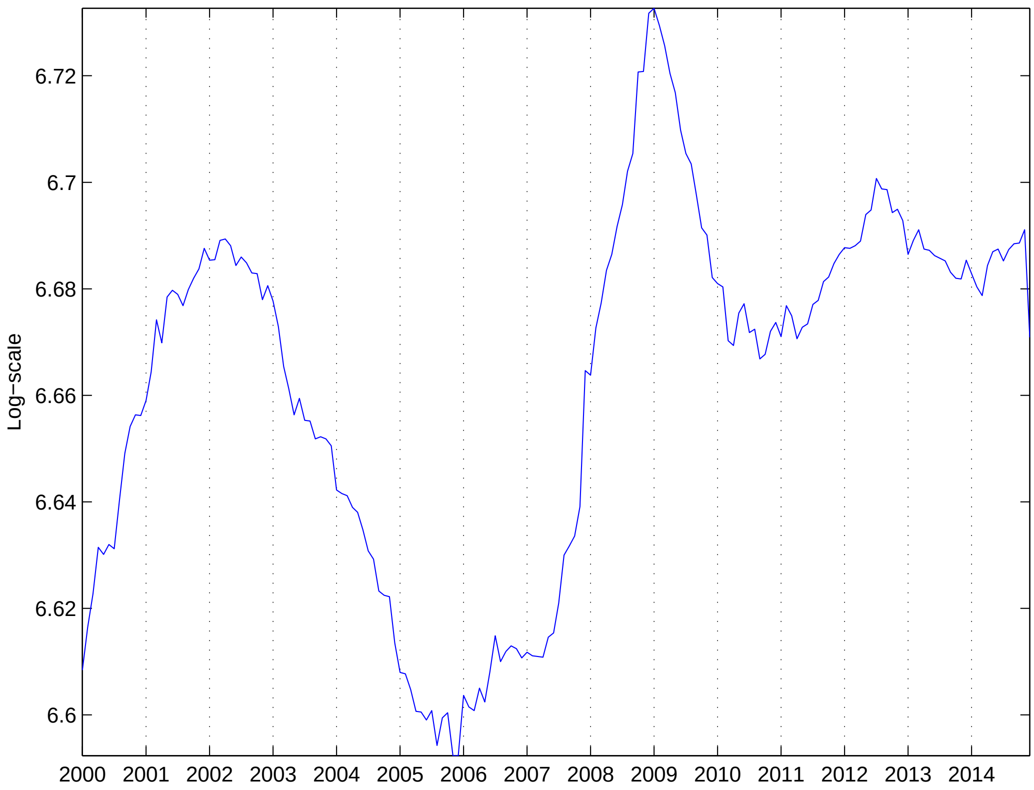


Figure 4.6: Supply side variables

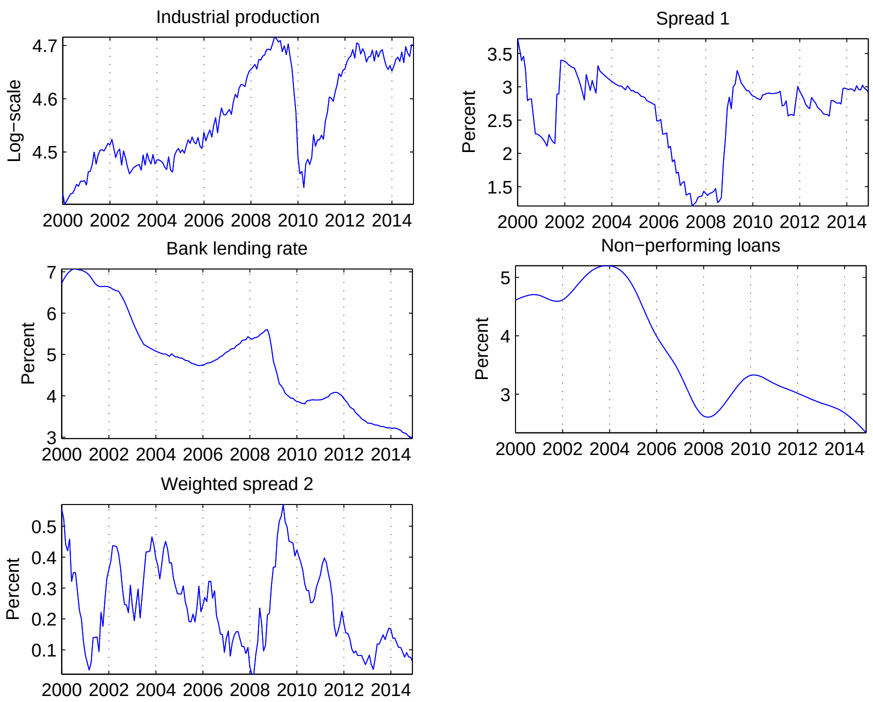


Figure 4.7: Demand side variables

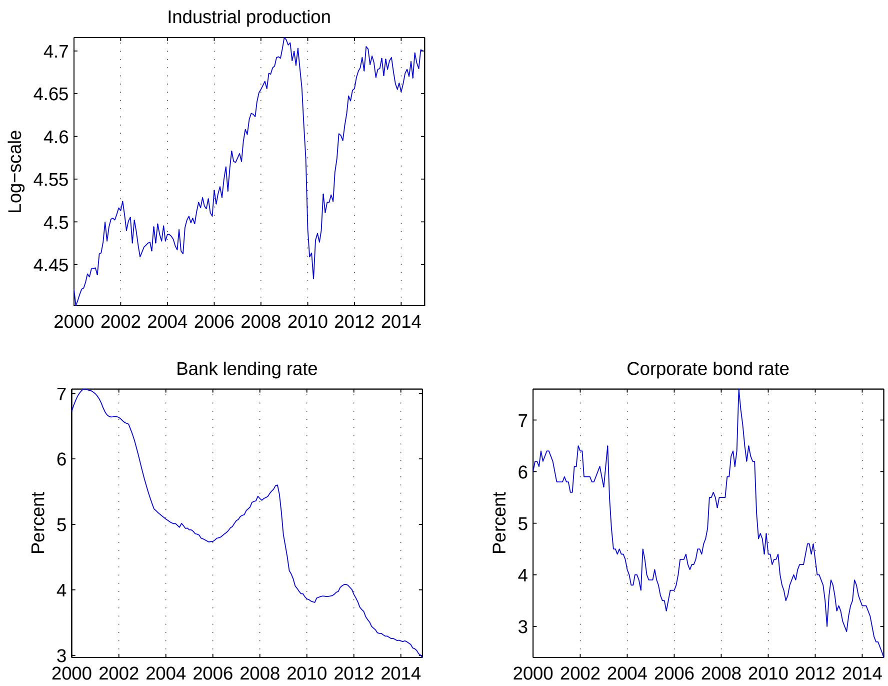


Table 4.7: Unit root tests for model variables

Variable	Test	P-val.		Test-stat.	Crit.-val.: 5%	Decision
log(loans)	ADF (w. trend)	0.3162				not stat.
	ADF (wo. trend)	0.1515				not stat.
	Phillips-Perron (w. trend)	0.0042				stat.
	Phillips-Perron (wo. trend)	0.0002				stat.
	KPSS (w. trend)			0.0951	0.146	not stat.
	KPSS (wo. trend)			0.7230	0.463	stat.
log(ip)	ADF (w. trend)	0.0654				not stat.
	ADF (wo. trend)	0.2789				not stat.
	Phillips-Perron (w. trend)	0.2297				not stat.
	Phillips-Perron (wo. trend)	0.4480				not stat.
	KPSS (w. trend)			0.0636	0.146	not stat.
	KPSS (wo. trend)			1.3846	0.463	stat.
loan rate	ADF (w. trend)	0.0330				stat.
	ADF (wo. trend)	0.9259				not stat.
	Phillips-Perron (w. trend)	0.1046				not stat.
	Phillips-Perron (wo. trend)	0.9435				not stat.
	KPSS (w. trend)			0.0673	0.146	not stat.
	KPSS (wo. trend)			1.5672	0.463	stat.
corporate bond rate	ADF (w. trend)	0.4380				not stat.
	ADF (wo. trend)	0.7352				not stat.
	Phillips-Perron (w. trend)	0.3706				not stat.
	Phillips-Perron (wo. trend)	0.6771				not stat.
	KPSS (w. trend)			0.1331	0.146	not stat.
	KPSS (wo. trend)			0.8615	0.463	stat.
spread 1	ADF (w. trend)	0.6843				not stat.
	ADF (wo. trend)	0.3799				not stat.
	Phillips-Perron (w. trend)	0.3465				not stat.
	Phillips-Perron (wo. trend)	0.1364				not stat.
	KPSS (w. trend)			0.1840	0.146	stat.
	KPSS (wo. trend)			0.2193	0.463	not stat.
Spread 2× bond ratio	ADF (w. trend)	0.1885				not stat.
	ADF (wo. trend)	0.2114				not stat.
	Phillips-Perron (w. trend)	0.0435				stat.
	Phillips-Perron (wo. trend)	0.0513				not stat.
	KPSS (w. trend)			0.0789	0.146	not stat.
	KPSS (wo. trend)			0.537	0.463	stat.
npl	ADF (w. trend)	0.0323				stat.
	ADF (wo. trend)	0.7272				not stat.
	Phillips-Perron (w. trend)	0.6824				not stat.
	Phillips-Perron (wo. trend)	0.9335				not stat.
	KPSS (wo. trend)			0.1480	0.146	stat.
	KPSS (wo. trend)			1.3741	0.463	stat.

ADF = Augmented Dickey Fuller test. KPSS = Kwiatkowski-Phillips-Schmidt-Shin test. w.= with; wo.=without.

Chapter 5

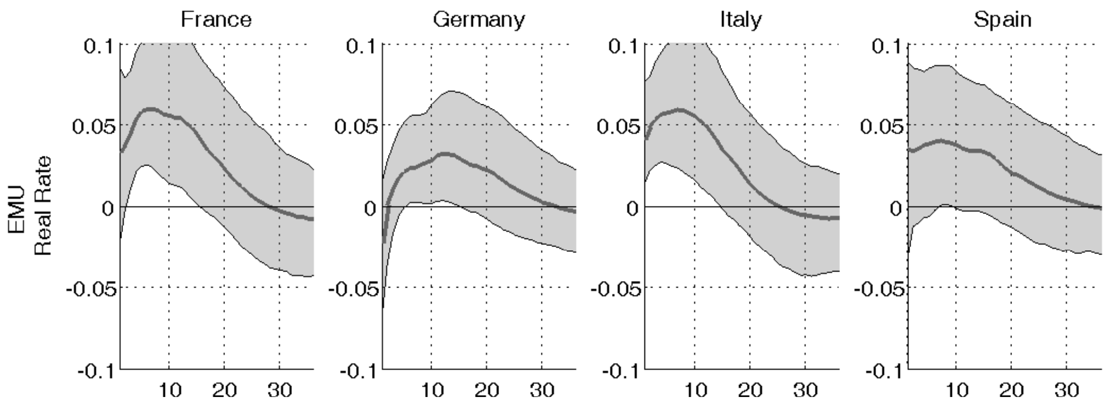
Synthesis

The last part of this dissertation relates and synthesizes the results from the three preceding chapters. As stated in the introduction of this dissertation, Chapter 2 and 3 complement each other in the sense that both chapters investigate different aspects of the Economic and Monetary Union.

Chapter 2 documents a change in the conduct of monetary policy when moving from the central banks of the EMS to the ECB. Conditional on inflationary supply shocks, the ECB stabilizes output rather than inflation. Moreover, country-specific inflationary demand shocks are not countered with the same intensity as it were the case with a national central bank. This is because the ECB targets the average price level of the Eurozone and not the price level of a specific country. Both observations suggest that the Taylor principle is violated for individual member countries of the EMU. Since the ECB responds only partially to asymmetric shocks, the likelihood that national dynamics develop a momentum on their own is increased. As a matter of fact, the violation of the Taylor principle resulted into “too” low real interest rates in Spain, which potentially added, among other factors, to the Spanish real estate boom.

The asymmetric effects of the ECB's policy rate are a fundamental feature of the EMU and play an important role in both of these studies. Chapter 2 highlights the insufficiency of the single policy rate to deal with asymmetric shocks in the EMU. To recall and illustrate this finding one more time, I present the responses of real market rates following a positive demand shock in Germany in Figure 5.1.

Figure 5.1: Impulse responses of real market rates following German demand shock



Notes: Impulse responses are based on a one standard deviation shock. The solid line represents the posterior median at each horizon and the shaded area indicates 16th and 84th percentiles.

The ECB responds to the demand shock in Germany and raises nominal interest rates. The increase in nominal interest rates is strong enough, due to the size of the German economy, and produces a significant increase in German real market rates. For France and Italy, which did not experience a demand shock, we observe even a stronger increase in real market rates.[1] This illustrates the externality of the single policy instrument of the ECB in case of asymmetric shocks. With no positive demand disturbances in the other EMU countries, an increase in their real market rates tends to slow down their economy. These spillover effects increase with the size of the country in which the shock occurs. Conversely, the smaller the country, in which the shock occurs, the smaller the reaction of the ECB and the externality for the other countries.

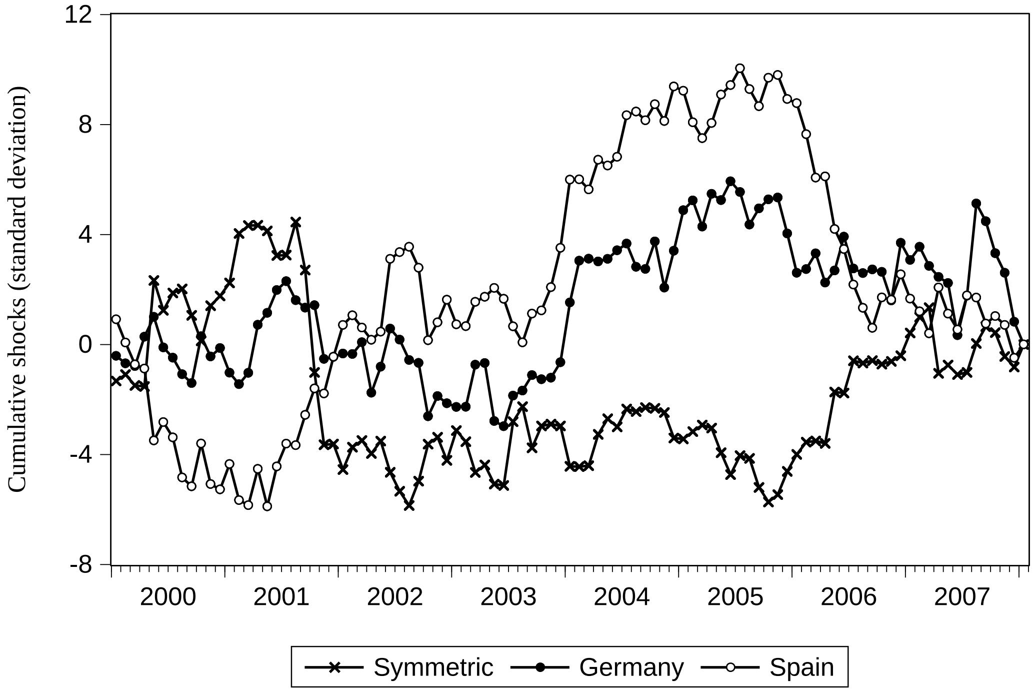
While Chapter 2 documents the asymmetry of monetary policy in a currency union by using an empirical approach, Chapter 3 implements this asymmetry for-

[1]Spain experiences only a small significant increase in real rates.

mally into a model and uses its implications at a later stage for the identification of shocks. More concretely, my co-authors and I build a two-country DSGE model that incorporates a Taylor rule-type of reaction function, which describes the behavior of the ECB. The single Taylor rule in combination with the two-country modeling design of the EMU yields the spillover effects of monetary policy, which are discussed in Chapter 2. Moreover, this "monetary policy externality" plays a vital role in determining robust sign restrictions for identifying the shocks in Chapter 3 via the sign-restriction approach. For instance, the savings glut shock is modeled as a recessionary demand shock in the rest of the Eurozone, which leads the ECB to lower its policy rate. The unaffected utility-optimizing agents in Spain then readjust their consumption towards the present, represented by an expansion in consumption of durables and non-durables (cf. Figure 3.8). This mechanism, innate to a monetary union, allows to separate this shock qualitatively from the other three shocks (cf. Table 3.2). Aside from addressing the asymmetric effects of monetary policy in a currency union, the study in Chapter 3 sheds light on the effects from institutional changes that are related to the creation of the EMU. For example, the risk premium shock can be related to changes in the institutional framework. The launch of the currency union created a common capital market, which signified a fundamental change in the architecture of financial markets in the Eurozone. As a consequence, previously charged risk premia on government bonds almost completely disappeared (risk premium shock) and Spanish banks could suddenly borrow from foreign banks in the EMU without any exchange rate risk.

The housing bubble shock and the financial easing shock, meanwhile, are rather indirectly connected to the creation of the monetary union. The launch of the currency union spurred expectations about a prosperous future, characterized by elevated economic growth, better job perspectives, and higher income. This "gold-rush atmosphere" created dynamics that can be described in part by the two latter shocks.

Figure 5.2: Cumulative demand shock series (Germany, Spain, and symmetric)



Recapitulating the study in Chapter 3, we are confident that the analysis singles out some of the implications of being a member of a currency union. And even though our focus is on Spain as a representative of the EMU, we believe that the mechanisms we uncover do not apply exclusively to Spain, but to any member of a currency union, irrespective of country-specific factors.

In addition to the common theme of Chapter 2 and 3, the estimation results of all three independent studies complement each other. The results from Chapter 2 can be related to the results of Chapter 3 and 4. Figure 5.2 shows the cumulative symmetric demand shock series and the cumulative demand shock series of Germany and Spain that have been obtained from the analysis in Chapter 2.[2]

From this figure we can observe that the Spanish economy experienced a series of positive demand shocks between 2001 and 2006 that coincide with the boom on the housing market and the rise in current account deficits (Figure 3.1). From 2006 to 2008, the series of positive national demand innovations turns negative, but positive symmetric demand shocks sustain the demand expansion. This observation would

[2]By construction, the sum of each shock series is equal to zero.

be consistent with the narrative of a demand-driven expansion in Spain until the crisis.

For Germany, we make a slightly different observation. Figure 5.2 suggests that in the early 2000s the German economy experienced on average negative demand shocks. This is consistent with the observations from Chapter 4, where Figure 4.3 indicates that until the mid of 2003, credit demand was below or equal to credit supply in the firm sector. Both observations, the series of negative aggregate demand shocks and the lack of credit demand by firms, match the picture of a sluggish German economy at the time. Then, from the end of 2003 until the beginning of 2006, Figure 5.2 suggests positive innovations in German demand. This observation blends in well with the elevated credit demand schedule from the end of 2003 until the end of 2008. From this point of view, the results of all three studies provide a consistent picture of the pre-crisis economic developments in Germany and Spain.

In summary, major parts of this dissertation study the implications of a monetary union for its member countries through the example of the EMU. In particular, the analysis focuses on monetary policy and on the effects of changes in the institutional framework. Importantly, the investigations are successful in identifying dynamics in Eurozone data that can be traced back to the new framework of the monetary union. While this dissertation focuses on analyzing specific features of the EMU, it is rather silent about possible remedies to certain deficiencies of the monetary union. Nevertheless, at the moment of writing this thesis, there exists a multitude of reform proposals for the EMU that are at the center of debate at conferences and summits. Therefore, the real challenge is not to come up with new reform proposals, but to choose a few from the many and put them together to a consistent reform agenda. This task belongs to the realm of politics, and the search for the right way to reform the Economic and Monetary Union promises challenging and exciting times ahead.

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