On fiscal and monetary integration in Europe

Verstegen, Loes

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Link to publication in Tilburg University Research Portal

Citation for published version (APA):
Verstegen, L. (2017). *On fiscal and monetary integration in Europe*. CentER, Center for Economic Research.

On Fiscal and Monetary Integration in Europe

Loes Verstegen

22 November 2017

On Fiscal and Monetary Integration in Europe

Proefschrift

ter verkrijging van de graad van doctor aan Tilburg University op gezag van de rector magnificus, prof. dr. E.H.L. Aarts, in het openbaar te verdedigen ten overstaan van een door het college voor promoties aangewezen commissie in de aula van de Universiteit op woensdag 22 november 2017 om 14.00 uur door

Loes Helena Wilhelmina Verstegen

geboren op 18 september 1990 te Venlo

Promotiecommissie:

Promotor:	Prof. dr. A. C. Meijdam
Copromotor:	Dr. B.J.A.M. van Groezen
Overige leden:	Prof. dr. C. van Ewijk
	Prof. dr. H. Fehr
	Dr. R.B. Uras
	Dr. E.W.M.T. Westerhout

Acknowledgements

Tijdens het schrijven van de bachelorthesis kwam ik voor het eerst echt in aanraking met onderzoek. Het starten met een interessante vraag, het puzzelen om een goede aanpak en de juiste data te vinden, en het daarna proberen te verpakken in een mooi geschreven verhaal, dat sprak mij wel aan. Lex vroeg me in een van onze gesprekken of de onderzoeksmaster misschien iets voor mij was. Nu, bijna vijf en een half jaar, een diploma voor de Research Master en heel wat bloed, zweet en tranen later sta ik dan op het punt om mijn PhD dissertatie te verdedigen.

Dit proefschrift was nooit tot stand gekomen zonder jouw begeleiding, Lex. Onze eerste echte kennismaking was bij de bachelorscriptie, waar jij bereid was om mee te gaan in een onderwerp dat ook het thema van dit proefschrift is, Europese eenwording. Puur op basis van interesse gekozen, en daarna gingen we wel kijken hoe we dit konden aanpakken. Deze wijze van werken werd voortgezet in mijn PhD, ik waardeer het zeer dat je me vrij liet om te onderzoeken wat ik wilde. Jij stelde in onze gesprekken altijd de juiste kritische vragen om te kijken of ik wist waar ik het over had en of de voorgestelde methode wel zou gaan werken. Daarnaast heb ik je geweldige economische intuïtie vaak bewonderd. Als ik weer eens vastliep met het model of niet wist waar een bepaalde simulatie vandaan kwam, had jij, zonder het zelf te hebben afgeleid, een perfect intuïtief antwoord op alle onduidelijkheden. Ook voor onderwijstaken kon ik met jou op een fijne samenwerking rekenen, waarbij we een fijn vak mochten doceren waarin studenten jouw aanpak zeer waarderen. Met je drukke agenda als decaan van onze faculteit heb ik het als een voorrecht ervaren dat je altijd tijd voor me hebt gemaakt en zoveel energie in mij en dit proefschrift hebt willen steken. Bedankt!

Bij de verdediging van die bachelorscriptie kwam Bas erbij. Vanwege de

betrokkenheid van jou toen, jouw samenwerking met Lex en ook onze samenwerking in het lesgeven was het een logische keuze dat je aansloot bij de begeleiding van mijn proefschrift in het tweede jaar van mijn PhD. In 2012 was ik voor het eerst teaching assistant voor jouw vak Macro-economie, en dat heb ik in totaal vier keer gedaan. Voor zowel de studenten als de TAs ben je een hele fijne coördinator die als geen ander de leerervaring van studenten als hoogste doel heeft gesteld. Buiten dat was je als co-promotor ook heel toegewijd. Je was altijd bereid om stukken te lezen en feedback te geven, met veel oog voor detail. Jouw aanwezigheid in het departement is erg prettig. Met jou kan ik lekker kletsen over kleine dingen, zoals wat we gingen koken, de klusjes in huis zoals wassen en de tuin, wat we in het weekend gingen doen. Maar ook over het reilen en zeilen van het departement en hoe de wetenschap in elkaar steekt hebben we uitgebreid gepraat. Je deur stond altijd open voor een gezellig praatje. Bedankt voor je luisterend oor, je interesse in mijn proefschrift en je betrokkenheid!

Burak, I met you as one of the most dedicated teachers in the Research Master. When you took over the role of education coordinator, you became even more interested and involved in mine and others' PhD's. During the pre-defense I received very useful comments from you, as well as from Casper van Ewijk, Hans Fehr and Ed Westerhout. Thank you all for the meaningful feedback. This truly helped to improve the quality of the chapters in this dissertation. Ed, bedankt voor je betrokkenheid en de kans om bij het CPB te presenteren. Daar komen we elkaar zeker nog wel tegen.

Binnen het departement Economie zijn er vele onderzoekers waar ik mee te maken heb gehad, waar Martin zeker genoemd moet worden. Jouw perfecte voetbalgeheugen zorgde ervoor dat we het altijd wel ergens over konden hebben, ook al hebben we geen voorliefde voor dezelfde club. In het eerste jaar van mijn studie kwam ik je al tegen bij Macro 1, waar je duidelijk liet zien hoe je een collegezaal vol eerstejaars onder controle houdt. Altijd geïnteresseerd in het wel en wee van studenten, het is fijn om je erbij te hebben. Louis, bedankt voor je kritische blik, je betrokkenheid bij de Macro Reading Group en de vele praatjes in ons kantoor en in de pantry. Gonzague, I appreciate our cooperation in your course and the advice on PhD life that you gave me. Harrie, jouw focus op de toepasbaarheid en maatschappelijke relevantie is een fijne afwisseling binnen de economische wetenschap. Ik waardeer de discussies met je en hoop dat je nog een tijd op de universiteit actief mag blijven. Bedankt Roel, dat ik dankzij jouw vak een fijn inkijkje in de pensioenwereld heb gekregen. Als econoom buiten de universiteit ben je voor mij een fijne gesprekspartner met goede loopbaanadviezen.

Op een universiteit zijn er ook mensen wiens werkzaamheden en prestaties weinig besproken worden, juist omdat zij hun werk zo goed doen. Mirjam, Jolanda en Jacqueline, er zouden heel veel mensen verloren zijn als jullie er niet waren. Bedankt voor jullie support in alles.

Without you, Michal, I am pretty sure I would not have survived the Research Master. You were always willing to explain the particularities of Mas-Colell to me (sorry for bringing this up) or to help me through the code of econometrics assignments. It was a great pleasure teaming up with you for so many of the never-ending assignments in those two years. I am delighted to have had you as my office mate for almost the whole three years of my PhD, though I would unofficially count to five including all the days in the RM rooms. It was great fun to talk to you, to drink lots of tea but also to help each other out from time to time. Thank you! I will miss you, and I wish the best for you, Ania and Maja.

The last five years at the university allowed me to spent time with great people. Anderson and Hasan, thank you for the last months where you gave me a warm welcome in your office. A huge thanks to Clemens, Sebastian, Roxana, Manuel, Dorothee, Abhilash and Renata for the fun and companionship during many lunches.

Iets meer dan negen jaar geleden begon mijn studietijd in Tilburg. Tijdens de drie jaar bachelor en het bestuursjaar heb ik ontzettend genoten van het combineren van de studie met gezellige etentjes, vele spelletjes en af en toe eens een feestje. Veel dank aan Sander, Frank, Joost, Stefan, Joris en Monique dat jullie mijn tijd in Tilburg zo leuk en bijzonder hebben gemaakt.

Mijn vrienden en familie zijn erg belangrijk geweest. Vriendinnen uit Helden (en omstreken), bedankt dat jullie altijd voor de nodige afleiding zorgden. Ook heb ik het geluk een gezellige familie te hebben. Onderzoek in de economie zouden jullie niet zien zitten, Moniek en Nick, maar veel dank voor jullie support. Pap en mam, bedankt dat jullie me altijd onvoorwaardelijk hebben gesteund en dat jullie me vrij hebben gelaten om mijn eigen keuzes te maken.

Lieve Ruud, jij hebt me altijd gemotiveerd om er met de volle honderd procent voor te gaan. Ondanks de vele late uurtjes en de weinige tijd die er soms voor jou over bleef, ben je me blijven steunen. Ik waardeer het enorm dat we elkaar helpen om ieders dromen en ambities na te jagen. Bedankt voor je gezelligheid, humor en liefde.

Loes Verstegen
Helden, oktober 2017

Contents

List of Tables

List of Figures

CHAPTER 1

Introduction

The process of monetary integration in Europe dates far back. After European countries became connected in a trade union, plans to set up a currency union were created. In October 1970, an expert group chaired by the Prime Minister of Luxembourg, Pierre Werner, presented the Werner plan, a blueprint to create an economic and monetary union. However, the collapse of the Bretton Woods system and the rising oil prices in the beginning of the 1970s, resulting in a new wave of currency instability, slowed down the project. In 1979, the European Monetary System (EMS) was launched, in which the exchange rates of eight participating EU member states were set towards the European Currency Unit (ECU).

While the efforts to create a single European market were intensified, the costs of unstable exchange rates became more evident. In this context, the idea of a monetary union was taken up again in June 1988, when the Delors Committee, a committee of the central bank governors of the twelve member states with the President of the European Commission, Jacques Delors, as chair, was assigned the task to come up with a new timetable for creating an economic and monetary union. The Delors report proposed a three-stage period from 1990 until 2002 to prepare for the transition into this economic and monetary union. The first stage would be to complete the internal market by free movement of capital before 1994. Moreover, in December 1991 the Treaty of Maastricht was signed that set out convergence criteria concerning public debt and deficit, interest rates, the inflation rate and exchange rate stability. The second stage entailed the creation of the European Central Bank (ECB) that would conduct the single monetary policy from 1999 onwards. The launch of the euro marked the start of the third stage in which a transition period of three years would lead the euro from 'bookmoney' alongside national currencies to the single currency in the Economic and Monetary Union (EMU) with actual coins and banknotes.

Although the launch of the euro in January 1999 started with 11 participating countries, the cash changeover, being the biggest in history, from national currencies to the euro took place in 12 EU countries. After Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain, Greece joined the third stage of the EMU in 2001. Later, also Slovenia (2007), Cyprus and Malta (2008), Slovakia (2009), Estonia (2011), Latvia (2014) and Lithuania (2015) adopted the euro and joined the EMU.

For the science of economics, it is a good time to take a step back and evaluate the process of monetary integration in Europe, especially with the recent financial crisis as a major test for the EMU. The focus of this dissertation is on the monetary integration in the form of the EMU and the euro as well as on the need and the potential for fiscal policy integration within the Euro area.

Successful monetary integration?

The process of monetary integration is quite far advanced, but the question is whether this EMU project has been successful. In this context, there are many different aspects one could consider as a measure of the success of a monetary union. The euro was supposed to boost economic growth and improve living standards in all member states, and to bring member states politically and economically closer together. The success of the euro in the eyes of the public is measured by the Eurobarometer, opinion polls conducted in both Euro area countries as well as new member states that expect to adopt the euro. Though the public opinion on the euro was fairly negative in the beginning, mostly because of the association with an increase in prices, nowadays a majority of the respondents across the Euro area sees the euro as a good thing for their own country. Whether the euro has been a success or a failure boils down to the question how the economies of the EMU countries would have developed if they had not been a member of the EMU. Finding the answer to this question is the main goal of Chapter 2, in which for each EMU member a counterfactual scenario is built for the hypothetical situation that the country had decided not to join the euro.

The EMU: a heterogeneous group of countries?

A distinctive aspect of the European monetary union in comparison to other currency areas is the heterogeneity within the group of members. Key dimensions of this heterogeneity relate to differences in institutions, demography and economic structures. An obvious type of heterogeneity is the variety of languages within the Euro area. As the language barrier is an obstacle to mobility, this aspect becomes really important in the adjustment of labor supply to country-specific shocks. Demography across the Euro area is highly different in size but also in age distribution. In Germany, for example, the old-age dependency ratio is around 31.5%, whereas that of Ireland is only 19.3%. This diversity has important repercussions on savings, productivity and also government expenditures.

Next to fundamental differences between the EMU countries, there also exists diversity of economic aspects that persisted during the almost two decades that the euro is old. Levels of competitiveness have not converged over time. The harmonized competitiveness indicator as reported by the ECB sheds some light on the EMU country's competitiveness relative to its main competitors in international markets. Germany, one of the most productive countries, has become even more competitive since 1988, its change being the largest among the group of EMU countries. On the other hand, Italy experienced only a very small increase in competitiveness, way below the average of the Euro area's increase in competitiveness. Related to international competitiveness are current account balances. The Netherlands and Germany have had increasing current account surpluses rising up to 10% and 7% respectively, whereas Greece and Spain have seen deficits of over 10% in some of the past years. Concerning labor markets, unemployment rates were diverging at the start of the EMU, and still are in recent times. In 2013, the unemployment rate has reached a highest point at 27.5% in Greece and 26.1% in Spain, whereas Belgium, Germany, the Netherlands, Austria and Finland had unemployment figures below double digits. On a related note, the rigidity of labor market institutions tends to be different across EMU members, leading to substantially different dynamic adjustment to shocks. Lastly, there are sizable differences in fiscal situation, with average government debt levels of Finland and the Netherlands being below 60% of GDP, whereas Italy's, Greece's and Portugal's average debt level in the period from 2005 until 2016 exceeded 100% of GDP. Though being far from a fully exhaustive list of key aspects in which EMU members differ, these aspects of diversity across EMU members will come to the attention in this dissertation, as these differences play an important role in the monetary and fiscal integration in Europe.

The heterogeneity within the Euro area leads to a distinction of the member countries into two groups, often called the 'core' and the 'periphery'. The southern countries belonging to the periphery are also referred to as PIGS-countries, including Portugal, Italy, Greece and Spain. Countries that could be considered the core of the Euro area are Germany and France, but also Austria, Belgium and the Netherlands for example. In this dissertation, the PIGS-countries will be referred to as the southern block, whereas the other countries will be part of 'North'.

The heterogeneity across EMU countries has been the foundation for one of the most critical arguments against the euro that has been raised from the beginning, which is that the business cycles and economic structures of Euro area countries are not sufficiently similar for a successful monetary union. The associated cracks in the design of the Economic and Monetary Union were even more clearly exposed during the economic and financial crisis that hit the Euro area in the last decade. Several EMU member states appeared unable to refinance or repay their public debts without the assistance of other Euro area countries, the ECB or the IMF. A number of support measures in the form of the European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM) were implemented from early 2010 onwards. The ECB lowered the interest rates and when the zero lower bound was hit, it offered cheap long-term loans for the interbank market. The crisis had substantial adverse effects on the economies and the labor markets of the European economies, leading to a revival of the debate whether the EMU should be complemented by deeper fiscal integration.

Integration in fiscal policy needed?

The Optimum Currency Area (OCA) literature describes the costs and benefits of joining a monetary union, and explains the conditions for a successful currency area. The main criteria for a successful Eurozone are labor and capital mobility, similarity of business cycles, price and wage flexibility and a risk sharing system. Asymmetric shocks in the countries of a monetary union could lead to worsening economic conditions. After joining a monetary union, the exchange rate and monetary policy are no longer instruments that can be used to boost the economy. The common central bank's policy will not be fine tuned to the particular situation of this economy and therefore the other OCA criteria will be important factors to prevent a severe recession. However, labor mobility is considered low in the Euro area, and also prices and wages might not be considered flexible enough. Other monetary unions, like the US and Canada, do have different federal fiscal policies in place, such as a system of federal taxes and transfers, or a federal unemployment scheme. The EMU does not have a risk sharing system to cope with country-specific economic downturns, and therefore lacks an instrument to stabilize the EMU and prevent recessions to become as deep as the recent one. Especially during and after the recent economic crisis, it appeared that the lack of a risk sharing device is making the architecture of the EMU fragile.

The idea of fiscal integration in Europe is not new, but dates back to the MacDougall report in 1977. The report proposed a federal budget with stabilization and distributive purposes to support the monetary union and deal with asymmetric macroeconomic shocks. However, the EU budget is currently only 1% of EU GDP and therefore unable to perform either of these functions. In 1997, the Stability and Growth Pact was implemented with the goal to maintain stability in the EMU by enforcing fiscal discipline on government debt and deficit levels. However, the Stability and Growth Pact has been criticized as being unable to enforce sanctions on the countries that violated the rules of the pact. Fiscal integration is thus, in comparison to monetary integration, very limited in the Euro area.

Politically, the process of coordinating and integrating fiscal policy is delicate in nature. Member states do want to retain their independence and act in the interest of their own citizens. Within the democratic systems in the member countries, voters have shown that skepticism against the euro and integration of policies into an EMU-wide level is still existent. A fear of many, especially in the northern countries, is that coordination of fiscal policies would lead to redistribution of finances and wealth in the direction of the southern economies. The population in southern countries sharply criticizes strict fiscal rules and austerity measures that might follow from policy coordination on the EMU-wide level. Designing common fiscal policies that act as a risk sharing device and facilitate stabilization without permanent redistribution within the EMU, while at the same time are insusceptible to moral hazard, is a challenging task.

In December 2012, the four presidents of the European Council, European Commission, Eurogroup and ECB presented ideas on how to design a risk sharing mechanism to insure the Euro area against asymmetric macroeconomic shocks in their report entitled *"Towards a genuine Economic and Monetary Union"*. Apart from their thoughts on the dimensions of an economic, financial and political union, the suggestions on a fiscal union are well reflected by this citation:

> *"An EMU fiscal capacity with a limited asymmetric shock absorption function could take the form of an insurance-type system between euro area countries. [...] The specific design of such a function could follow two broad approaches. The first would be a macroeconomic approach, where contributions and disbursements would be based on fluctuations in cyclical revenue and expenditure items [...]. The second could be based on a microeconomic approach, and be more directly linked to a specific public function sensitive to the economic cycle, such as unemployment insurance."* (Van Rompuy (2012)).

In this dissertation, both approaches for a risk sharing mechanism between Euro area countries will be considered. Chapter 3 will look into the macroeconomic approach, by examining the effectiveness of an automatic fiscal transfer mechanism. The microeconomic approach is the topic for Chapter 4, that will assess the effects of a European unemployment benefit scheme.

Looking back and looking forward...

The process of monetary integration in Europe and the potential for fiscal policy coordination within the EMU is the unifying theme of the chapters in this dissertation. From the policy perspective, the dissertation can be divided into two thematic parts. The first part consists of Chapter 2, with a focus on the effects of EMU participation for the individual Eurozone members. This chapter takes a backward-looking view and discusses which countries benefit from participation in the economic and monetary union of Europe and which circumstances affect the effects of monetary integration positively or negatively. The second part consists of Chapter 3 and Chapter 4, which applies a forward-looking approach and analyzes two alternatives for fiscal policy coordination, namely the introduction of a supranational automatic fiscal transfer mechanism and an EMU-wide unemployment insurance scheme.

Chapter 2 empirically identifies the benefits from participation in the EMU for individual Euro area countries. The synthetic control method is used to answer the following question: *"What would have been the level of real GDP per capita in a country had it not joined the EMU?"* This method uses a data-driven procedure to build this counterfactual scenario as a weighted combination of potential control countries, where the characteristics of the synthetic counterfactual are matched to those of the country of interest in the period before the introduction of the euro. The identification of the counterfactual is enhanced by focusing on the scenario that the individual EMU member had not joined the monetary union, rather than the situation in which the EMU had not existed. Besides, the synthetic control method is used to build a synthetic counterfactual for the period between 2008 and 2014 in order to estimate the differential impact of the crisis on EMU members relative to non-EMU members. The synthetic control method has clear advantages over the use of the fixed effects regression method, as it predicts more accurately and allows for variation in the effect of EMU participation over time.

The results show that most countries have profited from having the euro, an effect that is most evident for the period until the recent financial crisis hit the Euro area. Using confidence intervals and placebo tests, we find that the benefit of EMU participation for Austria, Belgium, the Netherlands and Spain is significant. Italy is the only EMU country that experiences a significant loss of EMU membership over the period between 1997 and 2014. Membership of the EMU during the crisis harmed most of the Eurozone countries. The latter effect is significant and substantial in size for the PIGS countries as well as Finland, though over the entire estimation period Greece and Spain have been benefiting from joining the euro.

Chapter 3 examines the effectiveness of a fiscal transfer scheme in the monetary union of Europe. The idea behind this mechanism is an interregional type of risk sharing, where a region that is sincerely hit by an adverse shock is temporarily subsidized by the other region. The transfer is based on the relative GDP level compared to the level at the introduction of the transfer mechanism, such that the transfers between regions are not permanent and will not set off continuous redistribution. Moral hazard issues are prevented as much as possible by the dependence of the transfers on relative changes in GDP. We incorporate this automatic fiscal transfer mechanism into a dynamic stochastic general equilibrium (DSGE) model with several standard features, such as capital adjustment costs and Calvo prices and wages with partial indexation, and with a common monetary authority and an extensive regional fiscal sector. The use of a DSGE model allows for normative and policy implications of the introduction of this transfer scheme. The model is estimated for the northern and southern region of the Euro area, in order to take the heterogeneity across the EMU countries into account. This estimated model is used to answer two main questions. On the one hand: *"Ex post, what would the transfer mechanism have meant for the regions of the Eurozone in the recent economic recession?"* On the other hand: *"Would the transfer mechanism be ex ante beneficial for both the northern and the southern region of the EMU?"*

The estimation of our DSGE model leads to substantial differences between the parameter estimates for the northern and southern region. Using the simulations of the estimated model, evidence was found that the transfer mechanism would have been effective in stabilizing the southern economy during the financial crisis. If introduced in 2007, the transfer mechanism would have led to higher GDP and consumption for the southern block of countries. The North would have paid for the transfer, implying a welfare loss for the North that is larger than the welfare gain for the South. However, if the scheme had been introduced at the start of the EMU, the South would have been paying to the North for many years, which indicates that the transfer scheme is not a one-way street. Besides, simulations for the future show that, ex ante, the transfer mechanism would be beneficial for both regions in terms of welfare and stabilization.

Chapter 4 explores the hypothetical introduction of a European unemployment benefit scheme (EUBS). A DSGE model with search and matching frictions in the labor market is estimated for the North and the South of the Eurozone. The model in this chapter shows some overlap with the model used in Chapter 3, though Chapter 4's model has a representative household setting in which labor supply is modeled on the extensive rather than the intensive margin. Together with the search and matching frictions and the hiring costs, this allows for a detailed structure of the labor markets in both regions. On the other hand, the model in Chapter 3 has both a tradables and a nontradables sector, whereas I economize on the size of the model in Chapter 4 by having only a tradables sector and no partial indexation of prices and wages. Using this model, I try to answer the two main research questions of this Chapter. Firstly: *"Ex post, what would an EMU-wide unemployment insurance scheme have meant for the EMU if it had been introduced in 2013?"*. Secondly: *"Would the EUBS be ex ante beneficial for both the North and the South of the Euro area?"* The advantage of this risk sharing mechanism in comparison to other schemes is the automatic link between payments and the business cycle. Furthermore, I set it up in such a way that the purpose is to provide only insurance without permanent redistribution.

The hypothetical introduction of the EUBS in 2013, replacing the existing regional unemployment benefit schemes, would have increased northern GDP and employment, whereas in the South unemployment would have gone up. Partially, this is due to the relatively higher benefit in the South, as the pure risk sharing aspect of the scheme would be positive for both regions. The political willingness to implement this scheme depends on the ex ante expectations for the future. The EMU-wide unemployment insurance would lead to higher welfare and expected stabilization of employment for both economies. Moreover, I find substantial heterogeneity in the labor market parameter estimates. Labor market harmonization among the northern and southern labor market, implemented by closing the discrepancy between labor market parameters, would lead to higher gains from the European unemployment benefit scheme.

The results of this dissertation highlight the impact of the process of monetary integration and the importance of fiscal integration for the Economic and Monetary Union of Europe. The remainder of this dissertation is organized in three stand-alone chapters, each with its own introduction and conclusion. Appendices, figures and tables related to each chapter are presented at the end of the chapters separately. A single bibliography section is included at the end for all chapters.

CHAPTER 2

Benefits of EMU Participation:

Estimates using the Synthetic Control Method

2.1 Introduction

The success of the Economic and Monetary Union has been widely debated. Many economists, as well as the public, wonder whether the introduction of the euro and participation in the EMU has brought prosperity to the individual members, or whether it actually has had negative consequences for the euro adopters.

Even before the introduction of the EMU, and the euro included, the success of the Euro area as a monetary union was questioned. Economists argued that the EMU did not satisfy the requirements as described in the Optimum Currency Area literature that would help the Euro area to be a successful currency union in terms of GDP and trade, for example. For individual countries, the cost of joining a monetary union is to give up the ability to use monetary policy to cope with (asymmetric) shocks. These costs are amplified in unions without sufficient labor mobility and a risk sharing mechanism to cope with asymmetric shocks, exactly two elements that are missing in the Euro area.

In the wake of the recent economic crisis in Europe, the discussion about the viability of the EMU has revived in most Eurozone countries. The Delors Report (Delors (1989)) and the 'One market, one money' report (Commission of the

This chapter is the result of joint work with Bas van Groezen and Lex Meijdam.

European Communities (1990)) predicted that the adoption of the euro would move the Euro area to a higher growth path. The question remains whether the individual Euro area countries really have benefited from the euro and the common monetary policy. With respect to the future of the Economic and Monetary Union, it is important that member countries are mostly benefiting from their participation in this currency union. A useful extension of this analysis would be to understand the determinants of the benefits or losses from participation in the EMU. A deeper understanding of this can help to take steps to bring the Euro area closer to an optimum currency area.

This chapter tries to contribute to this discussion by estimating the effects of having the euro and participating in the EMU for individual member countries. In order to identify a causal relationship, we need to find a counterfactual, given by the answer to the question: "What would have been the level of GDP per capita in a country had it not joined the EMU?" Of course, this counterfactual does not exist and the construction of a credible counterfactual GDP series for each country is difficult. By using the synthetic control method, pioneered by Abadie and Gardeazabal (2003), we aim to construct robust counterfactual GDP series to examine the impact of participation in the EMU in terms of real GDP per capita. The data-driven procedure of this method builds a counterfactual as a weighted combination of countries, such that the synthetic counterfactual's characteristics best match those of the country of interest in the period before the introduction of the EMU.

A great advantage of this method compared to the commonly used fixed effects regression is that the effect of EMU participation can vary over the period after the introduction of the EMU. Therefore, the research question for this part of the analysis does not only focus on the individual benefits and losses of the euro for the member states, but also investigates how these benefits or losses might change over time.

In contrast to the beliefs of many, our results show that most countries have benefited from their participation in the EMU, an effect that is even significant for Austria, Belgium, the Netherlands and Spain. The only country that initially experiences a loss from having the euro is Italy. Participation in the EMU was proven to be anticipated already two years before the official introduction of the euro in 1999. Moreover, the benefits and losses from EMU participation vary a lot over time. Until 2008, the year in which the financial crisis started, all countries except Italy were profiting from their EMU membership. However, during the crisis period many countries would have been better off if they had not been in the monetary union, especially Greece, Italy and Spain.

The impact of participation in the EMU is quite heterogeneous across countries, which logically leads to the follow-up research question of this chapter: "Which economic determinants are important for the losses or benefits of being part of the Euro area?" For this exercise, we run OLS regressions on the estimated payoffs from EMU membership, relating them to several potential determinants. The main drivers of the estimated effect of EMU participation are trade openness, competitiveness, fiscal stance, labor market flexibility and migration.

The rest of the chapter is organized as follows. Section 2 briefly discusses the relevant literature in this field. Section 3 presents the synthetic control method and potential issues with this method, a comparison to the fixed effects method and a description of the data. Section 4 shows the estimated payoffs of EMU participation for individual member countries and the variation in these estimates over different periods in time as well as the potential determinants of the benefits and losses of individual countries. Section 5 presents statistical inference on the results and the differences and similarities of the synthetic control method and the fixed effects method for this analysis. Section 6 concludes.

2.2 Related literature

This chapter attempts to estimate the impact of participation in the EMU and having the euro on per capita GDP for individual countries within the Euro area. Several papers have investigated the euro effect on trade rather than per capita GDP. For example, Frankel and Rose (2002) quantify the implications of having a common currency, using data for more than 200 countries. They first estimate that belonging to a currency union triples trade with other members of the currency union. Then they find that an increase of one percent in trade raises income per capita in that country by at least 0.33 percent. The two estimates combined leads them to conclude that there are beneficial effects of currency unions through a positive trade effect. There are more early papers on this topic, such as Barr et al. (2003), Micco et al. (2003) and Flam and Nordström (2006), that all report sizable and significantly positive trade effects of the euro. Baldwin et al. (2008) find that the euro has promoted trade and foreign direct investment significantly, and identify the relative price channel and the newly-traded goods channel as the main channels for this effect. On the other side of the literature, papers by, amongst others, Mancini-Griffoli and Pauwels (2006), Berger and Nitsch (2008) and Santos Silva and Tenreyro (2010) conclude that the effect of the euro on trade is not significantly different from zero.

Rather than estimating the effect of the euro on trade, there also exist papers trying to capture the effect of the euro on GDP or income for the whole Euro area. In the paper by Drake and Mills (2010) for example, Euro area GDP is decomposed into trend components and cyclical components. The authors find that the trend growth of Euro area real GDP has been reduced by the introduction of the euro. Using a VAR approach with the US as counterfactual, Giannone et al. (2010) show that Euro area per capita GDP growth is not different from what is expected based on pre-EMU economic structure and the US business cycle. The inability of the literature to agree upon the impact of the euro and the EMU on GDP is to a large extent related to the difficulty of establishing a reliable counterfactual by using the right method.

Our chapter will use the synthetic control method to estimate the effects of EMU participation on real GDP per capita. This method was pioneered by Abadie and Gardeazabal (2003), who used the approach to identify the impact of terrorist conflict in the Basque Country on GDP per capita. Moreover, this methodology has been used in Abadie et al. (2010) and Abadie et al. (2015) to estimate the effects of a tobacco control program in California as well as the economic impact of the German reunification. In the paper by Campos et al. (2014), the synthetic control method is used to analyze the gains from membership in the European Union. They find large benefits from EU membership (except for Greece), though these differ across countries and over time.

With regard to the impact of the euro introduction on GDP, there have been few papers using the synthetic control method. One example is the paper by Gomis-Porqueras and Puzzello (2015), who estimate the effect of joining a monetary union on GDP per capita for six of the early adopters of the euro. They find that Belgium, France, Germany and Italy would have had higher levels of GDP per capita if they had not joined the EMU, whereas the euro effect is positive for Ireland. For the Netherlands, the impact of the euro on income is negligible. In the paper by Fernández and García-Perea (2015), the focus is on the Euro area as a whole, for which there is only a small positive effect of the adoption of the euro which turns negative afterwards.

The contribution of this chapter to the literature is fourfold. Firstly, our focus is on the individual Euro area countries. Therefore, the counterfactual we are aiming for reflects the situation in which the individual member would not have joined the EMU, and not the situation in which the EMU would not have existed. We believe that the estimates produced by the synthetic control method are more suitable to provide an answer to this counterfactual question, rather than the question what GDP would have been if there had not been a monetary union at all.

Secondly, a broader data collection allows us to cover a longer period of time before the introduction of the euro. Next to that, more countries and more predictors for real GDP per capita are included in the analysis, all of which will improve the chances of creating a good counterfactual match. Participation within the EMU might have been anticipated, which we will take into account by starting the estimation some years before the introduction of the euro.

Thirdly, we study the different periods after the introduction of the EMU to analyze how the EMU effect might vary over time. An interesting extension is that we estimate the differential impact of the crisis on EMU members relative to non-EMU countries.

Finally, we provide a methodological contribution by making an explicit comparison between the synthetic control method and the fixed effects panel data regression, which is the most commonly used method in the literature. Using estimates from a fixed effects regression, counterfactuals are built using two approaches, and these are compared to the synthetic counterfactuals. The results show that the fit of the counterfactual to the EMU country in the pre-EMU period is actually much better when we use the synthetic control method compared to the fixed effects method.

2.3 Synthetic Control Method

Answering the question "What would have been the growth path of GDP per capita in a country, had it not joined the EMU?" is difficult, because of issues related to endogeneity, measurement errors, omitted variables and causality. In order to investigate the effects of EMU participation empirically, we build counterfactuals for each of the Euro area countries separately, using the synthetic control method pioneered by Abadie and Gardeazabal (2003) and further explored by Abadie et al. (2010, 2015).

2.3.1 Methodology

A simple comparison of the time path of GDP for the members and non-members would reflect the effect of participating in the EMU, but also the differences in predictors of GDP before the introduction of the euro. The synthetic control method tries to identify only the first effect by comparing the growth path of GDP for a given country to the growth path for a synthetic control group. This synthetic control resembles relevant economic characteristics of the country of interest before the introduction of the euro. This method is based on the presumption that a weighted combination of comparison units, the 'counterfactual' EMU country not participating in the EMU, does better in reproducing the EMU country than a single control unit.

In order to construct this synthetic control, the method searches for a weighted combination of control countries that is chosen to closely match the treated country for a set of predictors of GDP. The growth path for GDP per capita of the synthetic control is the estimate of the counterfactual, that is, the growth path of the Euro area country if the country had not joined the EMU. The growth path of this synthetic control is compared to the actual growth path of the Euro area country to find the effect of participation in the EMU. This procedure is repeated for every single EMU country to find the country-specific benefit or loss from being in the EMU.

More formally[1], there is a sample of $J+1$ countries indexed by j, in which country $j=1$ is the EMU country of interest and countries $j=2$ to $j=J+1$ are potential control countries, which is called the donor pool. The sample is assumed to be a balanced panel where all units are observed for each period $t=1,...,T$. Moreover, we assume that the intervention, e.g. the introduction of the euro, takes place in period T_0+1, such that T_0 is the number of preintervention periods and T_1 (with $T_0+T_1=T$) is the number of postintervention periods.

For each country j and time t we observe Y_{jt}, the outcome of interest. For the EMU country of our interest we observe Y_{1t} for the whole postintervention period, but we would also like to gain knowledge about the unobserved Y_{1t}^N, the outcome for this country if it had not been subject to the intervention. With this knowledge, the effect of the intervention on this EMU country can be estimated by:

$$\tau_{1t} = Y_{1t} - Y_{1t}^N \tag{2.1}$$

The counterfactual Y_{1t}^N is given by the GDP path of the synthetic control.

The synthetic counterfactual or control is defined as a weighted average of the units in the donor pool. The set of weights is given by $W=(w_2,...,w_{J+1})$, in which $0 \leq w_j \leq 1$ and $\sum_{j=2}^{J+1} w_j = 1$. A donor country can be given at least a zero weight and at maximum 100 percent weight, and all weights should sum to one. For each EMU country we will construct a different synthetic counterfactual and hence the weights for the countries in the donor pool will most likely be different across the EMU countries.

The selection of the control units is a step of crucial importance. The weights

[1]The notation in this section is similar to the notation in Abadie et al. (2015).

for the synthetic control should be chosen in such a way that the 'counterfactual EMU country' most closely resembles the actual EMU country before the introduction of the euro. The preintervention characteristics of the EMU country are captured in the $(k \times 1)$ vector X_1. The $(k \times J)$ matrix X_0 contains the values of the same variables for the units in the donor pool. Preintervention values of the outcome variable, which is GDP in this case, may also be included in X_0 and X_1.

The data-driven procedure to choose the synthetic control W^* is to minimize the difference between the preintervention characteristics of the country of interest and the synthetic control, given by the vector $X_1 - X_0 W$. For $m = 1, ..., k$, the value of the m-th variable for the EMU country is given by X_{1m}, whereas the values of this variable for the donor pool are given by the $(1 \times J)$ vector X_{0m}. Then we choose $W^* = (w_2^*, ..., w_{J+1}^*)$ that minimizes:

$$\sum_{m=1}^{k} \upsilon_m (X_{1m} - X_{0m} W)^2 \tag{2.2}$$

The weights $V = \upsilon_1, ..., \upsilon_k$ reflect the relative importance assigned to each of the k variables within X_1 and X_0. There are several methods for choosing the υ_m weights, which will influence the mean square error of the estimator, given by:

$$\frac{1}{T_0} \sum_{t=1}^{T_0} \left(Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \right)^2 \tag{2.3}$$

The choice could be based on a subjective measure of the relative importance of the predictors. In most cases however, the choice of V is data driven. One possibility is to let the weights be determined by a first step regression. Alternatively, we choose V such that W minimizes the mean square prediction error (MSPE) over a pre-specified set of pre-euro periods. That is, these weights are chosen so that the per capita GDP path of the EMU country is best reproduced by the resulting counterfactual EMU country. This involves a nested optimization problem, in which each choice of the vector of predictor weights V implies a choice of W, the weights for the donor countries, which then implies a value for the MSPE.

The postintervention values of the outcome variable for the EMU country are collected in the $(T_1 \times 1)$ vector $Y_1 = (Y_{1T_0+1}, ..., Y_{1T})'$, whereas the $(T_1 \times J)$ matrix Y_0 contains the postintervention values for the donor pool. The counterfactual path for the EMU country is the GDP path of the synthetic control, which is given by the vector $Y_1^N = Y_0 W^*$. Hence, the estimated effect of the introduction of the euro is given by the difference between the postintervention outcomes of the EMU country and the synthetic control, which is $Y_1 - Y_0W^*$. Similarly, the synthetic control estimator of the effect of participation in the EMU is given by:

$$\tau_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \tag{2.4}$$

for all postintervention periods $t \geq T_0$.

2.3.2 Potential issues

In order to identify the true effect of EMU participation for the Euro area countries, the synthetic control method entails two main identification assumptions. Firstly, the variables that are included in the preintervention characteristics in matrices X_0 and X_1 cannot be variables that anticipate the effects of EMU participation, but should include variables that are able to approximate the GDP path of the EMU member. Although it is hard to rule out any anticipation effects that the introduction of the EMU might have had, we will include different intervention years in our analysis, so-called in-time placebo tests, to investigate the existence of anticipation effects. If anticipation effects exist, then the effect of EMU participation will be estimated for the year in which the anticipation starts. The second assumption requires that countries in the donor pool should not be affected by the intervention. It is important to realize that the intervention is not the introduction of the EMU itself, but the participation of a country in the EMU. The counterfactual that we would like to estimate is for the situation that the country had not joined the EMU, and not for the situation that the EMU had not existed. The countries in the donor pool may be affected by the introduction of the EMU, so spillover effects of the introduction of the EMU could exist. However, if the EMU country had not joined the monetary union, it would have also been affected by the introduction of the euro. Hence we assume that these spillover effects for the EMU countries would have been the same as the spillovers for the control countries, had the EMU countries not joined the EMU. If the spillover effect to these countries would be even larger, and of the same sign as the benefit or loss, then the estimated effect might underestimate the true effect of EMU participation.

Choosing the donor pool requires great care. Countries that have been subject to large country-specific structural shocks to GDP should be excluded from the donor pool, if those shocks would not have affected the EMU country if it had not been a Euro area member. Besides, the donor pool should be restricted to countries with similar characteristics as the EMU countries to avoid interpolation biases and overfitting. The problem of overfitting occurs when the preintervention characteristics of the country of interest artificially match the idiosyncratic variations in the sample data. One could say that the model is too complicated for the dataset. Therefore, we start by using a large donor pool of countries for the synthetic control method, and then we limit the donor pool to a small subset of 14 countries that are more comparable to the EMU members. Moreover, we perform an in-sample forecast to detect the extent to which overfitting might pose a problem.

Even when the preintervention characteristics and the donor pool are carefully selected, the question remains whether the difference between the actual and synthetic growth path of the EMU country really reflects the effect of EMU membership rather than the inability to reproduce a counterfactual growth path for this country if it would not have joined the EMU. To address this question, a first check is to compare the behavior of the outcome variable of the country of interest and the synthetic control in the periods before the intervention. If these two series behave similarly, then the gap in the outcome variable between the two series after the intervention can be interpreted as a difference that arises because of the introduction of the EMU. As a second check, we will use a difference-in-differences approach to assess statistical significance by estimating confidence intervals for the estimated benefits and losses of EMU participation. Moreover, we will conduct placebo tests. The idea behind these falsification exercises is that one cannot be confident about the estimated effect of EMU participation if similar effects would be obtained for countries that have not joined the EMU. If the synthetic control method would estimate large effects if the intervention was applied to countries in the donor pool, a so-called in-space placebo test, we would not be confident about the estimated causal effect. Placebo tests in space can also be used for statistical inference. In particular, one could create a range of placebo effects by applying the synthetic control method to every potential donor country to find the estimated effect of the placebo intervention. The estimated effect of EMU participation can be evaluated against this range of placebo effects, for each of which the ratio of post- to pre-EMU RMSPE is calculated. If this ratio for the EMU member is larger than any of the ratios for the placebo effects, the estimated benefit or loss for the EMU member can be considered significant. Finally, confidence intervals based on subsamples of the donor pool are used for statistical inference on the EMU effect. We construct 50 counterfactuals, for which we randomly draw a subsample of the control countries to be in the donor pool. The synthetic control method is applied to these 50 counterfactuals, which leads to a distribution for the effect of EMU participation for each country.

2.3.3 Comparison to fixed effects regression

The construction of a counterfactual as a linear combination of real GDP per capita of control countries, as the synthetic control method does, might appear as an unusual method. However, regression methods also use a weighted combination of the outcome variable of control countries, with coefficients summing to one. There is a large difference, however, as regression methods do not impose the restriction on these coefficients that they have to be between zero and one. The regression weights may take on negative values or coefficients may be greater than one. Hence, a regression-based approach allows for extrapolation outside the support of the data. This means that even if the GDP predictors for the EMU country cannot be approximated by a weighted average of the GDP predictors of the donor pool countries, regression weights would extrapolate to produce a perfect fit. A related advantage of the synthetic control method is that these weights for the control countries are explicitly calculated, whereas the regression weights for fixed effects regressions are usually not reported.

The synthetic control method also has advantages in terms of required data. Time-invariant variables could be used as predictors for the outcome variable, whereas the fixed effects regression method does not allow for time-invariant variables. Besides, building a counterfactual using the fixed effects method requires that none of the predictors have missing values in the years before the intervention as well as all the years after the intervention. On the contrary, the synthetic control method could still use variables for which there are missing observations, as long as there are is at least one observation for the period before the intervention year.

Furthermore, a big advantage of the synthetic control method compared to the fixed effects method is that the effect of the intervention does not need to be constant over the period after the intervention. The synthetic counterfactual shows the time path of GDP over time, and does not limit the analysis to the average effect over a period of time. In this way, the synthetic control method allows us to not only compute the average EMU effect but also to compare the benefit or loss an individual country may have from EMU participation over different periods after 1997. This feature of the method is particularly interesting for comparing the EMU effect for the periods before the financial crisis and the recession period itself.

2.3.4 Data

The synthetic control method is used to analyze the effect of the introduction of the euro for the early members of the Economic and Monetary Union, as we leave out the late adopters because of data availability, as well as Luxembourg because of the difficulty to find a reliable counterfactual. Hence, we will report on the effects of EMU participation for Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain. We will collect country-level panel data for these countries as well as for a large sample of 39 potential countries (see Appendix 1 for details). The data is gathered for the period between 1960 and 2015, though the estimation period will be shorter as we will see later, for the main reason that this optimizes the matching process.

The outcome variable is real GDP per capita, measured in constant 2005 U.S. dollars. For the pre-EMU characteristics, economic growth predictors such as inflation, trade, labor force participation, unemployment, schooling, migration and several financial and political variables are used.[2] A list of all variables used in the analysis is provided in Appendix 1, along with the source of the data. The main source for this dataset is the World Bank database.

Data availability is the main reason to leave countries out of the analysis. This also holds for the late adopters of the euro, as these countries lack observations for certain variables in the early 1990s. The choice of countries within the donor pool is also driven by data availability, and upfront no countries are excluded from the analysis. In comparison to Fernández and García-Perea (2015) and Gomis-Porqueras and Puzzello (2015), we prefer to observe the matches that the synthetic control method comes up with in order to see which countries in the large donor pool are actually close to the EMU members. Then, by leaving out countries that miss data on important variables, or might have experienced large structural shocks or were not part of the synthetic control in the large pool, we limit the donor pool to a smaller subset. The small donor pool consists of countries that are most important in the synthetic controls for the large donor pool as well.

[2]The use of the word 'predictor' might seem confusing as economic growth is likely to be correlated with, and not necessarily caused by, these macroeconomic variables. However, one must bear in mind that we use pre-EMU values of these variables to find the counterfactual growth path after the introduction of the EMU which explains the use of the word 'predictor'. Endogeneity issues do not play a role here, as these so-called predictors are only used to find control countries that match well to the EMU country, and not to find a causal relationship between GDP and these variables.

2.4 Benefits or losses for individual countries

Using the methodology presented in the previous section, the individual gains and losses of EMU participation are estimated for both a large and a smaller donor pool of countries. We study possible anticipation effects concerning the introduction of the EMU, as well as the differential impact of the 2008 economic crisis on EMU member countries relatively to non-EMU member countries. Furthermore, we investigate the main drivers behind the gains and losses for the EMU members.

2.4.1 Starting from a large donor pool...

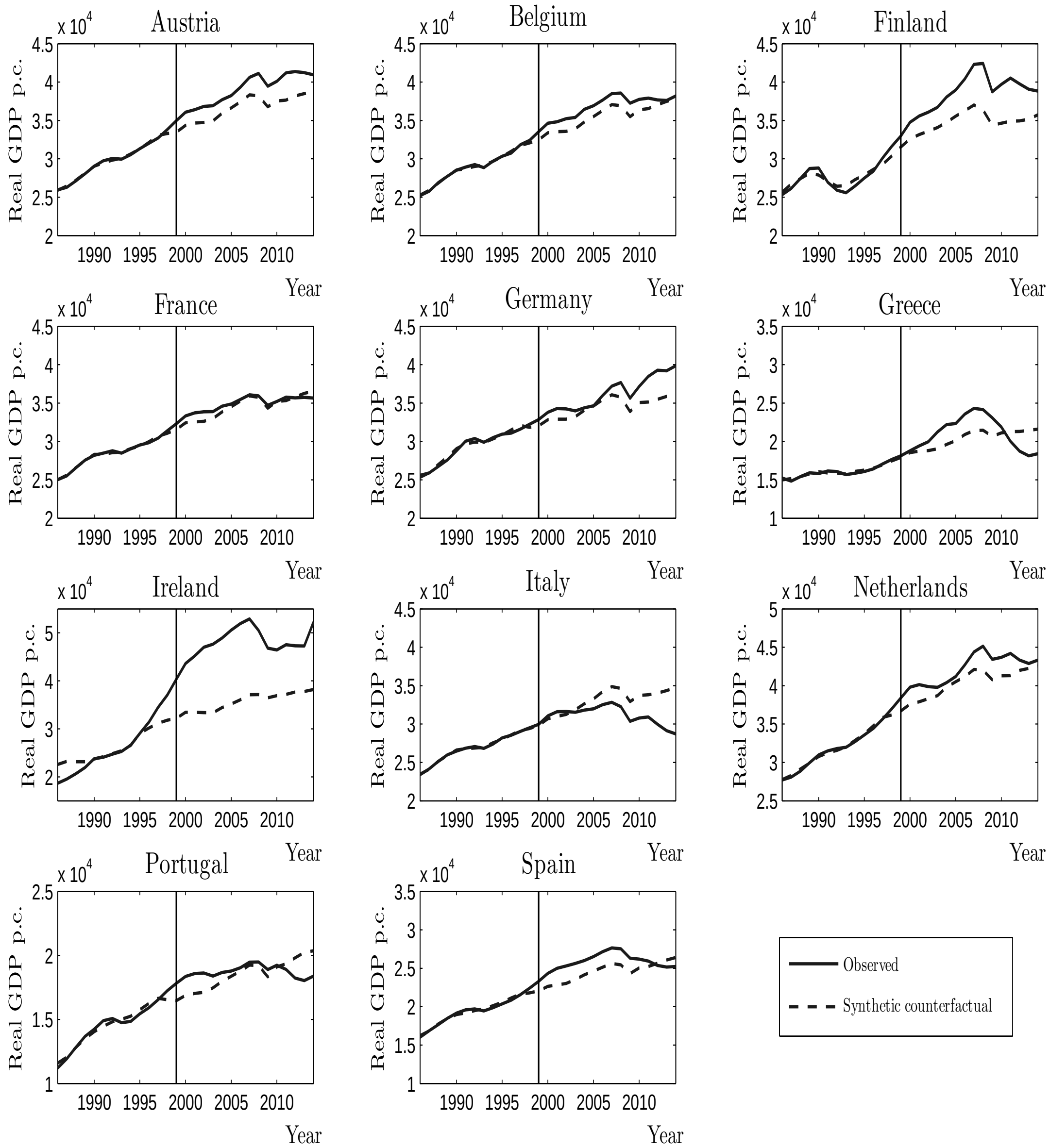
For the 11 individual member countries of the EMU a synthetic counterfactual is built based on a large donor pool of countries. This donor pool consists of 39 countries in Europe, Oceania and North America as well as Asia, Africa and South America, as to make this set as broad as possible given the data limitations. The synthetic weights in the counterfactual are displayed in table 2.A.1. The synthetic counterfactual is estimated using data from 1986 until 1996.[3] Figure 2.1 displays the observed series for real GDP per capita and the synthetic counterfactual for the individual member countries of the EMU.

For most EMU countries, the synthetic counterfactual tracks very well real GDP per capita before the introduction of the EMU in 1999, which is an important factor in establishing the validity of the result. The difference between the observed series and the synthetic counterfactual after 1999 is the effect of participation in the EMU, and is positive if the observed real GDP per capita lies above the line of the synthetic counterfactual. Our estimates show that most countries experienced a positive effect of having the euro over the whole period between 1999 and 2014. An interesting observation is that Greece, Portugal and Spain experience a benefit of being in the EMU first, whereas this turns into a loss during the 2008 economic crisis. According to these results, Italy would have been better off had it not introduced the euro, whereas the effect for France appears to be not significantly different from zero. Ireland is an exceptional case in this analysis, as the country has gone through a period of specific high growth rates in the 1990s and 2000s, which many attribute to a large extent to foreign direct investment and foreign multinationals. This makes it fairly hard to find a

[3] As a robustness check, we repeat the analysis for the small donor pool with intervention year 1997 using different starting years of the estimation period. The EMU effect does not differ substantially between the estimations based on starting year 1980 until starting year 1990 for most countries. However, for Belgium, Germany, Greece, Portugal and Spain there are some quantitative differences for the average effect when a different starting year is chosen.

reasonable counterfactual, the estimated EMU effect for Ireland should therefore be considered as largely overestimated.

Figure 2.1: Real GDP per capita: Observed vs synthetic counterfactual



2.4.2 ... to a smaller donor pool with more GDP predictors

In constructing a solid counterfactual, it is important that the combination of control countries matches well on the GDP path before the introduction of the EMU, as well as on the economic predictors of GDP. For that reason, we move to a smaller donor pool which enables us to include more GDP predictors as for these countries more data is available. Another advantage of using this smaller donor pool is that these control countries are more comparable to the EMU countries, which makes us confident that no structural changes in these countries trouble the view that the estimated EMU effect gives.[4] This small donor pool consists of 14 countries, namely Australia, Canada, Chile, Denmark, Iceland, Japan, Mexico, New Zealand, Norway, Sweden, Switzerland, Turkey, United Kingdom and United States. As table 2.A.1 shows, these countries were already important control countries for the results in the previous section.

From figure 2.2 it appears that the estimated EMU effect is similar for most countries when we adjust the donor pool to a smaller subset of countries. The only exception here is Finland, that seems to benefit less from being in the EMU than before. An important observation in both figure 2.1 and 2.2 is that the effect of EMU participation seems to start earlier than 1999 for most EMU members. These so-called anticipation effects might arise as consumers, firms and also governments anticipate the introduction of the euro in advance and start to behave accordingly. Taking anticipation effects into account can be done by applying the synthetic control method to a different year, and using the period until that year as basis for the matching. In this case, we will use the year 1997, since it appears that the EMU effect sets in at this time for most EMU members.

Figure 2.3 shows that except for Ireland, the synthetic control method for intervention year 1997 captures the introduction of the euro quite well. It is still clear that Austria, Belgium, Finland, the Netherlands and Spain have benefited from participation in the EMU, and the loss for Italy is also undisputed. Portugal and Greece started off by profiting from the euro, but around the economic crisis the effect is reversed. For France, hardly any effect of EMU participation is observed, whereas Germany appears to be only profiting during and after the crisis. As we discussed before, the case of Ireland is particular because of its rapid economic growth related to foreign direct investment which makes it hard to find a good match for Ireland in any case.

[4]The smaller donor pool indeed matches better on the economic predictors of real GDP per capita than the large donor pool, as the average distance between the predictors of the EMU country and its synthetic control is smaller.

Figure 2.2: Real GDP per capita: Observed vs synthetic counterfactual for small donor pool

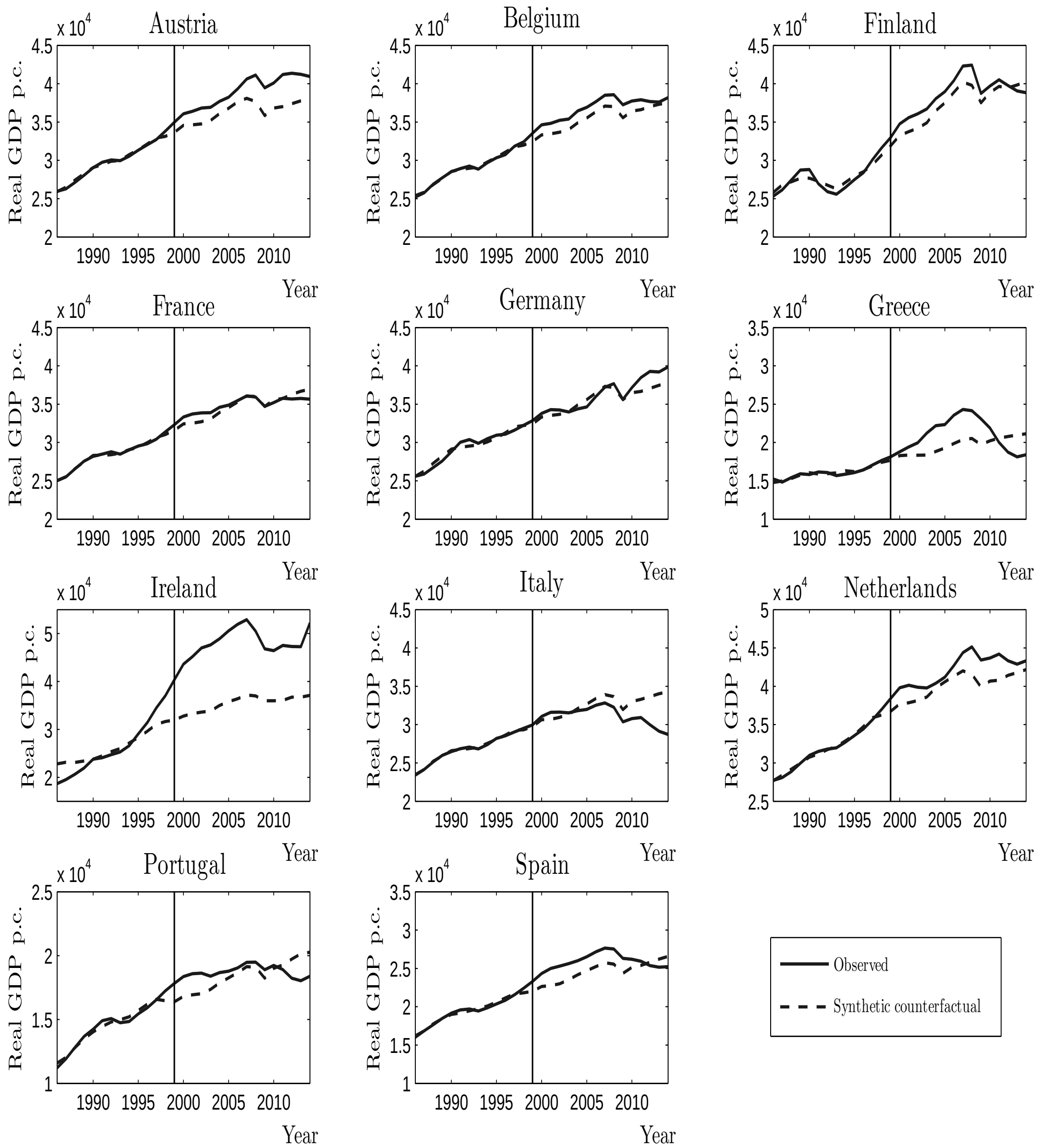
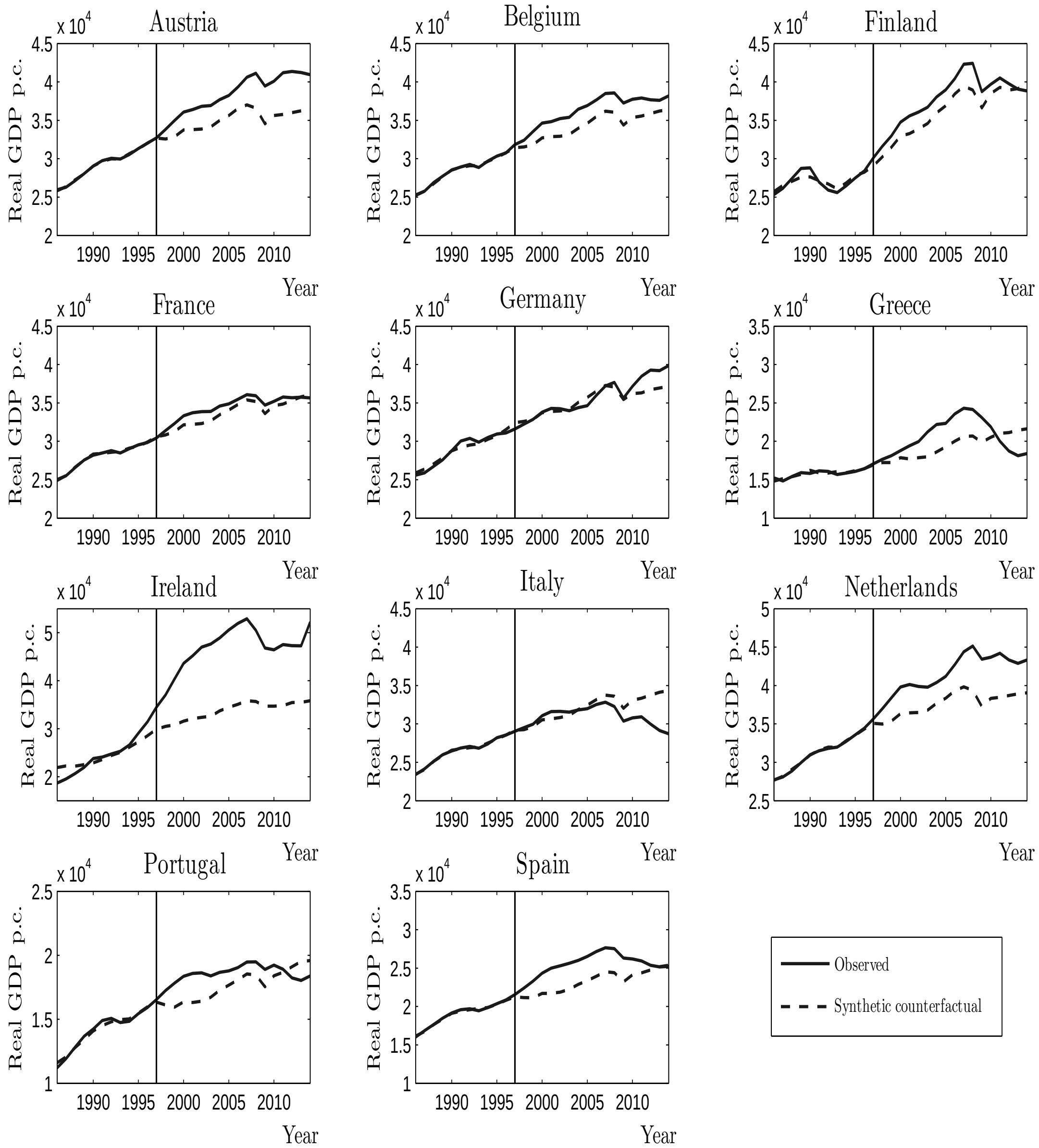


Figure 2.3: Anticipation effects: Observed vs synthetic counterfactual for small donor pool



The estimate of the effect of EMU participation is the difference between the observed per capita GDP in the EMU country and in its synthetic counterfactual. Figure 2.4 plots this yearly EMU effect for the 11 individual member countries. On the one hand, these graphs show that the synthetic counterfactual does quite well in matching the EMU country before 1997, where we would like to see the gap as close to zero as possible. It is clear that the matching process done by the synthetic control method is less successful for Finland, Greece, Ireland and Portugal than for the other countries. On the other hand, the graph shows for the period after 1997 how large the effect of joining the EMU is. The magnitude of the estimated effects is substantial, as is also laid out in table 2.4.1. This table reports the average yearly EMU effect over the period between 1997 and 2014 for the EMU country in the second and fourth column. However, for the countries that experience both benefits and losses related to the introduction of the euro, it might be useful to split the period after 1997 into the period until 2007 and the crisis period. These results for the period from 1997 until 2007 are shown in column 3 and 5.

Table 2.4.1: Estimated EMU effect on real GDP per capita

	Effect of EMU in euros		Effect of EMU in %	
	All years	1997-2007	All years	1997-2007
Austria	+3336	+2344	+8.50%	+6.27%
Belgium	+1985	+1876	+5.43%	+5.25%
Finland	+1622	+1933	+4.31%	+5.29%
France	+749	+930	+2.19%	+2.74%
Germany	+470	-268	+1.14%	-0.79%
Greece	+1182	+2111	+4.89%	+9.75%
Ireland	+12892	+12788	+27.23%	+27.41%
Italy	-1170	+97	-3.92%	+0.33%
Netherlands	+3810	+2968	+9.04%	+7.33%
Portugal	+871	+1434	+4.68%	+7.79%
Spain	+2187	+2643	+8.49%	+10.37%

Figure 2.4: Per-capita percentage gap EMU country and synthetic counterfactual

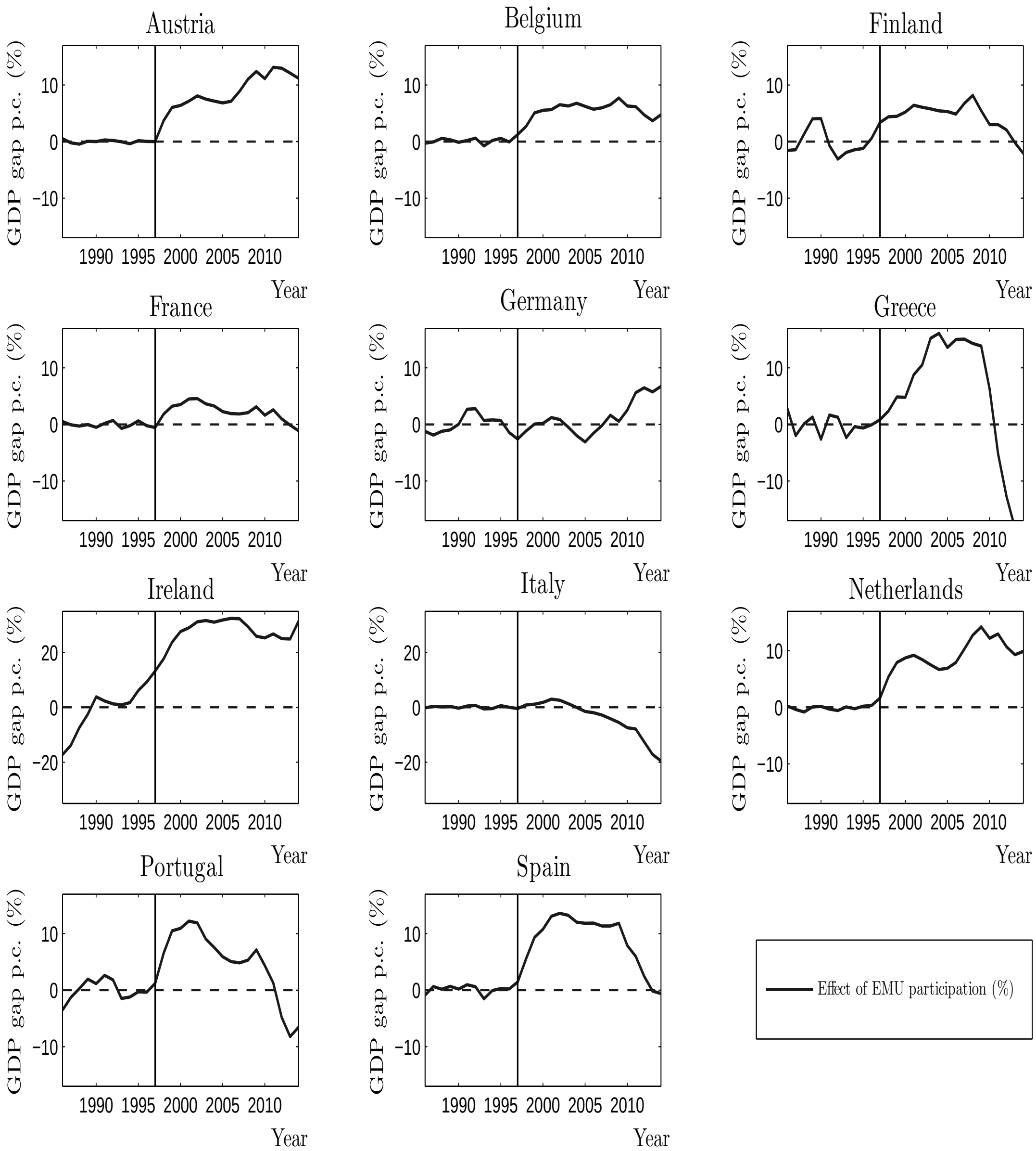


Table 2.4.1 confirms the general impression of figure 2.4. The estimated average effect of participation in the EMU is quite substantial, and positive for all economies except for Italy. For example, Austria had a benefit of 8.5% on average, meaning that its yearly GDP per capita would have been 8.5% lower had it not joined the EMU. The comparison between the whole period and the pre-crisis period displays the interesting fluctuations in the EMU effect over time as we have also seen in figure 2.4. For Greece, Portugal, and to a lesser extent Spain, the estimated EMU effect is substantially larger when only the period until 2007 is considered compared to the whole period until 2014. For Italy, the story is similar, as it has experienced a small benefit until 2007 but over the whole period there is a sizable loss. The numbers for Germany describe the opposite story, namely that Germany has not benefited until 2007, but since the average over the whole period is positive, it must have gained a lot during the recent crisis. Ideally, we would like to present the estimated average EMU effect during the period 2008-2014, however, using the synthetic counterfactuals as we constructed here would not be appropriate. The synthetic counterfactual for the years between 2008 and 2014 already takes into account everything that has happened before, there is a type of path dependence in the estimated EMU effect. Therefore, we could only evaluate the differential impact of the crisis on EMU member countries compared to non-EMU member countries if we redo this specific exercise using the synthetic control method for an intervention in 2008. The results of this exercise are discussed in section 2.4.3.

One may be concerned about the forecast error of our method, which might bias the results in the direction of the effect that we find. For that reason, we have split the preintervention period in a training period and an evaluation period. The training period from 1986 until 1992 is used to forecast the values of real GDP per capita for the evaluation period from 1993 until 1996. The results of these in-sample forecasts show that the forecast error is on average small, except for Finland, Greece and Ireland.[5] Moreover, for most EMU countries, the forecast error is negative implying that the synthetic control is estimated to be higher than actual GDP.[6] As a consequence, the mostly positive estimates of the EMU effect that we find are not caused by an upward biased forecast error.

Another valid concern one may have regarding these results on the EMU effect is the existence of potential spillover effects. It is plausible that the introduction of the EMU in Europe has affected real GDP per capita in other countries

[5] The forecast errors are reported in table 2.A.3.

[6] The forecast error over the period 1993-1996 is negative for Belgium, Finland, France, Germany, Greece, Italy, Portugal and Spain.

included in the donor pool. However, it is important to consider the question we ask in order to find the counterfactual: "What would have been real GDP per capita in the EMU country if it had not become an EMU member?" So the EMU effect that we estimate is the difference between joining and not joining a monetary union that is in any case existent, and not the effect of no monetary union in Europe at all. As long as a country in the synthetic control is a close match to the EMU country, we expect that this control country will have the same spillover effects as the EMU country in case it had not participated in the EMU. We believe this is very likely to hold, at least for our smaller pool of donor countries. However, even if there are larger positive spillover effects to other countries, the synthetic control would provide an overestimate of the GDP path in case the EMU country had not joined. In that case, the estimated effect of EMU participation would have been underestimated.[7]

2.4.3 Impact of crisis on EMU countries

In section 2.4.2 we discussed the benefits and losses of EMU participation for the period until 2014 as well as the shorter period until the start of the crisis. In order to discuss the separate effects of being in the EMU during the crisis period, we use the synthetic control method for the intervention in 2008 with the years between 1997 and 2007 as basis for the matching. The question that needs to be answered to find the counterfactual in this case is: "What would have been the level of GDP per capita during the period of the economic crisis if the country had not been in the EMU during the crisis?" Hence, the difference between the observed data and the counterfactual identifies the differential impact of the crisis on EMU countries relative to non-EMU countries.

Figure 2.5 shows the observed GDP series and the counterfactual for the crisis if not being in the EMU for the 11 individual member countries. For Austria and Germany, there is a clear benefit of EMU participation during the economic crisis, whereas the story is not as clear for Belgium and France. For Ireland and the PIGS-countries, Portugal, Italy, Greece and Spain, there is a clear loss associated with being in the EMU during the crisis. The results suggest that these countries would have had higher levels of GDP per capita if they had not been part of the monetary union. The loss is smaller for Finland and the

[7] The donor pool includes EU countries as well, which might bias the results in a certain direction as those are most likely to be experience spillover effects from the participation of a country in the EMU. Therefore, we perform a robustness check in which the synthetic control method is applied for each EMU country to the donor pool with only non-EU countries. As table 2.A.4 shows, the results remain qualitatively and mostly quantitatively similar.

Netherlands, but also these countries seem to have suffered from being in the EMU during the crisis. Table 2.4.2 reports the size of the loss or benefit of EMU membership during the 2008 economic crisis. The effects are quite substantial, especially for the PIGS countries. These results are in line with the impressions given by table 2.4.1 on this specific period in the history of the EMU.

Figure 2.5: Real GDP per capita: Observed vs synthetic counterfactual during crisis period

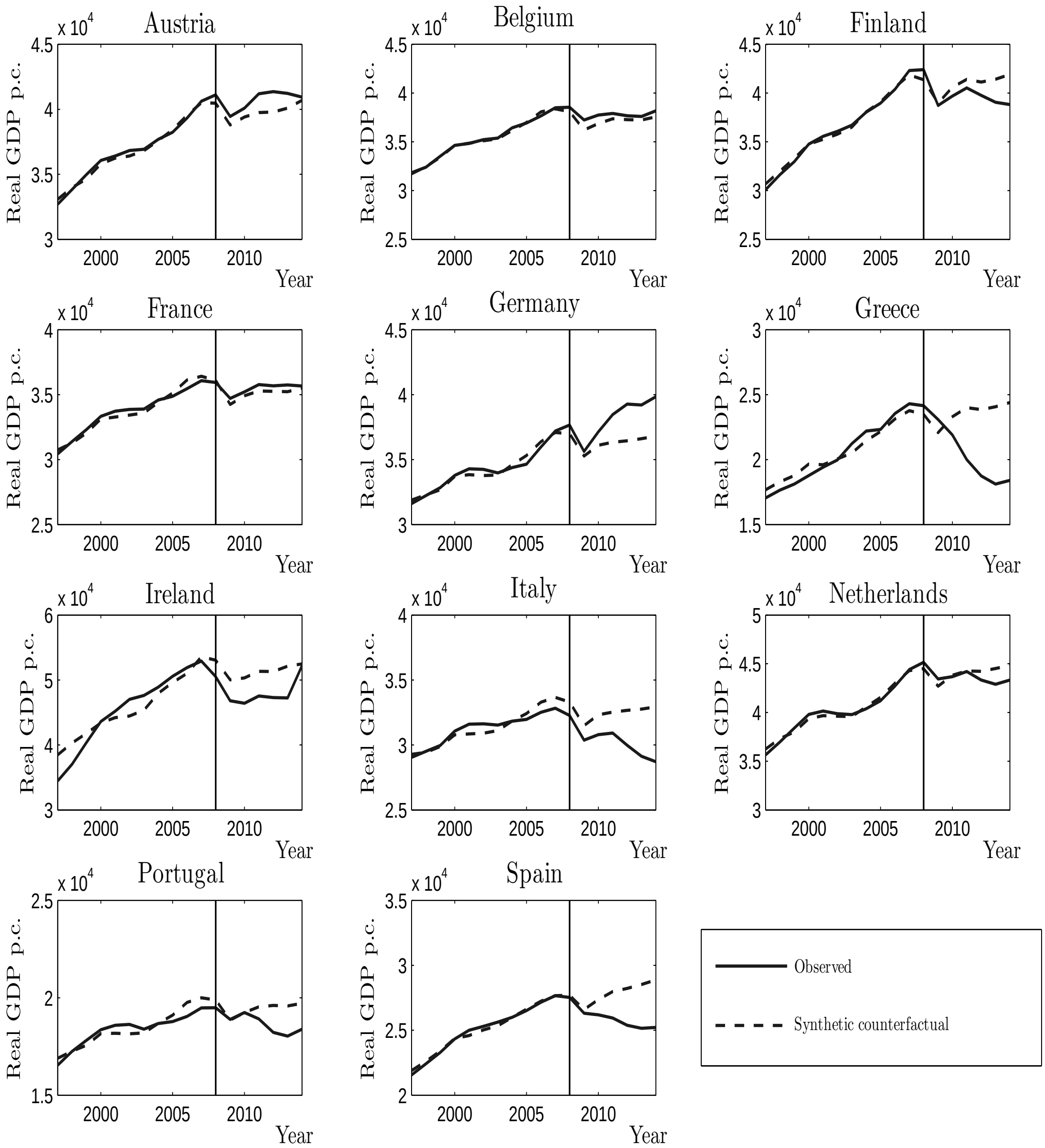


Table 2.4.2: Estimated EMU effect during the crisis period

	Effect of EMU in euros	Effect of EMU in %
Austria	+913	+2.23%
Belgium	+613	+1.62%
Finland	-1115	-2.87%
France	+313	+0.88%
Germany	+1810	+4.66%
Greece	-2971	-16.00%
Ireland	-3228	-6.80%
Italy	-2266	-7.61%
Netherlands	-405	-0.95%
Portugal	-749	-4.08%
Spain	-1935	-7.60%

2.4.4 What drives the gains and losses?

Understanding the variation in the benefits and losses of EMU participation across countries and over time is important for the current EMU members as well as possible future adopters of the euro. If the main drivers behind the estimated results of the previous sections are identified, steps could be taken to improve the Euro area's features so that the EMU gets closer to an optimum currency area. In this section, we try to identify these main drivers of the results using OLS regressions with the EMU effect as the dependent variable for 11 countries and the years after 1997. The EMU effect is the percentage difference between actual GDP per capita and the synthetic counterfactual as estimated in section 4.2. The variable EMU effect takes on positive values if the country has profited from participation in the EMU and negative values otherwise. A range of potential factors is included as independent variables in the regression, which are related to the literature on the benefits and costs of a monetary union. The goal of this exercise is not to retrieve a causal relationship from the OLS regression, but rather to highlight an important association between the EMU effect and its drivers.

The first factor considered here is trade openness, which we measure by the sum of exports and imports as percentage of GDP. Trade openness influences both the costs and benefits of joining a monetary union. The higher the degree of openness, the more a country might profit from lower transaction costs of trade within the union. Moreover, McKinnon (1963) argues that giving up independent monetary policy is less costly for more open economies, as the aggregate price level is determined to a larger extent by international prices of tradables. So small open economies, like Austria and the Netherlands, are more likely to gain from a fixed exchange rate as these countries are likely to be more open economies. The regression results in table 2.4.3 report a positive coefficient for the variable of trade openness, which confirms this story. One could also include the trade balance, being exports minus imports, in the analysis, but this variable is less suited to represent this aspect of the theory. However, in this case, the result would be similar, a country with a higher trade balance will have a more positive or less negative effect of EMU participation.

Table 2.4.3: Main drivers behind the effect of EMU participation

	(1)	(2)	(3)	(4)	(5)	(6)
Trade openness	0.0842* (1.81)		0.0774 (1.58)	0.102* (2.14)	0.0792* (2.09)	0.1503* (2.06)
Trade balance		0.0804 (0.21)				
Public debt	−0.101** (-2.43)	−0.106** (-3.01)		−0.122*** (-3.28)	−0.094*** (-4.10)	
Interest rate on public debt			-1.009 (-1.24)			
Employment protection	-1.906 (-0.96)	-3.679 (-1.41)	-1.925 (-0.97)		-1.109 (-1.26)	
Real unit labor cost				-0.448* (-1.87)	(-1.43)	-0.510
Migration					1.950** (2.35)	
Health banking						-0.4382 (-1.38)
N	187	187	165	197	44	79
R^2	0.431	0.302	0.373	0.467	0.572	0.450

Notes: t statistics in parentheses. Inference: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The dependent variable is the percentage difference between the actual and synthetic series of GDP per capita for each of the 11 EMU countries and each year after the intervention in 1997. Because of their correlatedness, trade balance and trade openness, public debt and the interest rate on public debt, and employment protection and real unit labor costs, are not included at the same time in the analysis. For collinearity reasons, public debt and health of the banking sector are not included simultaneously. No country and year fixed effects are included. Standard errors are clustered.

Fiscal stance of the economy might be important in determining the benefit or loss a country experiences after introducing a common currency. Having a high level of public debt increases the costs of joining a monetary union, as the country loses its ability to use monetary policy to create inflation to reduce the burden of its high debt level. Moreover, apart from not being able to use monetary policy to solve internal issues, the use of fiscal policy might be limited because of lower access to credit and an already high interest rate on public debt. Using either public debt or the interest rate on public debt as a regressor, we find that the coefficient is negative. This implies that countries with a high debt level, and hence a higher interest rate than other countries, experienced smaller benefits or even losses due to the introduction of the euro.

Mundell (1961) emphasized that labor mobility is crucial for a currency area to work optimally. The loss of independent monetary policy becomes aggravated if there is an asymmetric or country-specific shock in the union and there is no adjustment mechanism in the form of labor moving freely across the countries. Greater openness to migration thus reduces the loss of a fixed exchange rate. A variable for net migration is added to the regression analysis, which is the absolute amount of net migration in percentages.[8] Though we notice that the amount of observations for this regression is reduced by the amount of data available, we still find that a higher degree of migration has a positive effect on the effect of EMU participation.

A related point is the degree of wage flexibility and the rigidity of the labor market. Wage flexibility or less rigid labor markets could dampen the effects of a negative shock on unemployment and GDP. As a measure for the rigidity of labor markets, we use the indicator for strictness of employment protection as provided by the OECD (Organization for Economic Co-Operation and Development). As table 2.4.3 shows, countries with less rigid labor markets cope better with external shocks and hence profit more from having a joint currency.

Another factor that we consider is the competitiveness of the country in the monetary union. When a common currency is introduced, differences in competitiveness and strong imbalances in the union cannot be solved by currency adjustments. We include a proxy for competitiveness in the analysis, which is the real unit labor cost as provided by the AMECO database. The coefficient on this variable is significantly negative, which implies that the less competitive an economy is, the more it suffers from being in the EMU.

Finally, the health of the banking sector is taken as a potential related factor

[8] Here we do not distinguish between a country receiving many immigrants or where many migrants leave, the degree of openness is affected similarly by both cases.

to the profitability of joining the monetary union for a country. Member states in which the financial market does not function properly might experience deeper recessions than other countries with a healthier banking sector. As a proxy for the health of the banking sector we take the amount of nonperforming loans as a percentage of total gross loans.[9] Column 6 shows that this coefficient has the expected sign, as the healthier the banking sector is, the more likely it is that the member state profits from its membership.

2.5 Inference and counterfactuals for fixed effects method

The benefits and losses that were estimated in the previous section are substantial, but whether these results are both significant and truly the result of EMU participation has not been established yet. In this section, we will report different ways of statistical interference of the results on the EMU effect as well as additional robustness checks. Moreover, we provide a clear comparison of the synthetic control method to the fixed effects regression methods, in order to demonstrate the advantages of this method.

2.5.1 Statistical inference

To discuss the robustness of the results, one could use the difference-in-differences (DID) estimator for the actual versus the synthetic counterfactual series. This method reports on the statistical significance of the average EMU effect for the whole period, and hence it would also be useful to have DID estimates for the period before the crisis as we have seen that the effects in these two separate periods might go in opposite directions. The results for the DID exercise are reported in table 2.A.5 in the appendix. Considering the differential impact of being an EMU member during the crisis, the DID estimator could also be used to identify the significance of the results. Due to the shorter time period considered, as the crisis period here is from 2008 until 2014, significance is slightly harder to attain. The difference-in-differences estimator is applied to the actual and synthetic series as we have seen in figure 2.5, and the results are reported in table 2.A.6 in the appendix.

Another type of statistical inference for the synthetic control method is the use

[9]Data for this proxy of the health of the banking sector is not available for Finland and Greece, and there are years with missing observations for the other countries, such that the amount of observations is reduced to 79.

of placebo tests. These falsification exercises are meant to find out whether the estimated effect by the synthetic control method is truly the effect of EMU participation, or whether a similar effect would be obtained for the control countries. Figure 2.A.2 in the appendix shows for each of the 11 countries in our analysis the estimated EMU effect and the placebo effects for the control countries. Because of a large prediction error, four countries are left out of the analysis, namely Chile, Iceland, Norway and Switzerland.[10] If the match is not performing well in the period before 1997, the counterfactual for the years after 1997 is likely to be a bad prediction of reality which is detrimental to the reliability of the estimated placebo effect.

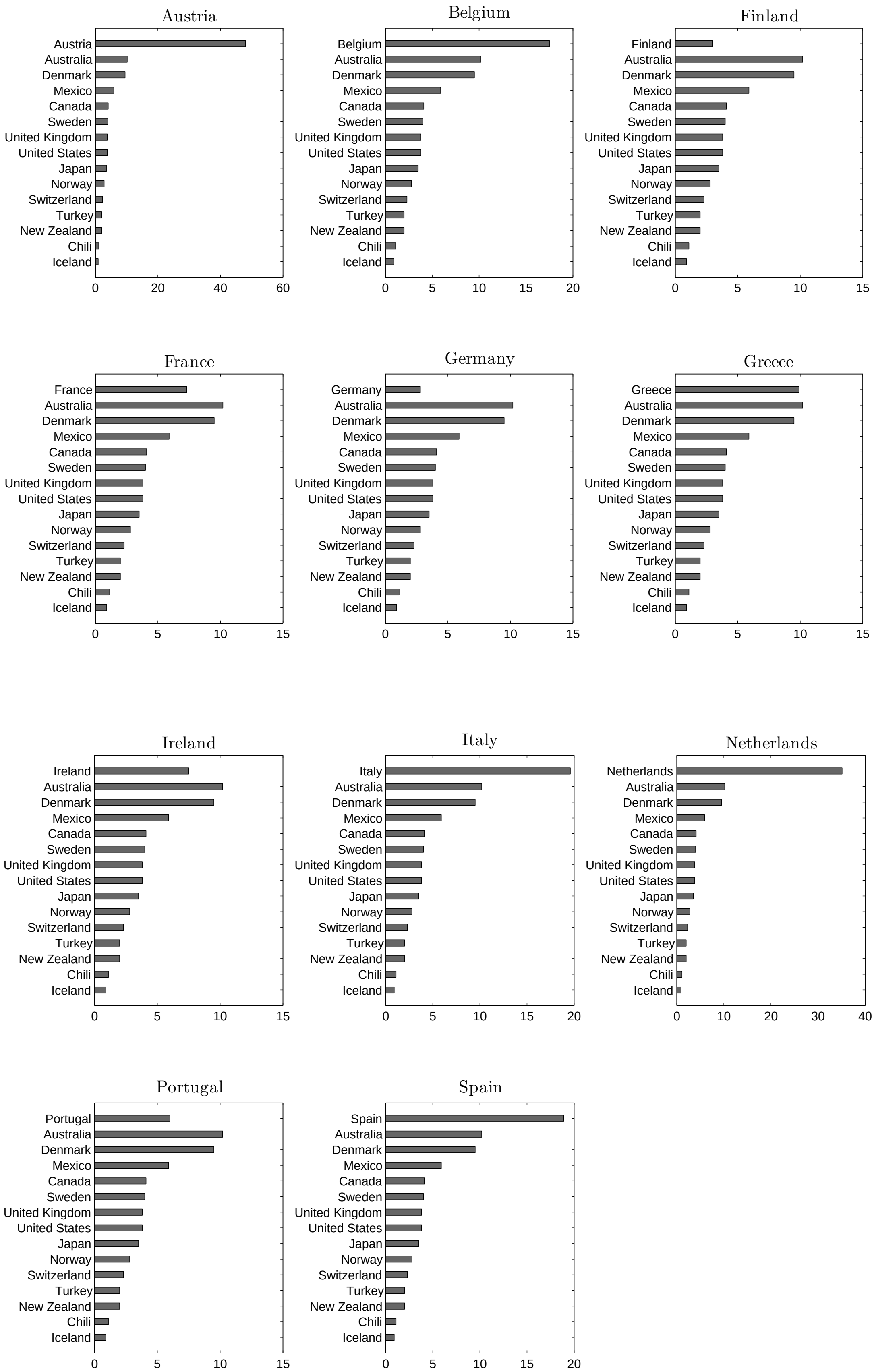
Ratio of post- to pre-EMU root mean squared prediction error

The DID estimates, in contrast to the placebo tests, take into account the quality of the match before the introduction of the EMU. On the other hand, the placebo test compares the estimated EMU effect to that of the other control countries, whereas the DID estimates shows the significance based on the own country only. Ideally, one would want to use a method that includes into its measure of significance both the quality of the match as well as the placebo effects on control countries. Moreover, the DID estimates and the placebo tests touch upon the fact that it is harder to obtain statistical significance if the EMU effect is not constant over the period after introduction of the EMU, and might actually go in opposing directions. For that reason, we will report on a measure that does not focus on the significance of the average effect, but rather the cumulative effect over the whole period that might include years with benefits and years with losses, which is the post- to pre-EMU RMSPE ratio.

The ratio of post- to pre-EMU root mean squared prediction error (RMSPE) measures the cumulative real GDP per capita gap after 1997 relative to the this gap before 1997, which reflects the quality of the match with the synthetic control. The ratios for the EMU countries can be compared to those of the control countries, that arise from the placebo tests. If the ratio is high enough relative to the ratios of the control countries, then the estimated EMU effect is significant. This measure combines advantages of both the placebo tests and the difference-in-differences estimates. The ratio of post- to pre-EMU RMSPE corrects for the prediction error in the period before 1997, just like the DID estimates, and allows for the control countries to play a role in the significance

[10] Countries in the small donor pool are left out of the analysis if either the RMSPE over the period before 1997 is larger than 2000 or the average prediction error over the period 1986-1996 is larger than 5 percent.

Figure 2.6: Ratio of post-EMU to pre-EMU RMSPE



measure, as in the placebo tests. In contrast to the placebo tests, this measure does not require a cut-off for excluding badly matched placebo counterfactuals. Figure 2.6 shows the ratios of post- to pre-EMU RMSPE measures for all the EMU members and the small donor pool.[11]

The significance of the estimated EMU benefit for Austria and the Netherlands is confirmed by the results in figure 2.6. The root mean squared prediction error after EMU introduction is respectively 47 and 35 times larger than the pre-EMU RMSPE, whereas no control country has such a large ratio. The estimated EMU effect for Belgium, Italy and Spain appear quite robust as the ratio of post-EMU to pre-EMU RMSPE of these countries is at least twice as large as that of the control countries. As we would expect, the EMU effect for Ireland is far from significant when using this measure, which is related to the bad quality of the match to the synthetic control reflected by the large RMSPE in the pre-EMU period.

Confidence intervals

An alternative approach to assess statistical significance of the estimated EMU effect is a subsampling method based on Saia (2017). Firstly, we construct 50 counterfactual groups, consisting of 11 randomly drawn countries out the small donor pool with 14 countries. Then, we apply the synthetic control method to all these 50 counterfactuals to find a distribution of the EMU effect for each EMU member. A confidence interval based on the 10th and 90th percentile of the distribution gives us insight in the credibility of the estimated effect and can also tell us whether the effect of EMU participation is significantly different from zero. The results are reported in table 2.5.1.

Table 2.5.1 shows the confidence intervals for the period from 1997 until 2014, as well as the period before the crisis and the crisis period itself. For example, we find that with 80% confidence the overall effect of EMU participation for Austria has been between 2.61% and 8.60%. For the overall period between 1997 and 2014, there are significant gains from EMU participation for Austria, Belgium, Finland, Greece and the Netherlands. If we only consider the period until 2008, also Spain had significant benefits. As before, it appears that the loss of EMU participation for Italy is significant as with 80% confidence the loss lies between 3.44% and 10.21%.

For the crisis period, we have calculated the confidence intervals in the same manner as before in which the synthetic control method is applied to the year 2008. Hence, we have calculated the differential impact of the crisis on EMU

[11] The RMSPE ratio for the control countries are the same in each of the 11 graphs.

Table 2.5.1: Confidence intervals by subsampling on donor pool

EMU country	Period	Average	Median	10% perc.	90% perc.
Austria	Overall	+7.18%	+8.45%	+2.61%	+8.60%
	Until 2008	+5.20%	+6.24%	+1.10%	+6.35%
	Crisis	+1.83%	+1.54%	-0.20%	+3.73%
Belgium	Overall	+4.75%	+5.66%	+0.50%	+6.46%
	Until 2008	+4.87%	+5.35%	+1.63%	+6.58%
	Crisis	-0.11%	-0.16%	-1.46%	+0.91%
Finland	Overall	+5.44%	+4.45%	+3.69%	+7.56%
	Until 2008	+6.10%	+5.45%	+4.69%	+7.71%
	Crisis	-2.51%	-2.67%	-2.87%	-2.06%
France	Overall	-0.34%	+1.14%	-3.58%	+2.58%
	Until 2008	+0.63%	+1.99%	-2.60%	+3.11%
	Crisis	-0.36%	-0.07%	-2.38%	+1.13%
Germany	Overall	+0.99%	+2.79%	-4.38%	+3.95%
	Until 2008	-0.84%	+0.71%	-5.37%	+1.66%
	Crisis	+3.02%	+2.20%	+1.13%	+7.38%
Greece	Overall	+4.05%	+4.50%	+0.37%	+6.76%
	Until 2008	+8.14%	+9.31%	+4.73%	+10.12%
	Crisis	-15.38%	-16.00%	-17.04%	-11.89%
Ireland	Overall	+29.65%	+27.65%	+27.23%	+35.46%
	Until 2008	+29.74%	+27.86%	+27.41%	+34.97%
	Crisis	-5.52%	-5.55%	-6.80%	-3.86%
Italy	Overall	-5.23%	-3.94%	-10.21%	-3.44%
	Until 2008	-0.92%	+0.27%	-5.05%	+0.56%
	Crisis	-8.78%	-7.61%	-10.91%	-7.13%
Netherlands	Overall	+5.49%	+5.44%	+1.75%	+9.01%
	Until 2008	+4.51%	+4.86%	+1.52%	+7.29%
	Crisis	-0.02%	-0.95%	-2.08%	+3.08%
Portugal	Overall	+2.40%	+3.10%	-4.89%	+7.21%
	Until 2008	+5.69%	+6.27%	-0.53%	+10.15%
	Crisis	-8.68%	-7.28%	-11.52%	-5.46%
Spain	Overall	+6.60%	+7.89%	+0.88%	+9.33%
	Until 2008	+8.52%	+9.73%	+3.64%	+10.96%
	Crisis	-7.47%	-7.21%	-7.81%	-6.38%

countries for 50 different subsamples of the donor pool. Germany has been significantly better off by being in the EMU during the crisis, whereas the loss is significant for Finland, Greece, Ireland, Italy, Portugal and Spain.

The subsampling method can also be applied to the computation of synthetic counterfactuals using different subsamples for the GDP predictors. The set of GDP predictors for the main analysis consists of 29 variables. Here we randomly draw 50 subsets with 25 out of 29 variables and estimate the synthetic counterfactual using these 50 subsets for the predictors. The confidence intervals based on this distribution of the EMU effect in table 2.5.2 give us insight in whether the EMU effect depends heavily on the set of GDP predictors and hence it is another way of assigning credibility to the results.

From table 2.5.2, one can observe that these confidence intervals are smaller. Hence, the EMU effect is somewhat more sensitive to changes in the composition of the donor pool than changes in the set of GDP predictors. Apart from the significant results in table 2.5.1, here we find a significant gain of EMU participation for Spain for the whole period. On the other hand, the result for Belgium becomes insignificant. For the period between 1997 and 2007, Germany has had a significant, though small, loss of EMU participation. With the smaller confidence intervals, Austria has a significantly positive EMU effect during the crisis, whereas that for the Netherlands is also negative and significant.

Conclusion

These different ways for statistical inference together support the significance of the estimated EMU benefit, at least until the crisis, for Austria, Belgium, the Netherlands and Spain, whereas there is a clear loss of EMU participation for Italy. Furthermore, being an EMU member during the crisis seems to have had a significantly positive effect on Germany, whereas this effect is negative and significant for Finland, Ireland and the PIGS-countries.

In comparison to the existing papers by Gomis-Porqueras & Puzzello (2014) and Fernandez & Perea (2015), the amount of data available and the size and composition of the donor pool allows us to produce counterfactuals of decent quality which lead to different estimates for the effects of EMU participation. Our results point to a significant benefit of EMU participation for Austria, whereas Fernandez & Perea where not able to find a gain or loss. Though both papers report a loss for Belgium, our analysis shows that Belgium did not experience a substantial loss but benefited from joining the Euro area. The paper by Gomis-Porqueras & Puzzello (2014) reports a loss of EMU participation of 13.2% for the German economy, which is not even close to the effect we find. Moreover,

Table 2.5.2: Confidence intervals by subsampling on GDP predictors

EMU country	Period	Average	Median	10% perc.	90% perc.
Austria	Overall	+7.59%	+8.39%	+5.91%	+8.90%
	1997-2007	+5.64%	+6.23%	+4.25%	+6.55%
	Crisis	+1.70%	+1.74%	+0.50%	+2.55%
Belgium	Overall	+4.10%	+5.46%	-0.83%	+5.98%
	1997-2007	+3.80%	+5.07%	-0.59%	+5.28%
	Crisis	+0.71%	+0.69%	-0.58%	+2.36%
Finland	Overall	+5.36%	+5.64%	+4.32%	+6.02%
	1997-2007	+6.02%	+6.19%	+5.28%	+6.53%
	Crisis	-2.79%	-2.87%	-2.87%	-2.67%
France	Overall	-3.55%	-3.40%	-7.67%	+0.32%
	1997-2007	-2.22%	-2.08%	-6.18%	+1.73%
	Crisis	-0.18%	+0.51%	-3.00%	+2.01%
Germany	Overall	-0.46%	-0.60%	-2.37%	+1.19%
	1997-2007	-1.94%	-2.37%	-3.64%	-0.22%
	Crisis	+2.79%	+2.33%	+1.62%	+4.49%
Greece	Overall	+2.64%	+3.89%	-0.61%	+5.45%
	1997-2007	+7.40%	+8.73%	+3.80%	+10.15%
	Crisis	-16.08%	-16.00%	-16.40%	-16.00%
Ireland	Overall	+26.20%	+25.00%	+25.00%	+27.92%
	1997-2007	+24.90%	+23.70%	+23.70%	+26.84%
	Crisis	-6.81%	-6.80%	-7.17%	-6.71%
Italy	Overall	-3.96%	-3.58%	-5.07%	-3.44%
	1997-2007	+0.10%	+0.43%	-0.96%	+0.56%
	Crisis	-9.47%	-9.62%	-11.69%	-6.85%
Netherlands	Overall	+5.06%	+5.10%	+2.25%	+8.05%
	1997-2007	+4.02%	+3.78%	+2.00%	+6.98%
	Crisis	-0.81%	-0.95%	-0.95%	-0.64%
Portugal	Overall	+2.73%	+3.09%	-3.05%	+7.21%
	1997-2007	+6.06%	+6.42%	+0.78%	+10.15%
	Crisis	-9.60%	-7.12%	-12.09%	-6.73%
Spain	Overall	+6.59%	+7.22%	+3.48%	+8.25%
	1997-2007	+8.55%	+8.77%	+5.75%	+10.26%
	Crisis	-7.86%	-7.60%	-8.35%	-7.44%

our results do not show a significant loss for Portugal, whereas the Netherlands benefits from its EMU participation. In general, the quantitative results in this chapter are very different from Gomis-Porqueras & Puzzello (2014) that report very large losses for Belgium, France, Germany and Italy between 7.7 and 17.3 percent.

2.5.2 Counterfactuals for the fixed effects method

The most common econometric method in the related literature to identify the effect of an event, such as the introduction of the euro, is the fixed effects panel data regression. The advantages of the synthetic control method compared to a fixed effects regression, in general, are discussed in section 2.3.3. In the specific case of the introduction of the euro, we will elaborate a bit more on the advantages. The use of a fixed effects regression prevents the use of time-invariant variables, which could potentially be very important predictors of real GDP per capita. Moreover, the fixed effects regression cannot deal with missing observations for the EMU country over the whole period between 1986 and 2013. Hence, in a fixed effects regression we would lose the political, financial, unemployment and school enrollment variables.

In order to facilitate a comparison between the synthetic control method and a fixed effects regression, we construct a counterfactual real GDP per capita for the 11 individual member countries based on the fixed effects regression. The synthetic control method bases the relationship between real GDP per capita and its predictors on the period between 1986 and 1996[12] and then the counterfactual is based on the weighted combination of its matching control countries. A comparison with the fixed effects regression thus allows for two possibilities. On the one hand, one could regress real GDP per capita on its economic predictors and a dummy variable for the introduction of the EMU. The counterfactual is then based on the relationship between the predictors and real GDP per capita setting the dummy for the EMU equal to zero. We will refer to this as fixed effects method 1. On the other hand, a regression based on the period between 1986 and 1996 is run to establish a relationship between GDP and its predictors which is then extrapolated until 2013.[13] This counterfactual refers to the fixed effects method 2.

These two methods have different similarities with the synthetic control method. Method 1 takes the development of GDP of the control countries in the years

[12]Here we make use of the results that take into account the anticipation effects of the introduction of the euro, hence the introduction is 'assumed' to take place in 1997.

[13]Note that it is not possible to extrapolate until 2014 because of missing observations.

after 1997 into account, which is not the case in method 2. However, the use of the dummy variable in method 1 leads to a constant coefficient for this dummy variable, meaning that the effect of the introduction of the EMU is assumed to be constant over time. This is quite a strong restriction being imposed on the results, which leads to a loss of valuable information as we have seen before that the effect of being in the EMU can vary a lot over time. Method 2 does allow the effect of having the euro to differentiate over time, but since the relationship between GDP and its predictors is based solely on the period until 1996, the counterfactual might miss out on major events affecting both EMU members and control countries.

Figure 2.7: Comparison synthetic control method & fixed effects regression for Greece

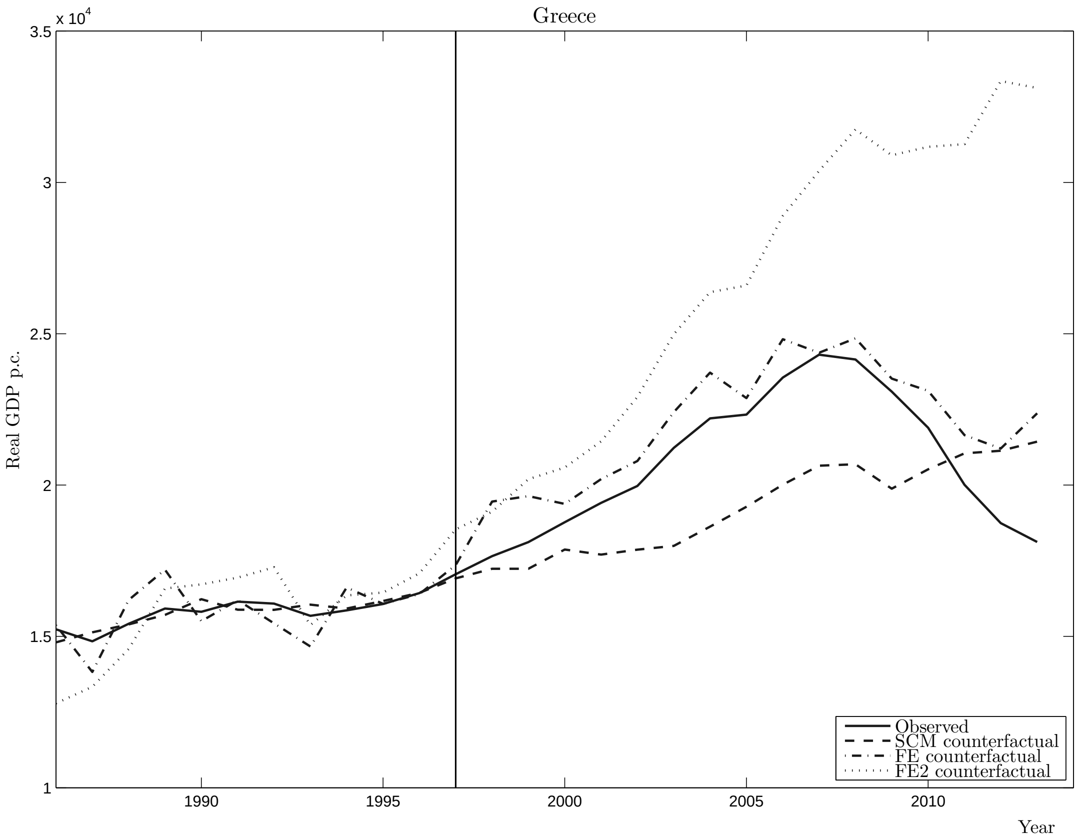


Figure 2.7 shows the comparison of the observed GDP series of Greece with the counterfactuals produced by the synthetic control method and the fixed effects regressions. The graphs for the other 10 EMU members in our study are shown in figure 2.A.1. The graph shows clearly that the counterfactuals based on the different methods can be very far apart. The counterfactual for the syn-

thetic control method is as we have seen in figure 2.3. The fit in the period before 1997 is fairly good, and then there is a large benefit from being in the EMU until the crisis, when this effect reverses. The counterfactual of the fixed effects method 1 does capture the rise and fall of real GDP per capita in the period after 1997, which is an implication of the method used. The regression is based on the whole period between 1986 and 2013, and only a constant effect of participation in the EMU is subtracted, which is the negative coefficient of the dummy variable for being in the EMU. However, the fact that this method captures the rise and fall of GDP well is not a signal that the method is reliable. For reliability of the different methods, we resort to table 2.5.3, which shows the root mean squared prediction error of the three methods in the period before 1997 for the 11 individual countries. A smaller prediction error in the period before the introduction of the euro indicates that the method does well in predicting real GDP per capita in this period, and hence the method is more likely to produce a reliable counterfactual for the period after the introduction of the EMU. The prediction error for most countries in the synthetic control method is much smaller than the RMSPE with fixed effects method 1.

Table 2.5.3: Root mean squared prediction error: SCM vs FE

	Synthetic	Fixed effects regression	
	control method	Method 1	Method 2
Austria	76	918	432
Belgium	118	692	380
Finland	627	1454	793
France	125	904	630
Germany	452	458	535
Greece	261	702	1093
Ireland	1744	1066	414
Italy	114	1225	465
Netherlands	115	1905	658
Portugal	232	1610	962
Spain	133	2099	392
average	363	1185	614

The counterfactual for fixed effects method 2 as shown in figure 2.7 shows that the fit in the period before 1997 is not great and, more importantly, that the counterfactual for Greece is on a very steep path up to a point where it is twice as high as actual GDP per capita in 2013. The unrealistic implication of this would be that the estimated loss of being in the EMU would be around 50% of its GDP per capita. Because the relationship between GDP and its predictors is only based on the period before 1997, there is a chance that in the 20 years after this point in time the world looks differently than this relationship depicts. Hence, this method allows the counterfactual to deviate far away from realistic numbers as it does not take into account events that would change economic growth either in the EMU countries or in the donor countries such as an economic crisis. Based on the prediction error, we see that the synthetic control method outperforms method 2 as well.

Figure 2.A.1 as well as table 2.5.3 show that the synthetic control method produces a better fit of the counterfactual to the observed GDP series before 1997 and a more reliable counterfactual afterwards. This is not only the case for Greece, but holds for all EMU members except for Ireland. Since Ireland has experienced a particular pattern of GDP growth that started off earlier than 1997, both method 1 and method 2 are better able to capture this in the counterfactual. For all other countries, the results provide evidence that the synthetic control method does a better job in constructing reliable counterfactuals for participation in the EMU than fixed effects methods would do.

2.6 Conclusion

In this chapter, the synthetic control method is used to estimate the effect of having the euro and participating in the Economic and Monetary Union for 11 individual countries in the Euro area. This method resulted in synthetic counterfactual GDP paths for the member countries, that reflect real GDP per capita if the country had not joined the EMU. An important aspect to highlight is that the counterfactual reflects the case in which a country decided not to introduce the euro, not the case in which the EMU and the euro would not have existed.

Austria, Belgium, the Netherlands and Spain have benefited from joining the EMU, and this benefit is substantial and significant according to several robustness measures. Italy would have been clearly better off if it had decided not to join the euro, an effect that is reinforced by the economic crisis in 2008. Most other countries have also profited from EMU participation, although this effect is not significant over the whole period. There is evidence of anticipation effects, as in most countries participation in the EMU was anticipated two years before the official introduction in 1999. Moreover, the main drivers of the benefits and losses of having the euro are identified as trade openness, openness to migration, fiscal stance as well as rigidity of labor markets and competitiveness.

It is interesting to observe the effect of EMU participation over time, and to split the period from 1997 until 2014 in the years before the financial crisis and the recession period. Until the crisis started in 2008, all countries except for Italy gained from being in the EMU. However, many members have lost from having the euro during the crisis, implying that they would have been better off if they had not been in a monetary union during the 2008 recession. This negative impact of being in the EMU during the crisis is substantial and even significant for Greece, Italy and Spain.

These results point to an important advantage of the synthetic control method compared to a fixed effects panel data regression, namely that the EMU effect is allowed to vary over time. We have made an explicit comparison between the counterfactuals of these two methods, showing that the counterfactual of the synthetic control method fits the actual series before the intervention much better, for all countries except for Ireland. Hence, the synthetic control method proves to be a useful method in analyzing the effect of such big policy events on economic outcomes.

There are several directions in which future research could extend this work. As more data on the years after introduction of the euro becomes available for the late adopters of the euro, the effect of EMU participation for these countries could be estimated in the near future. Extending the analysis to Cyprus, Estonia, Latvia, Lithuania, Malta, Slovenia and Slovakia might lead to interesting insights in whether these, mostly eastern European, countries benefit or lose from joining the monetary union. The advantages of this method could also be utilized for outcome variables different than GDP, for example for unemployment figures or inflation series. One might be curious to find out whether joining the EMU has been positive or detrimental for the unemployment rate. Finally, repeating the analysis in a couple of years could add value to the interpretation of the results. When data observations on the years after the crisis become available, the benefits or losses of EMU participation could be compared for the pre-crisis and crisis period as well as the post-crisis period.

2.A Appendix

2.A.1 Data collection

For the analysis of the effects of EMU participation on real GDP per capita, data is collected for EMU members and potential control countries from various databases. Here we will first discuss the countries for which data is collected and later we will discuss the variables used as economic predictors for real GDP per capita.

The EMU members considered in the analysis are the early adopters of the euro, which are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain. The late adopters of the euro, i.e. Cyprus, Estonia, Latvia, Lithuania, Malta, Slovenia, Slovakia, are not considered, as well as Luxembourg.

Countries in the large pool of donor countries are: Argentina, Australia, the Bahamas, Bangladesh, Burundi, Canada, Chile, Colombia, Costa Rica, Denmark, Ecuador, El Salvador, Fiji, Guatemala, Guyana, Honduras, Iceland, Indonesia, Israel, Japan, Mexico, Morocco, New Zealand, Nigeria, Norway, Panama, Paraguay, Philippines, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, United States, Venezuela and Zimbabwe. The small pool of countries is limited to Australia, Canada, Chile, Denmark, Iceland, Japan, Mexico, New Zealand, Norway, Sweden, Switzerland, Turkey, United Kingdom and United States.

The synthetic control method makes use of predictors for real GDP per capita to find a counterfactual that matches closely these characteristics. The variable of interest in this study is real GDP per capita, the variables following in the list are considered as predictors of this variable. Below we will explain the variables and disclose the source of the data used.

- **Real GDP per capita**: Gross domestic product divided by midyear population. Data is in constant 2005 U.S. dollars. The source of the data is the World Bank Database, and data is available for 215 countries from 1960 until 2015 (with some missing observations).

- **Growth rate of real GDP**: Gross domestic product in constant 2005 U.S. dollars. The source of the data is the World Bank Database.

- **Total population (in logs)**: Midyear estimates of all residents within a country. The source of the data is the World Bank Database.

- **Birth rate**: Crude birth rate per 1000 people. The source of the data is the World Bank Database.
- **Death rate**: Crude death rate per 1000 people. The source of the data is the World Bank Database.
- **Net exports (as % of GDP)**: The value of exports of goods and services minus the value of imports of goods and services as a percentage of nominal GDP. Both series for exports and imports are available in the World Bank Database.
- **Sum of exports and imports (as % of GDP)**: Sum of exports of goods and services and imports of goods and services as a percentage of GDP. Both series for exports and imports are available in the World Bank Database.
- **Gross fixed capital formation (as % of GDP)**: Gross fixed capital formation includes land improvements; plant, machinery, and equipment purchases; the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings; and net acquisitions of valuables, measured as a percentage of GDP. The source of the data is the World Bank Database.
- **GDP deflator**: Inflation as measured by the annual growth rate of the GDP deflator, measured as the ratio of GDP in current local currency to GDP in constant local currency. The source of the data is the World Bank Database.
- **Labor force participation (as % of working-age population)**: The proportion of the population aged 15 and older that supplies labor for the production of goods and services. The source of the data is the World Bank Database.
- **Female labor force participation (as % of female working-age population)**: Labor force participation of females as a percentage of the female population of the age of 15 and above. The source of the data is the World Bank Database.
- **Life expectancy**: Life expectancy at birth measured as the number of years a newborn would live if the patterns of mortality do not change throughout its life. The source of the data is the World Bank Database.

- **Patent applications (per capita)**: Worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office. These include patents filed by residents as well as nonresidents. The total number of patent applications is divided by midyear population. The source of the data is the World Bank Database.

- **Primary school enrollment (in percentages)**: Ratio of total enrollment in primary education to the population of the age group that officially corresponds to primary education. The source of the data is the World Bank Database.

- **Secondary school enrollment (in percentages)**: Ratio of total enrollment in secondary education to the population of the age group that officially corresponds to secondary education. The source of the data is the World Bank Database.

- **Tertiary school enrollment (in percentages)**: Ratio of total enrollment in tertiary education to the population of the age group that officially corresponds to tertiary education. The source of the data is the World Bank Database.

- **Unemployment (as % of the labor force)**: Share of the labor force that is without work but available for and seeking employment. The source of the data is the World Bank Database.

- **Youth unemployment (as % of youth labor force)**: Share of the labor force aged between 15 and 24 without work but available for and seeking employment. The source of the data is the World Bank Database.

- **Urban population (as % of total population)**: Share of the population living in urban areas as defined by national statistical offices. The source of the data is the World Bank Database.

- **Public debt (as % of GDP)**: Gross government debt measured as percentage of GDP. The source of the data is the Historical Public Debt Database (Abbas et al. (2011)).

- **Net migration (as % of the population)**: Net total migrants measured as percentage of the population, which is the total number of immigrants less the the annual number of emigrants, including both citizens and noncitizens. The source of the data is the World Bank Database.

- **International migrant stock (as % of the population)**: The number of people born in a country other than that in which they live, including refugees, measured as a percentage of the population. The source of the data is the World Bank Database.
- **Liquid liabilities (as % of GDP)**: Liquid liabilities as a percentage of GDP. The source of the data is the Global Financial Development Database constructed by the World Bank.
- **Private credit (as % of GDP)**: Domestic private credit by deposit money banks and other financial sector to the real sector as percentage of local currency GDP. The source of the data is the Global Financial Development Database constructed by the World Bank.
- **Deposit money banks' assets (as % of GDP)**: Assets of deposit money banks as a percentage of GDP. The source of the data is the Global Financial Development Database constructed by the World Bank.
- **Credit to government (as % of GDP)**: Credit to government and state owned enterprises as a percentage of GDP. The source of the data is the Global Financial Development Database constructed by the World Bank.
- **Voice and accountability**: This measure reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. The estimate ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance. The source of the data is the Worldwide Governance Indicators Dataset by Kaufmann et al. (2010).
- **Political stability**: The variable for political stability and absence of violence or terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism. The estimate ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance. The source of the data is the Worldwide Governance Indicators Dataset by Kaufmann et al. (2010).
- **Government effectiveness**: This measure reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. The estimate ranges from approximately -2.5 (weak) to 2.5

(strong) governance performance. The source of the data is the Worldwide Governance Indicators Dataset by Kaufmann et al. (2010).

- **Regulatory quality**: This measure reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. The estimate ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance. The source of the data is the Worldwide Governance Indicators Dataset by Kaufmann et al. (2010).

- **Rule of law**: This measure reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. The estimate ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance. The source of the data is the Worldwide Governance Indicators Dataset by Kaufmann et al. (2010).

- **Control of corruption**: This measure reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. The estimate ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance. The source of the data is the Worldwide Governance Indicators Dataset by Kaufmann et al. (2010).

The set of variables for the synthetic control method using the small pool of countries includes 37 predictors. Firstly, the averages of real GDP per capita and the growth rate of real GDP of three separate subperiods are used in the analysis. Next to these 6 predictors, the set includes: birth rate, death rate, life expectancy, log population, urban population, labor force participation, female labor force participation, public debt, net exports, fixed capital formation, GDP deflator, patents per capita, primary school enrollment, secondary school enrollment, tertiary school enrollment, unemployment, youth unemployment, private credit, credit to government, deposit banks' assets, liquid liabilities, emigration of tertiary educated, international migrant stock, net migration, sum of exports and imports, voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, control of corruption. When the synthetic control method is applied to the year 1997, the variables 'government effectiveness' and 'control of corruption' are left out because of data availability.

The set of predictors is smaller for the large pool, as the data is not available for all of the control countries. Here, the variables public debt, patents per capita, credit to government, government effectiveness and control of corruption are not part of the analysis.

2.A.2 Tables and graphs

Table 2.A.1: Synthetic weights of large donor pool countries

	Austria	Belgium	Finland	France	Germany	Greece
Argentina	0	0	0	0	0.034	0.015
Australia	0	0	0	0	0	0
Bahamas	0	0	0.374	0	0	0
Bangladesh	0	0	0	0	0	0
Burundi	0	0	0	0	0	0
Canada	0	0	0	0	0	0
Chile	0.3	0.124	0	0	0	0
Colombia	0	0	0	0	0	0
Costa Rica	0	0	0	0	0	0
Denmark	0	0	0	0	0.192	0.069
Ecuador	0	0	0	0	0	0
El Salvador	0	0	0	0	0	0
Fiji	0	0.011	0	0	0.008	0.011
Guatemala	0	0	0	0	0	0
Guyana	0	0	0	0	0	0
Honduras	0	0	0	0	0	0
Iceland	0	0	0.087	0	0	0
Indonesia	0	0	0	0	0	0
Israel	0	0.064	0	0	0	0
Japan	0.336	0.311	0	0.299	0.607	0
Mexico	0	0	0	0	0	0
Morocco	0	0.012	0	0.056	0	0.163
New Zealand	0	0	0	0	0	0
Nigeria	0	0	0	0	0.051	0
Norway	0.196	0.069	0	0.023	0	0
Panama	0	0	0	0	0.042	0
Paraguay	0	0	0	0	0	0
Philippines	0	0	0	0	0	0
Sri Lanka	0	0	0	0	0	0
Sweden	0	0	0.109	0	0	0.076
Switzerland	0.168	0.144	0	0.153	0.053	0.15
Thailand	0	0	0	0	0	0
Trinidad and Tobago	0	0	0	0	0.013	0.079
Tunisia	0	0.052	0	0.17	0	0.378
Turkey	0	0	0	0	0	0
United Kingdom	0	0.01	0.43	0	0	0
United States	0	0.203	0	0.299	0	0.059
Venezuela	0	0	0	0	0	0
Zimbabwe	0	0	0	0	0	0

	Ireland	Italy	Netherlands	Portugal	Spain
Argentina	0	0	0	0	0
Australia	0	0	0.303	0	0
Bahamas	0	0	0	0	0
Bangladesh	0	0	0	0	0
Burundi	0	0	0	0	0
Canada	0	0	0	0	0
Chile	0	0	0	0.629	0.292
Colombia	0	0	0	0	0
Costa Rica	0	0.024	0	0	0
Denmark	0	0.11	0	0	0
Ecuador	0	0	0	0	0
El Salvador	0	0	0	0	0
Fiji	0	0.058	0.008	0	0
Guatemala	0	0	0	0	0
Guyana	0	0	0	0	0
Honduras	0	0	0	0	0
Iceland	0	0	0	0	0
Indonesia	0	0	0	0	0
Israel	0.681	0	0	0	0
Japan	0	0.333	0.345	0.314	0.28
Mexico	0	0	0	0	0
Morocco	0	0.021	0.075	0	0
New Zealand	0	0	0	0	0
Nigeria	0	0.025	0	0	0
Norway	0.319	0	0.247	0	0
Panama	0	0	0	0	0
Paraguay	0	0	0	0	0
Philippines	0	0	0	0	0
Sri Lanka	0	0	0	0	0
Sweden	0	0	0	0	0
Switzerland	0	0.083	0.021	0	0
Thailand	0	0	0	0	0
Trinidad and Tobago	0	0.1	0	0	0
Tunisia	0	0	0	0	0.145
Turkey	0	0	0	0	0
United Kingdom	0	0.246	0.001	0.057	0.145
United States	0	0	0	0	0.138
Venezuela	0	0	0	0	0
Zimbabwe	0	0	0	0	0

Table 2.A.2: Synthetic weights of small donor pool countries: intervention year 1997

	Austria	Belgium	Finland	France	Germany	Greece
Australia	0	0.048	0	0.002	0	0
Canada	0	0.028	0	0.118	0	0
Chile	0.015	0.208	0	0	0	0
Denmark	0.327	0.185	0	0	0.067	0.005
Iceland	0	0	0	0	0	0
Japan	0.517	0.405	0	0.389	0.355	0
Mexico	0.049	0	0	0.192	0.218	0
New Zealand	0	0	0	0	0	0.064
Norway	0	0	0	0	0.165	0
Sweden	0	0	0.828	0	0	0
Switzerland	0	0.125	0	0.103	0.118	0.223
Turkey	0.092	0	0.172	0	0.077	0.708
United Kingdom	0	0	0	0	0	0
United States	0	0	0	0.196	0	0

	Ireland	Italy	Netherlands	Portugal	Spain
Australia	0	0	0	0	0
Canada	0	0.245	0.008	0	0
Chile	0.547	0.189	0.094	0.398	0.222
Denmark	0	0.087	0.366	0	0
Iceland	0	0	0	0	0
Japan	0	0.407	0.52	0.36	0.369
Mexico	0	0	0	0	0
New Zealand	0	0	0.013	0	0
Norway	0.453	0	0	0	0
Sweden	0	0	0	0	0
Switzerland	0	0.06	0	0	0.06
Turkey	0	0.011	0	0.241	0.266
United Kingdom	0	0	0	0	0.082
United States	0	0	0	0	0

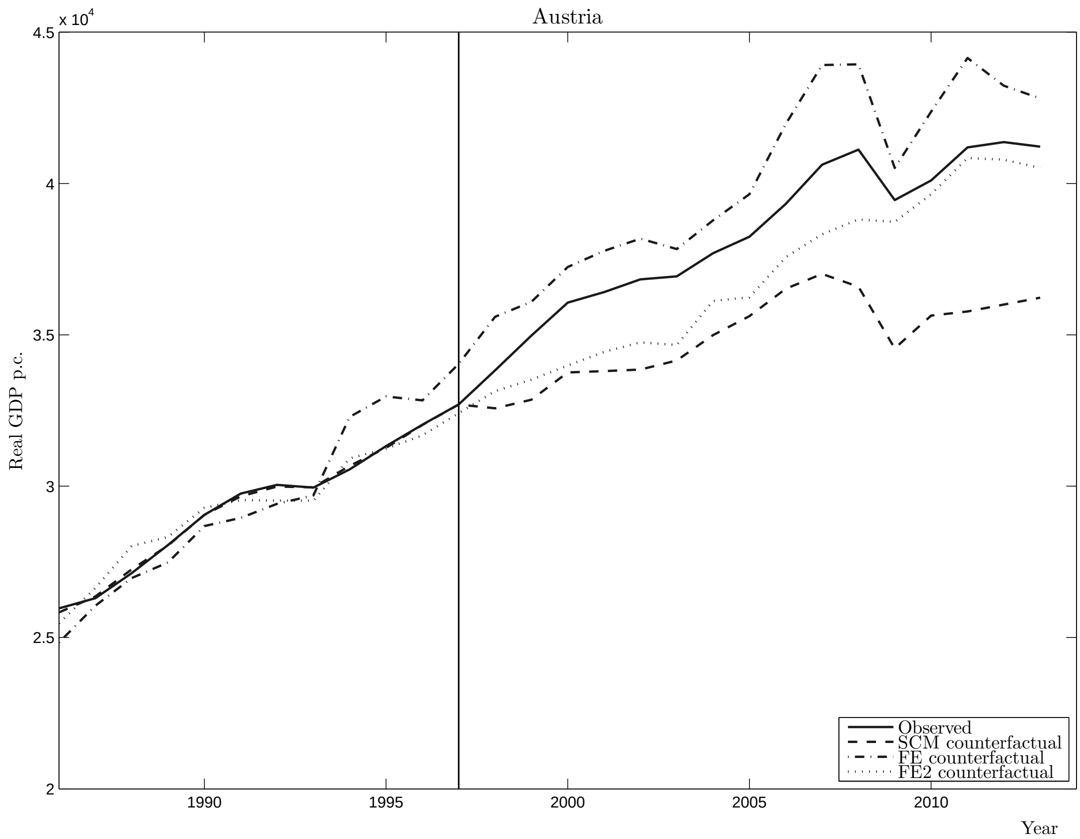
Table 2.A.3: In-sample forecasts: average forecast error over 1993-1996

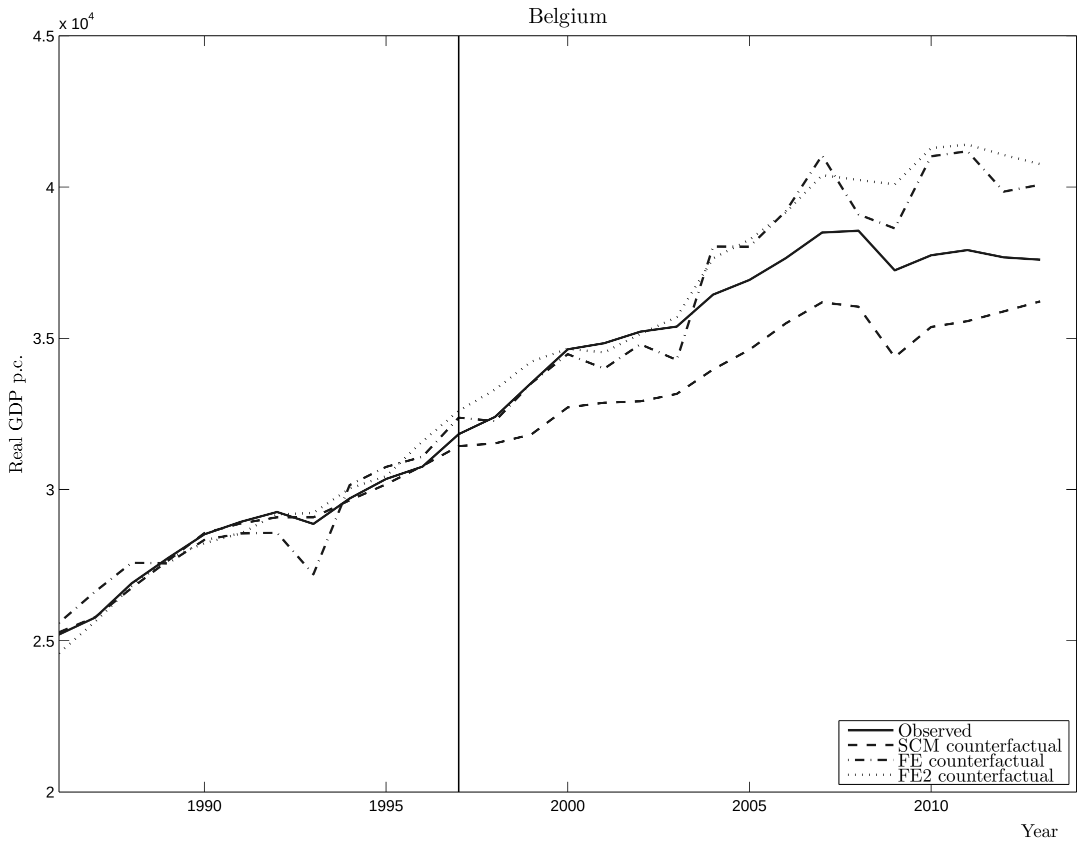
EMU country	average error
Austria	+1.50%
Belgium	-0.70%
Finland	-4.54%
France	-2.16%
Germany	-1.21%
Greece	-5.45%
Ireland	+16.52%
Italy	-2.75%
Netherlands	+0.60%
Portugal	-2.24%
Spain	-2.11%

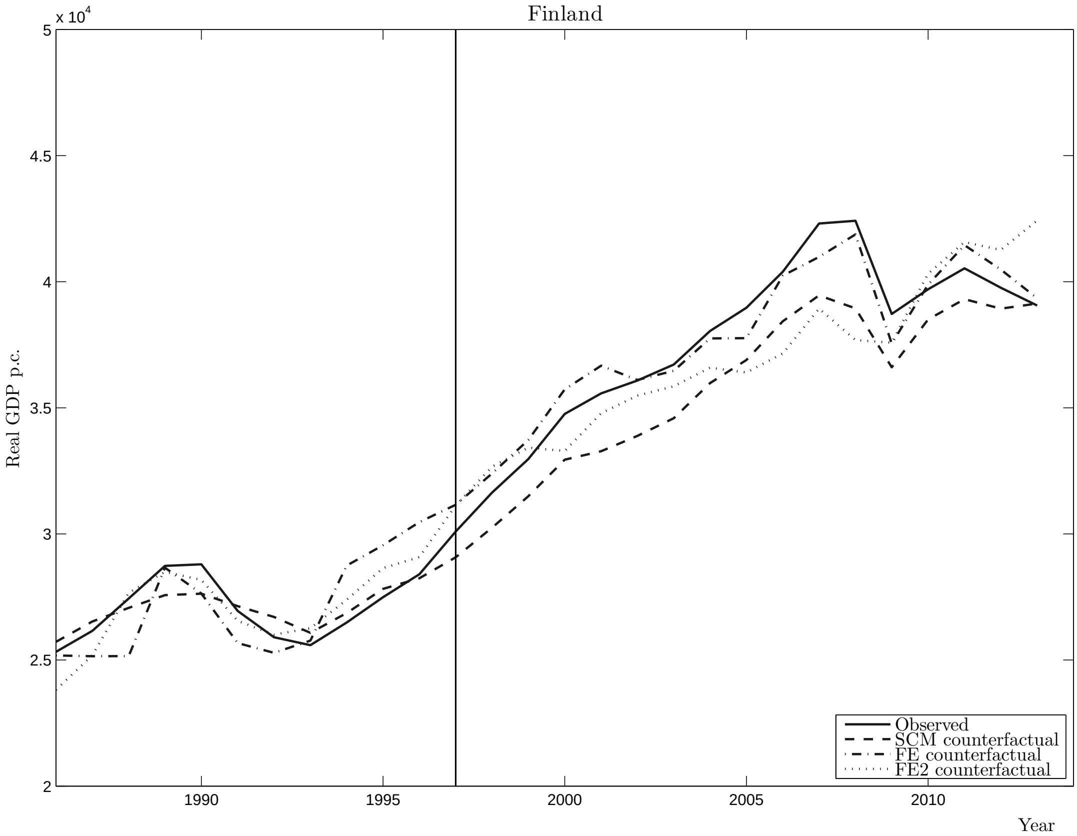
Table 2.A.4: Estimated EMU effect (in %) for non-EU donor pool

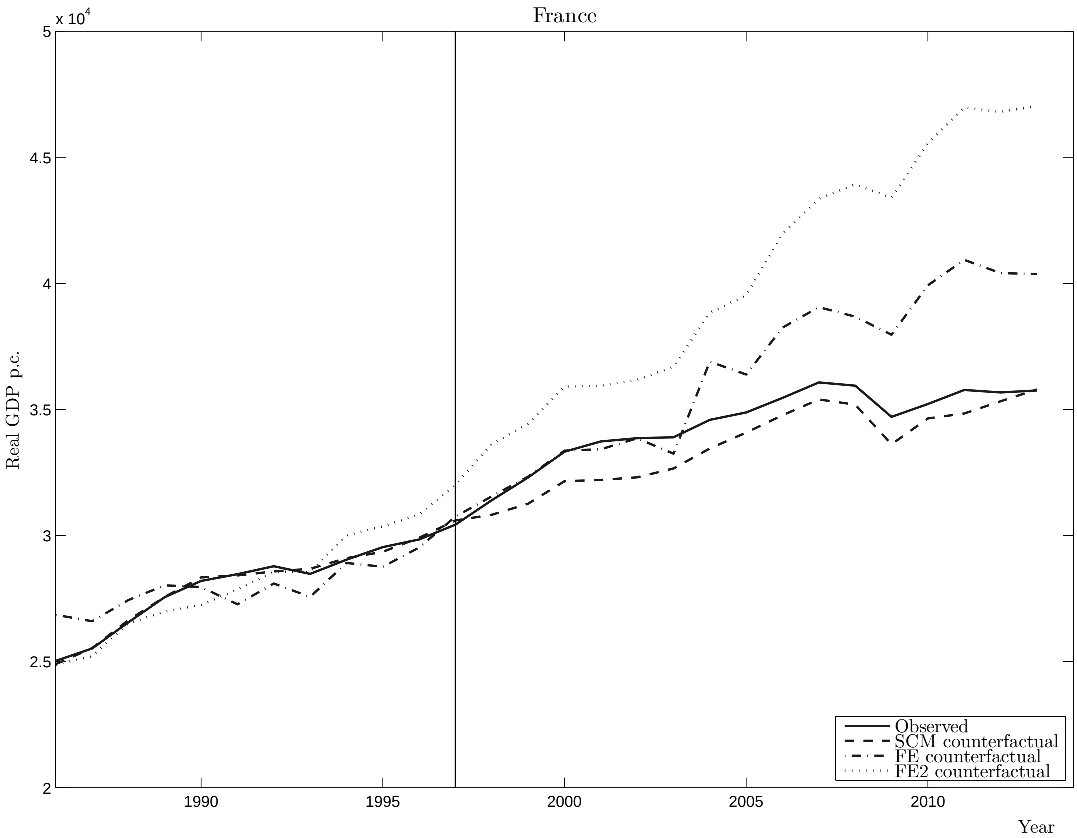
EMU country	All years	1997-2007	Crisis
Austria	+5.3%	+6.2%	-0.3%
Belgium	+6.2%	+6.0%	-1.9%
Finland	+8.9%	+9.4%	-0.8%
France	+1.0%	+2.2%	-2.0%
Germany	+1.1%	-0.0%	+2.8%
Greece	+5.8%	+10.4%	-11.0%
Ireland	+29.0%	+29.4%	-6.8%
Italy	-4.2%	+0.1%	-10.9%
Netherlands	+3.0%	+2.7%	-0.2%
Portugal	+4.8%	+8.9%	-7.2%
Spain	+8.9%	+10.9%	-7.0%

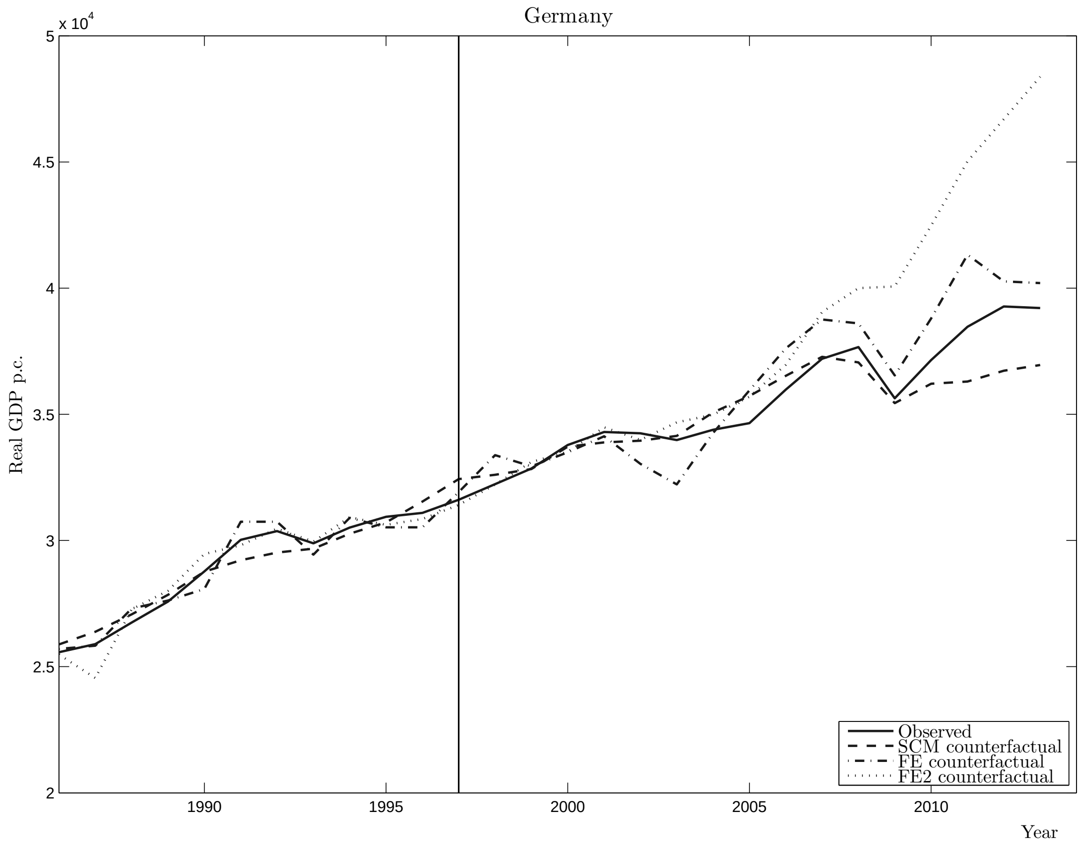
Figure 2.A.1: Comparison synthetic control method & fixed effects regression

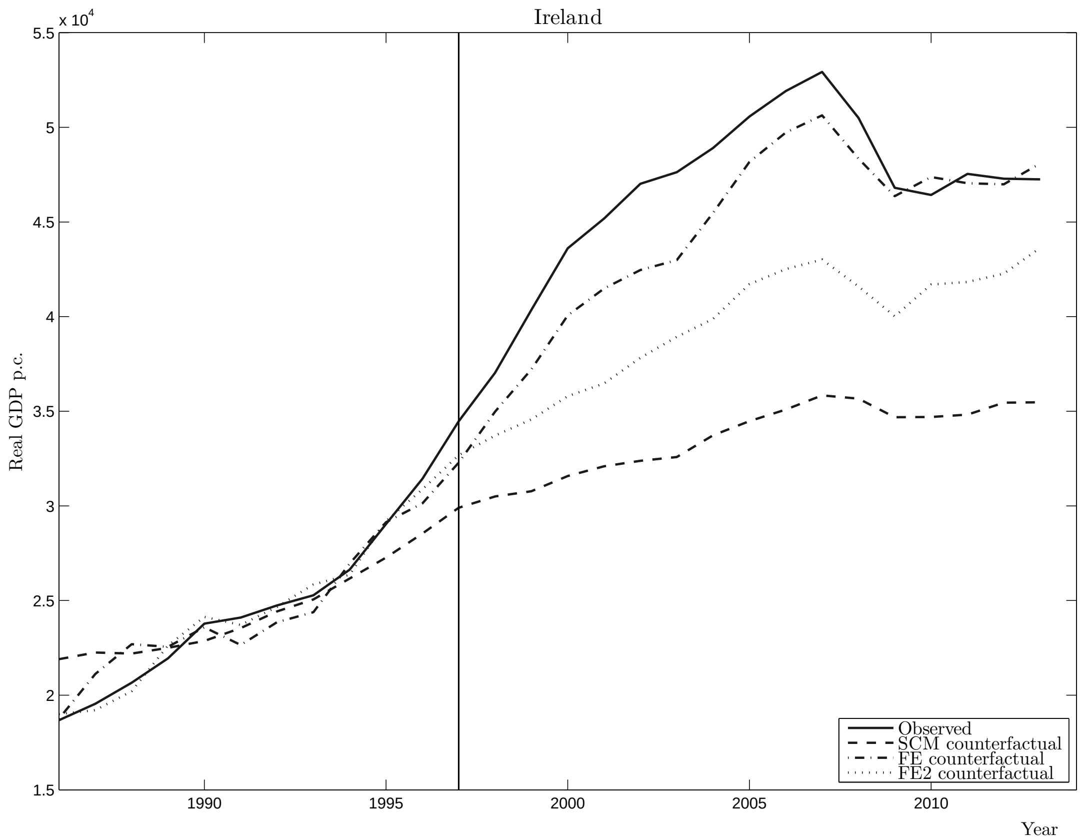


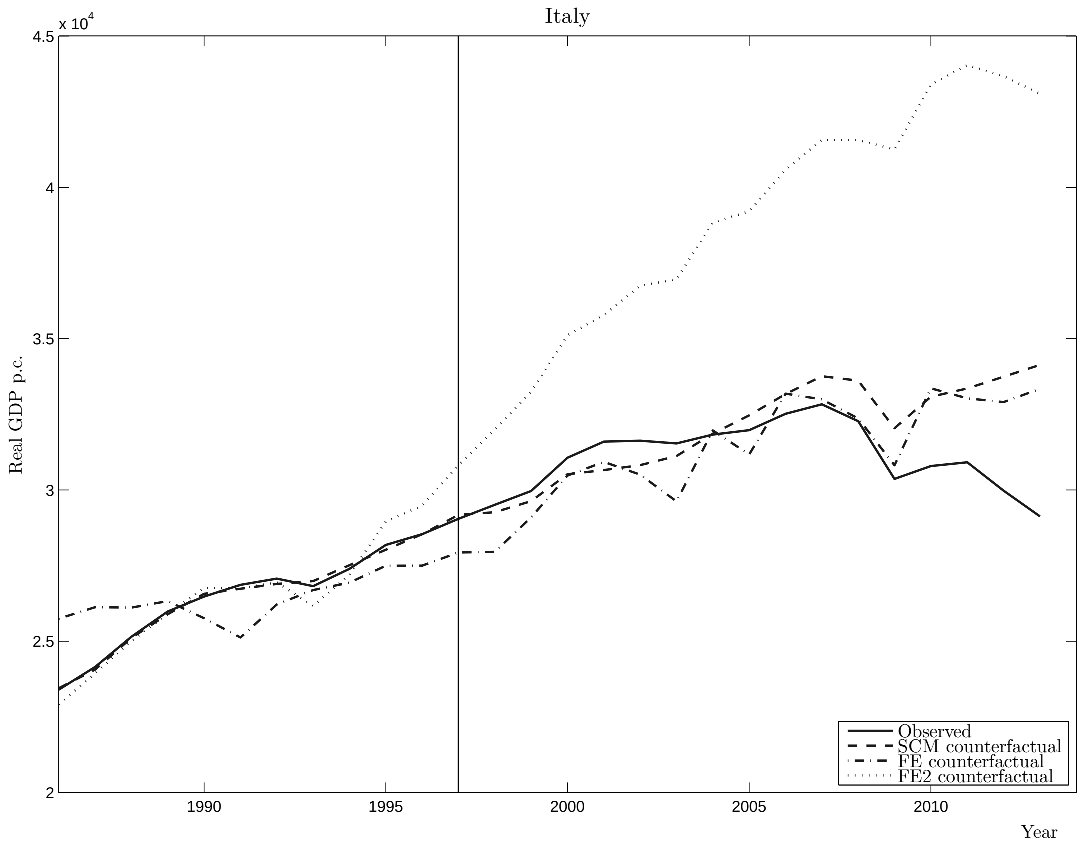


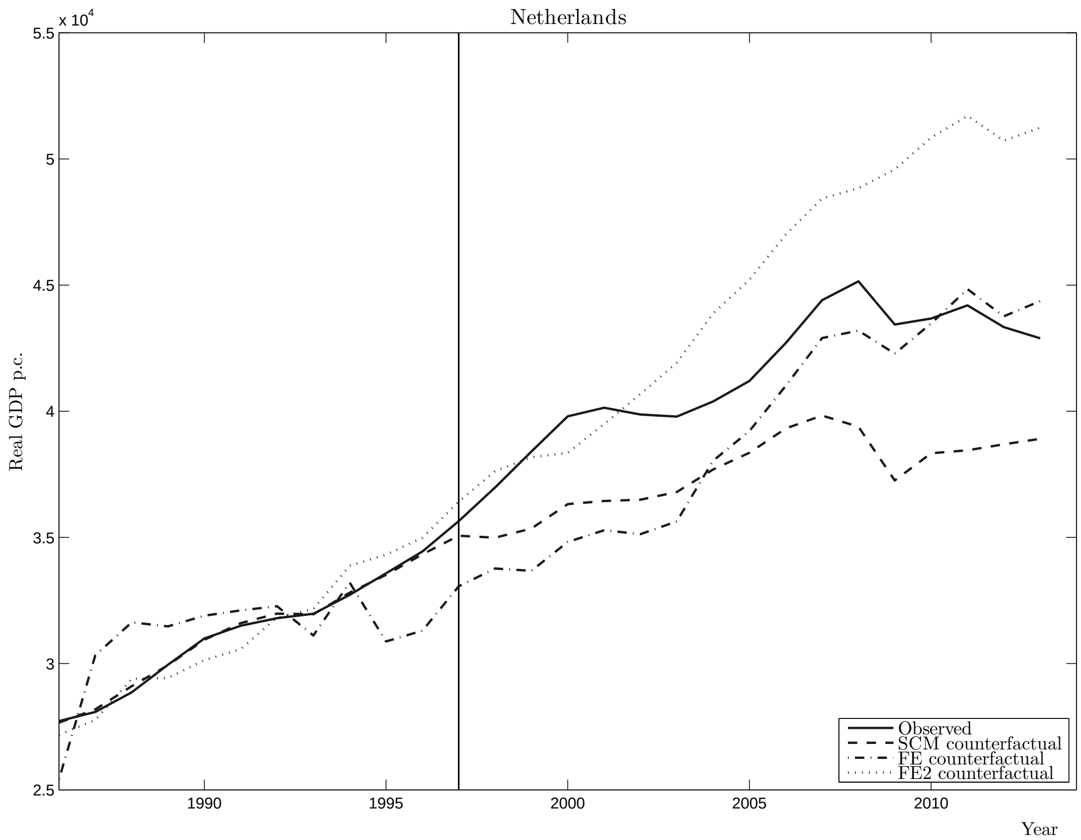

Finland
x 10^4
5
4.5
4
3.5
3
2.5
2
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual

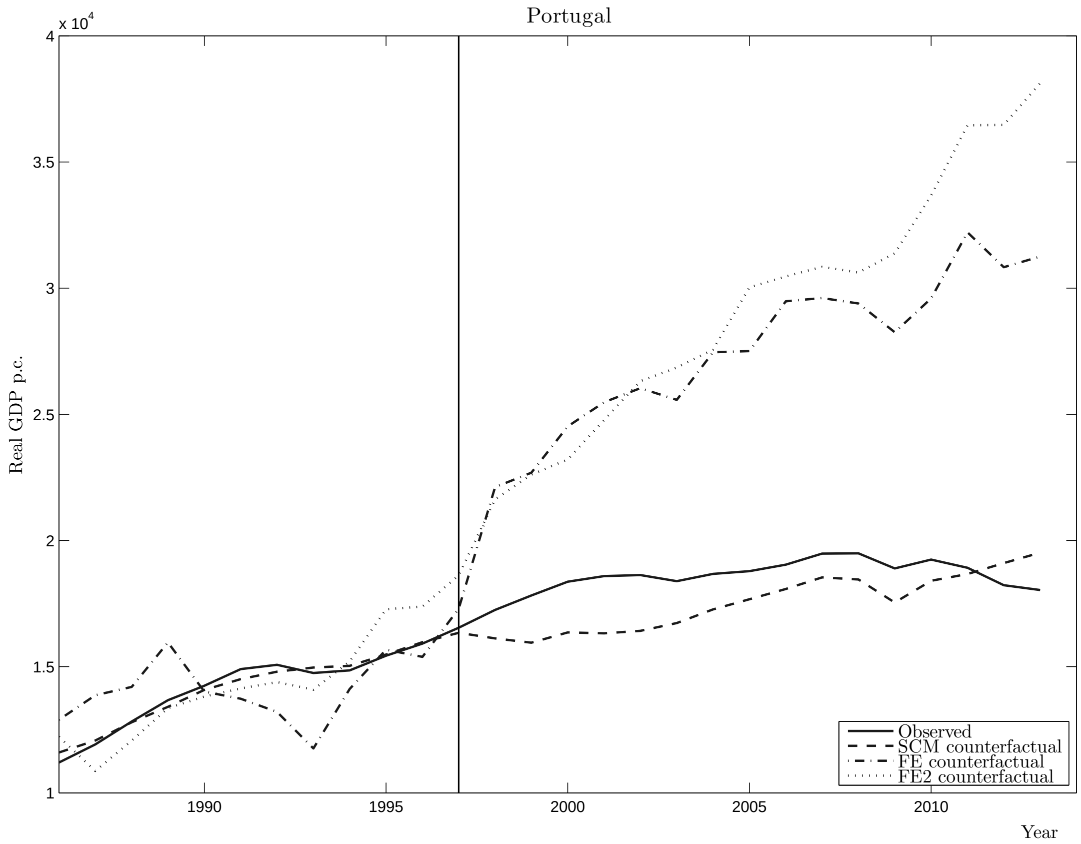

France
x 10^4
5
4.5
4
3.5
3
2.5
2
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual

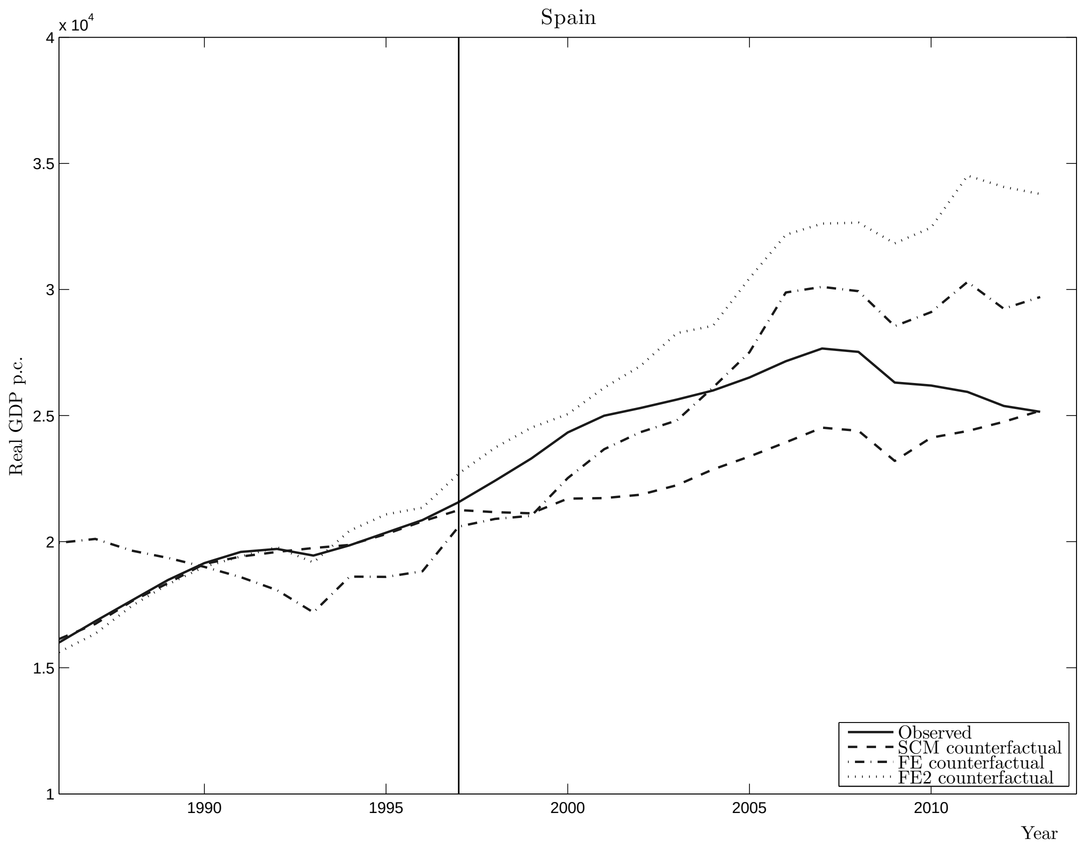

Germany
x 10^4
5
4.5
4
3.5
3
2.5
2
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual


Ireland
x 10^4
5.5
5
4.5
4
3.5
3
2.5
2
1.5
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual


Italy
x 10^4
4.5
4
3.5
3
2.5
2
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual


Netherlands
x 10^4
5.5
5
4.5
4
3.5
3
2.5
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual


Portugal
x 10^4
4
3.5
3
2.5
2
1.5
1
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual


Spain
x 10^4
4
3.5
3
2.5
2
1.5
1
Real GDP p.c.
1990
1995
2000
2005
2010
Year
Observed
SCM counterfactual
FE counterfactual
FE2 counterfactual

2.A.3 Difference-in-differences and placebo results

Table 2.A.5: Difference-in-differences estimates of EMU effect

	Complete period		Period before crisis	
	DID estimate	Standard error	DID estimate	Standard error
Austria	3330.127***	1150.356	2338.432*	1194.934
Belgium	1954.835*	1013.445	1845.980*	1096.013
Finland	1631.393	1525.125	1942.336	1556.190
France	750.784	897.846	931.467	973.455
Germany	423.768	1122.210	-313.874	1070.357
Greece	1193.108	890.011	2121.508**	850.686
Ireland	12973.10***	1948.834	12869.04***	2346.762
Italy	-1193.243	833.5524	73.721	899.878
Netherlands	3844.590***	1186.272	3002.626**	1282.831
Portugal	862.918	649.293	1426.180*	721.474
Spain	2163.361**	829.776	2619.676***	933.509

The results in table 2.A.5 confirm that the benefits from EMU participation are significantly different from zero for Austria, Belgium, Ireland, the Netherlands and Spain. If we look at the sub-period from the introduction of the EMU until the start of the crisis in 2008, we find that there are more countries for which the positive EMU effect is significant. Greece and Portugal experience a large benefit from EMU participation before the crisis, which decreases during the crisis leading to a lower difference-in-differences estimate for the whole period.

Table 2.A.6: DID estimates of crisis effect on EMU countries

	DID estimate	Standard error
Austria	859.715	1274.265
Belgium	592.681	1164.780
Finland	-1081.831	2006.849
France	277.462	978.407
Germany	1827.362*	984.683
Greece	-2926.24**	1419.851
Ireland	-3182.42	2999.109
Italy	-2271.86***	824.9841
Netherlands	-415.027	1332.512
Portugal	-714.526	524.664
Spain	-1940.723*	1075.558

Table 2.A.6 reports the DID estimates of the gains and losses that EMU members experience relative to countries outside the EMU during the crisis. Many

countries have been suffering during the crisis as a result of their participation in the EMU, and for Greece, Italy and Spain this loss has actually been significant. Germany is one of the few countries that would have been worse off if it would have not been in the EMU during the crisis, and it is the only country for which this positive effect is significant.

Figure 2.A.2: EMU effect vs placebo effects

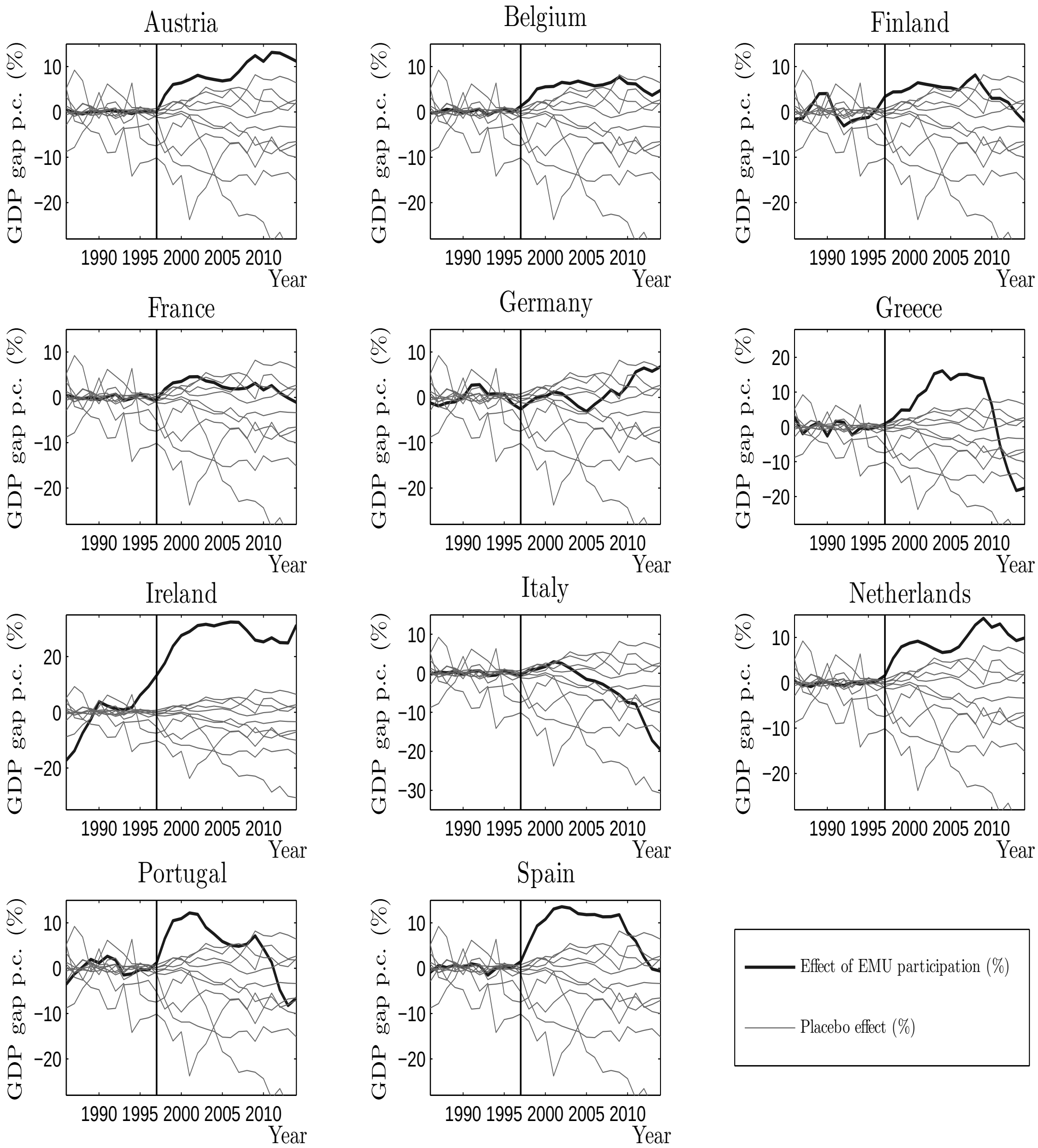


Figure 2.A.2 displays the estimated EMU effect for the EMU members and the estimated placebo effect for 10 countries in the donor pool. For some of the EMU members, this figure strengthens the confidence in the estimated effect of EMU participation. For Austria and the Netherlands, we see that the EMU effect is clearly above all the placebo effects, which are subject to larger deviations before 1997 as well. The estimated EMU effect for Ireland is clearly significant, however, there are doubts about whether the effect is truly due to EMU participation, as we have noted before. It is harder to acknowledge a significant effect for Belgium and Finland, whereas there is no significant effect for France, Germany and Italy, because the estimated EMU effect is similar in size as the placebo effects. For some countries, we only observe a significant effect in the period just after the introduction of the euro, and the significance decreases as the crisis starts to affect these economies. This is the case for Greece, Portugal and Spain.

CHAPTER 3

The Effectiveness of a Fiscal Transfer Mechanism in a Monetary Union:

A DSGE Model for the Euro Area

3.1 Introduction

The recent lively discussion about the need to complement the Economic and Monetary Union (EMU) in Europe with common fiscal institutions, is one that has revived after the great economic turbulence in Greece and other European countries related to the sovereign debt crisis. Fiscal transfers appeared necessary to help some of the countries that were in trouble by means of the European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM). The events of the past few years have led many politicians and economists to weigh the pros and cons of deeper fiscal integration and even a common fiscal authority.

Existing federations have a system of federal fiscal transfers, that acts as an automatic insurance against asymmetric macroeconomic shocks in the federation. The EMU does not have an explicit mechanism either to absorb asymmetric shocks or to insure against the asymmetric effects of symmetric shocks within the currency union. An automatic fiscal transfer mechanism that stabilizes asymmetric shocks to member countries of the EMU might be a first step towards federal fiscal integration.

This chapter is the result of joint work with Lex Meijdam.

Two important policy issues concerning the design of a fiscal transfer scheme arise with regard to the implementability of this scheme in the Euro area. First, the system should be susceptible to moral hazard as little as possible. One would not want governments to behave strategically by increasing their chances of receiving a transfer at the cost of other countries. The member countries of the EMU will not approve a system of fiscal transfers if the rules may induce more risk-taking behavior of other members, for example by continuously increasing their burden of debt or by underreporting tax revenues and other fiscal variables in order to receive a (higher) transfer. Our design of the transfer rule will take this into account, by conditioning the transfer on GDP rather than fiscal policy variables, and by conditioning on the change in this measure rather than the level of GDP. Secondly, there will be political resistance in member countries to allow for a fiscal transfer scheme if policymakers and the public believe that their country is likely to be a net contributor to this system. As our simulations for the future will show, the probabilities of becoming a net contributor or net recipient will ex ante be approximately equal for each member, regardless of whether this country is a northern or southern country of Europe.

There is a responsibility for the science of economics to analyze the effects of implementing such a transfer mechanism in the Euro area, as these results will affect the willingness of Euro area countries to strive for fiscal integration. The purpose of this chapter is to carry part of this responsibility and to contribute to the existing literature on this topic, in the first place, by incorporating an automatic fiscal transfer mechanism into a dynamic stochastic general equilibrium (DSGE) model. This system makes sure that resources are automatically transferred from one region to the other when this economy performs worse than the other, without the interference of governments or other decision-making bodies. Our model contains several standard features of DSGE models, such as nominal rigidities, but there are also non-standard elements in the model, such as a common monetary authority together with a very rich regional fiscal sector. Besides, the transfer mechanism that is built into the model is less prone to moral hazard issues than other transfer schemes proposed in the literature, such as tax revenue sharing or GDP-contingent bonds. Secondly, the model presented in this chapter is estimated for the northern and southern region of Europe to analyze the effectiveness of a transfer scheme within the Euro area. So far, models that include a transfer scheme were only symmetrically calibrated, whereas our method is the first, to the best of our knowledge, to take the heterogeneity between European regions into account. Specifically, we allow for the structural and the fiscal policy parameters of the model to have different estimates for the North and the South.

The Bayesian estimation of the model allows us to apply federal fiscal transfers to the specific case of the EMU, rather than the general case of two countries or regions within a monetary union. In the third place, we focus on two main questions to give a comprehensive overview of the implications of a fiscal transfer scheme in the Euro area. On the one hand, ex post, what would the transfer mechanism have meant for the regions of the Euro area in the recent crisis? On the other hand, would the transfer mechanism be ex ante beneficial for both the northern and southern region of the EMU? Fourthly, the model allows us to quantify the exact size of the net transfers, as well as the effects of these transfer on the main macroeconomic variables, welfare and risk sharing.

We will show that the results from the Bayesian estimation differ quite substantially between countries, which underlines the need to take the heterogeneity among countries in a monetary union into account. Simulations of the estimated model for the main macroeconomic variables are quite close to the corresponding observed time series. We find that an automatic fiscal transfer mechanism can help stabilizing the economy in periods of recession, as a transfer mechanism introduced in 2007 would have led to higher GDP and consumption for the southern block of countries. The country paying the transfer, in this case the North, has to give in some of its GDP and consumption, leading to a welfare loss for the North that is larger than the gain for the South (in terms of steady state consumption). The timing of the introduction of the transfer scheme is fairly important, since the transfer depends on the growth of GDP from that moment onwards. If the mechanism would have been introduced at the start of the EMU, the transfer would have been coming from the South in the direction of the North, implying that this type of transfer scheme is by no means one-way traffic. Furthermore, we will show that the transfer scheme is ex ante beneficial for both the North and the South, which will increase the willingness to implement such a scheme in the future.

The rest of the chapter is organized as follows. Section 2 describes the relevant literature related to this topic and section 3 gives an overview of the two-region model of the monetary union. Section 4 explains the data and the priors needed for the Bayesian estimation and gives the estimation results for the parameters of the model. Section 5 shows the main results, including simulations and welfare analysis for the introduction of a transfer mechanism in 2007, and results on the introduction of a transfer mechanism at the start of the EMU as well as the implications for the future of introducing a transfer scheme. Section 6 explains how the various channels for interregional risk sharing work within the EMU and shows the effect of a transfer mechanism on these. Section 7 concludes.

3.2 Related Literature

The necessity of a risk sharing mechanism in the European monetary union has been a vivid debate in the last years. President of the European Council Herman van Rompuy explained his views on how the stability in the EMU can be guaranteed in the long run in a report (Van Rompuy (2012)). He pleads, amongst others, for an integrated budgetary framework with common debt issuance or other forms of fiscal solidarity. The idea to introduce a scheme of federal fiscal payments in the EMU is far from new and was already stated in the MacDougall report (MacDougall and Commission of the European Communities (1977)). The report recommended a system of transfers between member states of the EMU to stabilize the effects of asymmetric shocks. Later in 1989, Jacques Delors pointed out that the coordination of national fiscal policies in terms of a federal adjustment mechanism would be needed for the Economic and Monetary Union to survive (Delors (1989)).

The basic argument for a system of federal fiscal transfers comes from the Optimum Currency Area (OCA) literature, that started with the pioneering articles by Mundell (1961), McKinnon (1963) and Kenen (1969). Next to labor mobility, capital mobility, price and wage flexibility and similarity in business cycles, a successful currency area should also have a risk sharing system. In a monetary union there is no possibility to use monetary policy for national policy purposes, and since there is also no exchange rate flexibility, fiscal transfers are needed if these other adjustment mechanisms fail to stabilize asymmetric shocks. This chapter relates to the OCA literature as it focuses on the necessity of having a risk sharing mechanism in the form of a fiscal transfer mechanism in the EMU.

There are broadly two strands in the literature for macroeconomic aspects of federal fiscal arrangements in monetary unions. The empirical literature for fiscal federalism is plentiful. Many papers have tried to estimate the effect of a central fiscal authority or federal arrangement in stabilizing idiosyncratic shocks to regions of an existing monetary union or a federalist country. The pioneering contribution is by Sala-i Martin and Sachs (1992) who estimate that around 40% of the initial effect of a shock to income is absorbed by the federal taxes and transfers in the US. The most influential study is by Asdrubali et al. (1996) that identifies the importance of the channels of risk sharing across US states. The results show that federal fiscal transfers smooth around 13% of a shock to GDP. Similar studies have been performed for Canada, Germany, the UK and Italy, amongst others by Melitz and Zumer (1999), Antia et al. (1999) and Hepp and von Hagen (2013). In the past it has been shown by Sorensen and Yosha (1998), and also recently by Furceri and Zdzienicka (2013), that federal risk sharing mechanisms are less effective in the Euro area than in other federalist countries such as the US and Germany.

Considering the extensive literature on the empirical aspects of federal fiscal policy in monetary unions, one might view it as surprising that the theoretical side of this literature is relatively unexplored, especially for the EMU. There are few papers that provide a sound theoretical analysis for their policy recommendation to coordinate some aspects of fiscal policy on a union-wide level. An example of such a paper is Bargain et al. (2013), that incorporates the element of an EU-wide tax and transfer system into EUROMOD, which is a European tax-benefit calculator used by the Institute for Social and Economic Research (ISER). Their result is that the majority of the countries in the Euro area would profit from it. They also analyze the effects of a fiscal equalization mechanism in this calculator and find that this mechanism has clear redistributing effects between countries, but the effects on macroeconomic stability are ambiguous.

Recently, Farhi and Werning (2012) gave a boost to the theoretical literature that is using DSGE models to examine the effectiveness of federal fiscal transfers. They show analytically that there is a role for the government providing insurance, contingent on the shock that a country experiences, as private insurance and risk-sharing across countries is too low. Evers (2012) provides a quantitative analysis of federal transfer rules that could target regional differences in nominal GDP, consumption, labor income or fiscal deficits. Evers (2015) is so far the most extensive study in this field. The author shows that a fiscal equalization system, in which nominal tax revenues are shared, acts destabilizing due to the responses of consumption, and leads to welfare losses compared to decentralized fiscal authorities. A common fiscal authority with a unitary tax system does stabilize output and consumption. In contrast to Evers (2015), this chapter focuses on a rule for the transfers between countries that depend on the differences in economic growth between countries. The model that Evers (2015) uses, incorporates symmetric tax rates in both countries to facilitate nominal tax revenue sharing, but although this type of federal arrangement could be observed in existing federations, it is hard to picture this type of stabilization mechanism within the EMU due to several moral hazard issues.

A deficiency of the existing literature is that the theoretical models are calibrated for symmetric countries. Since EMU countries are very different in many respects, it is important to analyze asymmetric countries in order to be able to deduct any policy implications from the research in this field. This chapter uses a DSGE model for asymmetric regions that is based on Pytlarczyk (2005) and Kolasa (2009). The two-country DSGE model in this chapter also incorporates several established features such as tradables and non-tradables, capital adjustment costs and Calvo price and wage setting. In this sense, this chapter builds on a larger history of DSGE models for currency unions, or specifically for the Euro area, by Smets and Wouters (2003), Galí and Monacelli (2008), Jondeau and Sahuc (2008). These nominal frictions are important to include in our analysis of a transfer scheme in a monetary union, as Farhi and Werning (2012) show that in a monetary union, nominal rigidities lead to significant uninsurable effects of country-specific shocks. This leaves room for government intervention, since the asymmetric shocks cannot be stabilized in a currency union due to the constrained monetary policy from a single country's perspective. Besides, the nominal frictions are also helping to fit the model to the data. Instead of calibrating the model with asymmetric countries, we use Bayesian methods to estimate the model for the North and the South of Europe. For calibrated parameters and priors, we rely on parameters and priors chosen in the existing literature, as in Smets and Wouters (2003), Pytlarczyk (2005), Jondeau and Sahuc (2008), Kolasa (2009) and Hollmayr (2012), as well as on OECD data.

The contribution of this chapter to the existing literature is fourfold. First, we have extended the theoretical literature on monetary unions by implementing a rich fiscal sector with an automatic fiscal transfer mechanism into a DSGE model for a currency area. The transfer rule that we impose is least susceptible to moral hazard as possible since it is conditioned on the growth in GDP, and not on the level of fiscal policy variables that are easier to influence. Secondly, this chapter adds to the existing empirical literature on federal fiscal policy by using an estimated DSGE model for the Euro area, hence allowing for heterogeneity between regions. Therefore, we can analyze the effectiveness of a fiscal transfer mechanism specifically for the case of the EMU. Thirdly, we provide a comprehensive overview of the implications of a fiscal transfer scheme in the EMU by our dual analysis. On the one hand, we analyze how the transfer mechanism would have changed the situation in the EMU, had it been introduced before the recent crisis. On the other hand, we study whether the transfer mechanism would ex ante be beneficial for both regions of the Euro area. Finally, the setup of the transfer scheme within the model allows us to quantify the size of the transfers between the northern and southern EMU region, as well as the exact effect on the main macroeconomic variables, welfare and risk sharing in the regions. Taking into account the heterogeneity of the countries within the EMU and quantifying precisely the impact on the real economy is important in order to genuinely assess the implications of a transfer mechanism for the EMU.

3.3 Model of a Two-Region Monetary Union

The theoretical model that is described in this section builds on a wide range of DSGE models for monetary unions. We will present a model that contains several features that are established in the papers by Obstfeld and Rogoff (1995), Christiano et al. (2005), Smets and Wouters (2003) and Galí and Monacelli (2008), amongst others. The paper by Jondeau and Sahuc (2008) also uses this type of DSGE models, but focuses on the heterogeneity of countries within the currency union. More closely related to the model in this chapter is the model by Pytlarczyk (2005) and Kolasa (2009). Both use the same model that has a very detailed structure.

In the model, there are two regions[1], Home and Foreign, and they are assumed to be member of a monetary union. Hence, the regions use the same currency and there is a common central bank that conducts monetary policy. As links between regions within the monetary union are stronger than with the rest of the world, trade with the rest of the world is neglected.[2] Every region gives shelter to households, firms and a government. Within a region, households are identical, but preferences with respect to consumption and labor are allowed to be heterogeneous across regions. Households provide labor to firms, rent capital to domestic firms and can consume both domestically produced goods and foreign goods. Firms in every region produce a continuum of differentiated tradable goods for the international market, as well as nontradable goods. Prices and wages are set according to a Calvo mechanism combined with partial indexation to past inflation to make the model more realistic and fit better to the European data. It is assumed that there is no migration between regions and that the production factor labor is immobile. There is free international trade, so that transaction costs to trade do not exist. A central monetary authority of the union sets its policy according to a feedback rule that takes into account the union-wide inflation and output gap. Fiscal authorities in every region collect taxes on consumption, capital income and labor income to finance their expenditures. The automatic transfer mechanism is introduced by setting a rule that automatically directs resources from one region's government budget to the budget of the other when that region faces a larger negative (or smaller positive) GDP gap compared to the other region. In this way, the transfer rule is not very prone to moral hazard

[1]In the next section, we will estimate the model for the northern and southern region of the Euro area, so with regard to terminology we will use region instead of country.

[2]According to Masson and Taylor (1993), the European Union as a whole is a relatively closed economy, although all countries within the European Union are very open. Therefore, the countries are modeled as open economies within the monetary union, but at the same time, their paper justifies neglecting the rest of the world.

issues, as we will explain in this section. Furthermore, by conditioning on the change in GDP this setup avoids a continuous redistribution between regions and the political resistance that would come with this.

In what follows we will describe the model for the home economy only, since the general setup for the foreign economy is similar. Variables referring to the home region are indexed by i and foreign variables are indexed by i^*. Parameters are allowed to be heterogeneous across regions, and for that reason, foreign parameters are marked with an asterisk. The size of the home region H in terms of population is $[0, n]$ and the size of the foreign region is $[n, 1]$, so that the size of the union is normalized to 1.

3.3.1 Households

Consumption

Both regions are populated by infinitely-lived households. Households may be hit by idiosyncratic shocks, but households have access to complete markets for state-contingent bonds and therefore all households in a given region behave in the same manner and we will consider the optimization problem of the representative household. The preferences of the representative household j are reflected by the following lifetime utility function:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t^i(j), L_t^i(j)) \tag{3.1}$$

The household derives negative utility from providing labor, but private consumption affects utility positively. The instantaneous utility function is assumed to be of the standard CES form:

$$U_t^i(C_t^i(j), L_t^i(j)) = \varepsilon_{C,t}^i \frac{(C_t^i(j) - hC_{t-1}^i)^{1-\sigma}}{1-\sigma} - \varepsilon_{L,t}^i \frac{(L_t^i(j))^{1+\phi}}{1+\phi} \tag{3.2}$$

with habit formation that is related to past consumption. The shocks processes $\varepsilon_{C,t}^i$ and $\varepsilon_{L,t}^i$ reflect exogenous shocks to consumption and labor supply preferences, and are assumed to follow an AR(1) process.

In line with the existing strand of DSGE models, the consumption bundle of a household in region i, C_t^i, is defined as:

$$C_t^i = \frac{(C_{T,t}^i)^{\gamma_c}(C_{N,t}^i)^{1-\gamma_c}}{\gamma_c{}^{\gamma_c}(1-\gamma_c)^{1-\gamma_c}} \tag{3.3}$$

where $C^i_{T,t}$ is the consumption of tradable goods and $C^i_{N,t}$ the consumption of nontradable goods. The share of tradables in consumption is denoted by γ_c. The bundle of tradable goods is composed of both home goods and imported foreign goods:

$$C^i_{T,t} = \frac{(C^i_{D,t})^{\alpha}(M^i_{C,t})^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \tag{3.4}$$

The weight of the imported goods $M^i_{C,t}$ in the consumption bundle is given by $1-\alpha$, such that $\alpha > 0.5$ implies a home bias in consumption.

The household maximizes lifetime utility subject to a sequence of intertemporal budget constraints:

$$\begin{aligned}
&(1+\tau^i_{C,t})\left(P^i_{N,t}C^i_{N,t}(j) + P^i_{D,t}C^i_{D,t}(j) + P^i_{M,t}M^i_{C,t}(j)\right) + \\
&\left(P^i_{N,t}I^i_{N,t}(j) + P^i_{D,t}I^i_{D,t}(j) + P^i_{M,t}M^i_{I,t}(j)\right) + \mathrm{E}_t\left\{Q_{t,t+1}, D^i_{t+1}(j)\right\} \\
&\leq D^i_t(j) + (1-\tau^i_{L,t})W^i_t(j)L^i_t(j) + (1-\tau^i_{K,t})R^i_{K,t}K^i_t(j) + \Pi^i_t(j)
\end{aligned} \tag{3.5}$$

where $P^i_{N,t}(j)$ and $P^i_{D,t}(j)$ denote the prices of the consumed nontradable and tradable domestic varieties of goods, and $P^i_{M,t}(j)$ denotes the price of the consumed imported variety of goods produced the foreign region. D^i_{t+1} is the nominal payoff in period $t+1$ of the government bonds held at the end of period t and $Q_{t,t+1}$ is the stochastic discount factor, which is assumed to be common across regions, since $\mathrm{E}_t\{Q_{t,t+1}\} = R_t^{-1}$, which is common for the monetary union. The nominal wage is given by W^i_t and households receive an income $R^i_{K,t}$ on renting capital K_t. Both capital and labor income are taxed by $\tau^i_{K,t}$ and $\tau^i_{L,t}$, respectively, and consumption is taxed by $\tau^i_{C,t}$. The households own the firms and hence they receive dividends Π^i_t.

The indexes for consumption of domestically produced goods and imported foreign goods are respectively given by the following aggregators:

$$C^i_{D,t} = \left(\left(\frac{1}{n}\right)^{\frac{1}{\phi_D}} \int_0^n C^i_{D,t}(z)^{\frac{\phi_D-1}{\phi_D}} dz\right)^{\frac{\phi_D}{\phi_D-1}} \tag{3.6}$$

$$M^i_{C,t} = \left(\left(\frac{1}{1-n}\right)^{\frac{1}{\phi_M}} \int_n^1 M^i_{C,t}(z)^{\frac{\phi_M-1}{\phi_M}} dz\right)^{\frac{\phi_M}{\phi_M-1}} \tag{3.7}$$

Moreover, the consumption bundle of nontradable goods is given by[3]:

$$C^i_{N,t} = \left(\left(\frac{1}{n}\right)^{\frac{1}{\phi_N}} \int_0^n C^i_{N,t}(z)^{\frac{\phi_N-1}{\phi_N}} dz\right)^{\frac{\phi_N}{\phi_N-1}} \tag{3.8}$$

The elasticities of substitution between varieties of domestic tradable goods (ϕ_D), between varieties of imported goods from the foreign region (ϕ_M) and between varieties of nontradable domestic goods (ϕ_N) are all allowed to vary across regions.

The consumption demand functions for each variety of goods can be derived from intratemporal optimization:

$$C^i_{D,t}(z) = \frac{1}{n}\gamma_C\alpha\left(\frac{P^i_{D,t}(z)}{P^i_{D,t}}\right)^{-\phi_D}\left(\frac{P^i_{D,t}}{P^i_{C,t}}\right)^{-1} C^i_t \tag{3.9}$$

$$M^i_{C,t}(z) = \frac{1}{1-n}\gamma_C(1-\alpha)\left(\frac{P^i_{M,t}(z)}{P^i_{M,t}}\right)^{-\phi_M}\left(\frac{P^i_{M,t}}{P^i_{C,t}}\right)^{-1} C^i_t \tag{3.10}$$

$$C^i_{N,t}(z) = \frac{1}{n}(1-\gamma_C)\left(\frac{P^i_{N,t}(z)}{P^i_{N,t}}\right)^{-\phi_N}\left(\frac{P^i_{N,t}}{P^i_{C,t}}\right)^{-1} C^i_t \tag{3.11}$$

The price indexes are defined as follows:

$$P^i_{D,t} = \left(\frac{1}{n}\int_0^n P^i_{D,t}(z)^{1-\phi_D} dz\right)^{\frac{1}{1-\phi_D}} \tag{3.12}$$

$$P^i_{M,t} = \left(\frac{1}{1-n}\int_n^1 P^i_{M,t}(z)^{1-\phi_M} dz\right)^{\frac{1}{1-\phi_M}} \tag{3.13}$$

$$P^i_{N,t} = \left(\frac{1}{n}\int_0^n P^i_{N,t}(z)^{1-\phi_N} dz\right)^{\frac{1}{1-\phi_N}} \tag{3.14}$$

where $P^i_{D,t}$ is the price index of domestically produced goods in region i which are traded, $P^i_{N,t}$ is the price index of domestically produced goods in region i which are not traded, and $P^i_{M,t}$ is the price index of imported goods, produced in region i^* and imported into i. The price index of the tradable goods (consumed

[3]For the foreign economy, the term $\frac{1}{n}$ in equation (3.6) and (3.8) is replaced by $\frac{1}{1-n}$ and in equation (3.7) the term $\frac{1}{1-n}$ is replaced by $\frac{1}{n}$.

in region i) is given by:

$$P^i_{T,t} = (P^i_{D,t})^{\alpha}(P^i_{M,t})^{1-\alpha} \tag{3.15}$$

and the consumer price index is given by:

$$P^i_{C,t} = (P^i_{T,t})^{\gamma_c}(P^i_{N,t})^{1-\gamma_c} \tag{3.16}$$

Investment

Households rent out capital which is assumed to be invested in a homogeneous investment good. The law of motion for capital accumulation is given by:

$$K^i_{t+1}(j) = (1-\delta)K^i_t(j) + \varepsilon^i_{I,t}\left(1 - S\left(\frac{I^i_t(j)}{I^i_{t-1}(j)}\right)\right) I^i_t(j) \tag{3.17}$$

where $\varepsilon^i_{I,t}$ represents the technological progress that is specific for investment, and $S(\cdot)$ represents the adjustment cost function. The value of $S(\cdot)$ is equal to zero if $\frac{I^i_t(j)}{I^i_{t-1}(j)} = 1$, hence if investment stays at the same level, there are no adjustment costs.

The investment bundle of a household in region i is defined as:

$$I^i_t = \frac{(I^i_{T,t})^{\gamma_I}(I^i_{N,t})^{1-\gamma_I}}{\gamma_I^{\gamma_I}(1-\gamma_I)^{1-\gamma_I}} \tag{3.18}$$

with γ_I as the share of tradables in investment. Moreover, investment in the tradables sector is given by:

$$I^i_{T,t} = \frac{(I^i_{D,t})^{\alpha}(M^i_{I,t})^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \tag{3.19}$$

where

$$I^i_{D,t} = \left(\left(\frac{1}{n}\right)^{\frac{1}{\phi_D}} \int_0^n I^i_{D,t}(z)^{\frac{\phi_D-1}{\phi_D}} dz\right)^{\frac{\phi_D}{\phi_D-1}} \tag{3.20}$$

$$M^i_{I,t} = \left(\left(\frac{1}{1-n}\right)^{\frac{1}{\phi_M}} \int_n^1 M^i_{I,t}(z)^{\frac{\phi_M-1}{\phi_M}} dz\right)^{\frac{\phi_M}{\phi_M-1}} \tag{3.21}$$

$$I^i_{N,t} = \left(\left(\frac{1}{n} \right)^{\frac{1}{\phi_N}} \int_0^n I^i_{N,t}(z)^{\frac{\phi_N - 1}{\phi_N}} dz \right)^{\frac{\phi_N}{\phi_N - 1}} \tag{3.22}$$

The investment demand functions for each variety of goods are as follows:

$$I^i_{D,t}(z) = \frac{1}{n} \gamma_I \alpha \left(\frac{P^i_{D,t}(z)}{P^i_{D,t}} \right)^{-\phi_D} \left(\frac{P^i_{D,t}}{P^i_{I,t}} \right)^{-1} I^i_t \tag{3.23}$$

$$M^i_{I,t}(z) = \frac{1}{1-n} \gamma_I (1-\alpha) \left(\frac{P^i_{M,t}(z)}{P^i_{M,t}} \right)^{-\phi_M} \left(\frac{P^i_{M,t}}{P^i_{I,t}} \right)^{-1} I^i_t \tag{3.24}$$

$$I^i_{N,t}(z) = \frac{1}{n} (1-\gamma_I) \left(\frac{P^i_{N,t}(z)}{P^i_{N,t}} \right)^{-\phi_N} \left(\frac{P^i_{N,t}}{P^i_{I,t}} \right)^{-1} I^i_t \tag{3.25}$$

The price index for investment is defined as:

$$P^i_{I,t} = (P^i_{T,t})^{\gamma_I} (P^i_{N,t})^{1-\gamma_I} \tag{3.26}$$

Household optimization

The household maximizes its utility function, taking into account the budget constraint and the law of capital accumulation. The first-order conditions of this optimization problem lead to the Euler equation[4]:

$$\frac{1}{R_t} = \beta \mathrm{E}_t \left[\frac{\varepsilon^i_{C,t+1}}{\varepsilon^i_{C,t}} \frac{(C^i_{t+1}(j) - hC^i_t)^{-\sigma}}{(C^i_t(j) - hC^i_{t-1})^{-\sigma}} \frac{P^i_{C,t}}{P^i_{C,t+1}} \frac{(1+\tau^i_{C,t})}{(1+\tau^i_{C,t+1})} \right] \tag{3.27}$$

Moreover, the first-order conditions imply the following equations for investment demand and the relative price of installed capital, which is also known as Tobin's Q:

$$\begin{aligned} \frac{P^i_{I,t}}{P^i_{C,t}} = {} & Q^i_{T,t}(j) \varepsilon^i_{I,t} \left(1 - S\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) - \frac{I^i_t(j)}{I^i_{t-1}(j)} S'\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) \right) \\ & + \mathrm{E}_t \left[Q^i_{T,t+1}(j) \frac{P^i_{C,t+1}}{P^i_{C,t} R_t} \varepsilon^i_{I,t+1} \left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)^2 S'\left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right) \right] \end{aligned} \tag{3.28}$$

$$Q^i_{T,t}(j) = \mathrm{E}_t \left[\frac{(1-\tau^i_{K,t}) R^i_{K,t+1}}{P^i_{C,t} R_t} \right] + (1-\delta) \mathrm{E}_t \left[Q^i_{T,t+1}(j) \frac{P^i_{C,t+1}}{P^i_{C,t} R_t} \right] \tag{3.29}$$

[4]The derivation of this and other first-order conditions can be found in the appendix.

Wage setting

Labor services of households are aggregated into a homogeneous labor input:

$$L_t^i = \left(\left(\frac{1}{n} \right)^{\frac{1}{\phi_W}} \int_0^n L_t^i(j)^{\frac{\phi_W - 1}{\phi_W}} dj \right)^{\frac{\phi_W}{\phi_W - 1}} \tag{3.30}$$

The aggregate wage index W_t^i is given by:

$$W_t^i = \left(\frac{1}{n} \int_0^n W_t^i(j)^{1-\phi_W} dj \right)^{\frac{1}{1-\phi_W}} \tag{3.31}$$

where ϕ_W is the elasticity of substitution between labor inputs for different production varieties.

There is Calvo adjustment in the wage setting, which means that only a fraction $1 - \theta_W$ can renegotiate the wage contracts in each period, whereas the wages of the remaining households are partially indexed to past inflation in consumer prices. With δ_W being the degree of partial indexation, the wage of these households in period t is given by:

$$W_t^i(j) = W_{t-1}^i(j) \left(\frac{P_{C,t-1}}{P_{C,t-2}} \right)^{\delta_W} \tag{3.32}$$

Households that are able to renegotiate their wages maximize the expected present discounted value of future utility, because they know that they may not be able to change their wage for a while. Households do take into account that if wages are not re-optimized, they are still partially indexed to past CPI inflation. The optimal wage is then derived[5] as:

$$\tilde{W}_t^i(j) = \frac{\phi_W}{\phi_W - 1} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k MRS_{t+k}^i(j) \varepsilon_{C,t}^i L_{t+k}^i(j) C_{t+k}^i(j)^{-\sigma}}{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \frac{(1-\tau_{L,t+k}^i)}{P_{C,t+k}^i} \varepsilon_{C,t}^i L_{t+k}^i(j) C_{t+k}^i(j)^{-\sigma}} \tag{3.33}$$

where $MRS_t^i(j) = \frac{\varepsilon_{L,t}^i L_t^i(j)^{\phi}}{\varepsilon_{C,t}^i (C_t^i(j) - hC_{t-1})^{-\sigma}}$ is the marginal rate of substitution of consumption for leisure.

[5] The derivation of the optimal wage can be found in the appendix.

Given this optimization process, the evolution of the aggregate wage index is:

$$W_t^i = \left(\theta_W \left(W_{t-1}^i \left(\frac{P_{C,t-1}^i}{P_{C,t-2}^i} \right)^{\delta_W} \right)^{1-\phi_W} + (1-\theta_W)(\tilde{W}_t^i)^{1-\phi_W} \right)^{\frac{1}{1-\phi_W}} \tag{3.34}$$

The structural parameters for the degree of partial indexation of wages δ_W and for the fraction of households that cannot renegotiate their contracts θ_W are allowed to be different across regions.

3.3.2 Firms

Production

For the production side of the economy, it is assumed that there is monopolistic competition in both the tradables and nontradables sector. There is a Cobb-Douglas production function in both sectors:

$$Y_{N,t}^i(z) = a_{N,t}^i (K_{N,t}^i(z))^{\eta} (L_{N,t}^i(z))^{1-\eta} \tag{3.35}$$

$$Y_{D,t}^i(z) = a_{D,t}^i (K_{D,t}^i(z))^{\eta} (L_{D,t}^i(z))^{1-\eta} \tag{3.36}$$

where both $a_{N,t}^i$ and $a_{D,t}^i$ follow an AR(1) process in the log-linearized model that is specific for each region. Then the output indexes in both sectors are as follows:

$$Y_{N,t}^i = \left(\left(\frac{1}{n} \right)^{\frac{1}{\phi_N}} \int_0^n Y_{N,t}^i(z)^{\frac{\phi_N - 1}{\phi_N}} dz \right)^{\frac{\phi_N}{\phi_N - 1}} \tag{3.37}$$

$$Y_{D,t}^i = \left(\left(\frac{1}{n} \right)^{\frac{1}{\phi_D}} \int_0^n Y_{D,t}^i(z)^{\frac{\phi_D - 1}{\phi_D}} dz \right)^{\frac{\phi_D}{\phi_D - 1}} \tag{3.38}$$

Cost minimization of the firms implies that the capital-labor ratio, which implicitly determines labor demand, is given by:

$$\frac{W_t^i L_t^i}{R_{K,t}^i K_t^i} = \frac{1-\eta}{\eta} \tag{3.39}$$

where η is the output elasticity with respect to capital. The real marginal cost $MC^i_{D,t}$ is defined as

$$MC^i_{D,t} = \frac{1}{P^i_{D,t} a^i_{D,t}} \left(\frac{W^i_t}{1-\eta} \right)^{1-\eta} \left(\frac{R^i_{K,t}}{\eta} \right)^{\eta} \tag{3.40}$$

Similarly, the real marginal cost for the nontradables is defined as:

$$MC^i_{N,t} = \frac{1}{P^i_{N,t} a^i_{N,t}} \left(\frac{W^i_t}{1-\eta} \right)^{1-\eta} \left(\frac{R^i_{K,t}}{\eta} \right)^{\eta} \tag{3.41}$$

Factor markets are assumed to be perfectly competitive, such that the rental price of capital $R_{K,t}$ and the aggregate wage index W_t are taken as given by producers. Therefore, the marginal cost for the production of one unit is the same for all firms.

Price setting

Similar to wages, prices are set according to Calvo staggered price setting. A fraction $1 - \theta_D$ of firms that produce for the domestic market can optimally set its prices, while the other firms see their prices partially indexed to past inflation. Inflation is measured here by price levels for products in the same sector. Therefore, for the tradables sector, prices of firms that cannot optimally set prices are given by:

$$P^i_{D,t}(z) = P^i_{D,t-1}(z) \left(\frac{P^i_{D,t-1}}{P^i_{D,t-2}} \right)^{\delta_D} \tag{3.42}$$

where δ_D is the degree of partial indexation.

The firms that can change their prices will maximize the expected present discounted value of future profits. In doing this, they also take into account that if prices are not re-optimized they will still be partially indexed to past inflation.

The derivation[6] shows that the optimal price for firms is given by:

$$\tilde{P}^i_{D,t} = \frac{\phi_D}{\phi_D - 1} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \frac{U^i_C(C_{t+k})}{U^i_C(C_t)} Y^i_{D,t+k} MC^i_{D,t+k} \left(\frac{P^i_{D,t+k}}{\left(\frac{P^i_{D,t+k-1}}{P^i_{D,t-1}} \right)^{\delta_D}} \right)^{\phi_D}}{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \frac{U^i_C(C_{t+k})}{U^i_C(C_t)} Y^i_{D,t+k} \left(\frac{P^i_{D,t+k}}{\left(\frac{P^i_{D,t+k-1}}{P^i_{D,t-1}} \right)^{\delta_D}} \right)^{\phi_D - 1}} \tag{3.43}$$

All firms that are allowed to adjust their prices will choose the same optimal price since there are no firm-specific shocks, therefore the firm-specific index j is left out. Given the optimal price that will be set by forward-looking firms if they are allowed to, the evolution of the price index for the domestic tradable goods is given by:

$$P^i_{D,t} = \left(\theta_D \left(P^i_{D,t-1} \left(\frac{P^i_{D,t-1}}{P^i_{D,t-2}} \right)^{\delta_D} \right)^{1-\phi_D} + (1 - \theta_D)(\tilde{P}^i_{D,t})^{1-\phi_D} \right)^{\frac{1}{1-\phi_D}} \tag{3.44}$$

The optimization problem solved by firms in the nontradables sector is similar and therefore the optimal price and the evolution of the price index are analogous to equations (3.43) and (3.44). In the foreign region, there is a similar process for $P^{i*}_{D,t}$ and $P^{i*}_{N,t}$. Again, the parameters for the pricing behavior, $\delta_D, \delta_N, \theta_D$ and θ_N are allowed to vary across regions.

Since there are no trading frictions, the law of one price holds. As a result, the price of domestically produced goods sold in region i equals the price of these goods sold in region i^* when converted into the same currency:

$$P^i_{D,t}(z) = E^i_{i*,t} P^{i*}_{M,t}(z) \tag{3.45}$$

Similarly, the price of goods imported by region i, so produced by region i^*, equals the price of goods produced and sold in region i^* when converted to the same currency:

$$P^i_{M,t}(z) = E^i_{i*,t} P^{i*}_{D,t}(z) \tag{3.46}$$

[6]The optimal price is derived in the appendix.

where $E^i_{i*,t}$ is the nominal exchange rate denoting the currency of region i in terms of the foreign currency of region i^*. An increase in $E^i_{i*,t}$ thus implies that the home currency depreciates. Of course, in a currency union the nominal exchange rate between the two regions equals one, hence the general expressions in (3.45) and (3.46) can be replaced by $P^i_{D,t}(z) = P^{i*}_{M,t}(z)$ and $P^i_{M,t}(z) = P^{i*}_{D,t}(z)$. Because of home-biased preferences, purchasing power parity (PPP) does not need to hold even though the law of one price holds, as we will later show.

3.3.3 Common monetary authority and national fiscal authorities

A new feature of this model compared to the model by Kolasa (2009) is the common monetary authority that conducts a single policy for the whole currency area, since in that paper both countries had their own monetary policies. The monetary authority in the currency union responds to the economic conditions on the union-level, as the interest-rate feedback rule takes into account the union-wide inflation and output gap:

$$R_t = (R_{t-1})^\rho \left[\left(\frac{Y_t^{EMU}}{\bar{Y}^{EMU}} \right)^{\psi_y} \left(\frac{\pi_{C,t}^{EMU}}{\bar{\pi}^{EMU}} \right)^{\psi_\pi} \right]^{1-\rho} u_{R,t} \tag{3.47}$$

where $\bar{Y}^{EMU}$ is the steady state level of total output in the union, $\bar{\pi}^{EMU}$ is the steady state level of inflation in the union, and $u_{R,t}$ is an i.i.d. monetary policy shock.

In our model, there is a rich fiscal sector in order to allow for a more realistic setting to assess the effectiveness of a fiscal transfer mechanism. National fiscal authorities collect consumption, capital income and labor income taxes. The government spends resources on government consumption, which is directed at nontradable goods, on interest on government debt, and on lump-sum transfers to households. The policy rules concerning taxes and expenditures allow for responses to output, which implies fiscal policy has a role as automatic stabilizer, and for responses to government debt in order to ensure fiscal solvency. Debt is accumulated by the government through the issue of bonds, whenever the expenditures by the government are larger than the revenues. The government budget constraint is given by:

$$B^i_t = (1 + R_t)B^i_{t-1} + G^i_t + Z^i_t - \tau^i_{C,t}C^i_t - \tau^i_{K,t}R^i_{K,t}K^i_t - \tau^i_{L,t}W^i_t L^i_t \tag{3.48}$$

where B_t^i is government debt, G_t^i is government consumption, Z_t^i are lump-sum transfers from the government to households, and $\tau_{C,t}^i$, $\tau_{K,t}^i$ and $\tau_{L,t}^i$ are the tax rates on consumption, capital income and labor income, respectively. Government consumption is determined by the following policy rule:

$$\log G_t^i = \rho_G \log G_{t-1}^i + \gamma_G \log B_{t-1}^i + u_{G,t}^i \tag{3.49}$$

There is habit formation in government consumption if ρ_G is unequal to zero. Consumption by the government is assumed to respond to government debt, whereas lump-sum transfers Z_t will respond to the business cycle:

$$\log Z_t^i = \rho_Z \log Z_{t-1}^i + \phi_Z \log Y_{t-1}^i + u_{Z,t}^i \tag{3.50}$$

The response of the transfer to the state of the economy is expected to be negative, so during recessions transfers, such as unemployment insurance, will automatically go up. The reasoning behind the division of government expenditures in government consumption and lump-sum transfers is that the welfare or social security part of expenditures will not be very responsive to government debt and will not add to the GDP of a country. On the other hand, the consumption part of government expenditures is included in GDP, such as investment in infrastructure. Since this type of expenditures is easier to defer and is not as fixed as social security, it is reasonable to assume that government consumption will be decided upon by looking at the level of government debt. The higher the debt level already is, the more likely it is that consumption by the government is lower.

Tax rates will depend on government debt:

$$\log \tau_{C,t}^i = \rho_{\tau_C} \log \tau_{C,t-1}^i + \gamma_{\tau_C} \log B_{t-1}^i + \phi_{\tau_C \tau_K} u_{\tau_K,t}^i + \phi_{\tau_C \tau_L} u_{\tau_L,t}^i + u_{\tau_C,t}^i \tag{3.51}$$

$$\log \tau_{K,t}^i = \rho_{\tau_K} \log \tau_{K,t-1}^i + \gamma_{\tau_K} \log B_{t-1}^i + \phi_{\tau_K \tau_C} u_{\tau_C,t}^i + \phi_{\tau_K \tau_L} u_{\tau_L,t}^i + u_{\tau_K,t}^i \tag{3.52}$$

$$\log \tau_{L,t}^i = \rho_{\tau_L} \log \tau_{L,t-1}^i + \gamma_{\tau_L} \log B_{t-1}^i + \phi_{\tau_L \tau_C} u_{\tau_C,t}^i + \phi_{\tau_L \tau_K} u_{\tau_K,t}^i + u_{\tau_L,t}^i \tag{3.53}$$

Shocks affecting one tax rate are also allowed to affect other tax rates contemporaneously.

The transfer mechanism is introduced by setting a rule that automatically directs resources from one region to the other if that region is facing a large negative GDP gap or a positive but smaller GDP gap relative to the other region. The GDP gap is measured as the gap between the level of GDP in a certain time period and the steady state level of GDP. In the simulations, this steady state level will be the level of GDP at the time of the introduction of the transfer scheme.

Every period, each region pays a certain amount to a common pool, an amount that is proportional to GDP in that region. The payments of both regions come together in the common pool, from which resources are distributed to each region, based on the ratio of that region's GDP to the union-wide GDP level at the time of the introduction of the scheme. In this way, the region with a larger GDP gap compared to the introduction will receive a transfer in net terms, and in the beginning the transfer equals zero. The payment to the common pool is given by:

$$PAY_t^i = \psi_{PAY} Y_{t-1}^i \tag{3.54}$$

and

$$PAY_t^{i^*} = \psi_{PAY} Y_{t-1}^{i^*} \tag{3.55}$$

The contribution to the common pool in percentages, determined by ψ_{PAY}, is the same for both regions. The common pool is then determined by:

$$CP_t = PAY_t^i + PAY_t^{i^*} = \psi_{PAY} Y_{t-1}^i + \psi_{PAY} Y_{t-1}^{i^*} = \psi_{PAY} Y_{t-1}^{EMU} \tag{3.56}$$

where Y_t is the union-wide GDP level. The receipts from the common pool are:

$$REC_t^i = \frac{\bar{Y}}{\bar{Y}^{EMU}} CP_t \tag{3.57}$$

and

$$REC_t^{i^*} = \frac{\bar{Y}^*}{\bar{Y}^{EMU}} CP_t \tag{3.58}$$

where $\bar{Y}$, $\bar{Y}^*$ and $\bar{Y}^{EMU}$ are the steady state levels of GDP in Home, Foreign and the EMU. For the simulations, these values will be the values of GDP at the introduction of the scheme. Hence, the net transfer received by region i, which is negative in case the region effectively pays a transfer, is given by:

$$TR_t^i = REC_t^i - PAY_t^i \tag{3.59}$$

Country i^* receives the amount that region i is paying, or vice versa[7]:

$$TR_t^{i^*} = REC_t^{i^*} - PAY_t^{i^*} = PAY_t^i - REC_t^i = -TR_t^i \tag{3.60}$$

At the time of the introduction of the scheme, the payment to and receipt from the common pool by each region are equal and hence the net transfer equals zero.[8]

The automatic fiscal transfer mechanism will ease the budget constraint of the government with TR_t^i, the difference between receipts from and payments to the common pool:

$$\begin{aligned} B_t^i = {} & (1 + R_t)B_{t-1}^i + G_t^i + Z_t^i - \tau_{C,t}^i C_t^i - \tau_{K,t}^i R_{K,t}^i K_t^i - \tau_{L,t}^i W_t^i L_t^i \\ & - \left(REC_{t-1}^i - PAY_{t-1}^i \right) \end{aligned} \tag{3.61}$$

The idea behind the transfer scheme is to provide temporary relief to a region that is hit by a negative business cycle shock, without starting off a continuous redistribution from rich to poor regions. By conditioning on the change in GDP relative to the starting point of the transfer system rather than the level of GDP, it is just as likely that the transfer will go from the rich to the poor region as that it will go in the opposite direction. In this way, the transfer rule avoids the political resistance that would arise if the system would have clear winners and losers upfront. In the long run, however, the year of introduction of the transfer mechanism might not be an appropriate base year to condition the transfer on, as structural trend growth could govern the direction of the transfer, and then a recalculation could be deemed necessary.

Basing the transfer mechanism on the change in GDP, rather than on fiscal policy variables, has clear advantages concerning moral hazard issues. First of all, it is important to base the transfer on a number that cannot be influenced easily, as could be done either by influencing the actual number itself or by under- or overreporting the numbers in your region. A government will find it more difficult to influence its GDP number than the tax revenues for example, which is the variable on which the transfer is based in the study by Evers (2015). Secondly, the susceptibility to fraud will be less if it is not in the region's own

[7] This transfer mechanism is by definition a zero-sum game, as $PAY_t^i + PAY_t^{i^*} = CP_t = \frac{\bar{Y}}{\bar{Y}^{EMU}} CP_t + \frac{\bar{Y}^*}{\bar{Y}^{EMU}} CP_t = REC_t^i + REC_t^{i^*}$.

[8] In the steady state, or similarly at the introduction of the transfer mechanism, the payment to the common pool by the home region is given by $\bar{PAY} = \psi_{PAY}\bar{Y}$. The receipt from the common pool is given by $\bar{REC} = \frac{\bar{Y}}{\bar{Y}^{EMU}}\bar{CP}$, and the steady state of the common pool is $\bar{CP} = \psi_{PAY}\bar{Y}^{EMU}$. As a result, $\bar{REC} = \frac{\bar{Y}}{\bar{Y}^{EMU}}\psi_{PAY}\bar{Y}^{EMU} = \bar{PAY}$. The same analysis holds for the foreign region.

interest to influence the variables on which the transfer is based. Having a lower GDP in order to receive the transfer will never yield a region as much income as the income it has lost by this practice. On the other hand, if the transfer is based on the amount of tax revenues, a region might be incentivized to decrease tax rates that, besides the receipt of the transfer, will lead to higher utility of their inhabitants. The effectiveness of this transfer scheme does depend on enforcement at the supranational level, as governments have to be enforced to contribute their amount to the common pool. Slight deviations from the perfect enforcement set-up that we use in the simulations, would lead to slightly lower effects of the transfer scheme. However, since governments do not realize ex ante whether they will become net contributor or net recipient, there might not be an incentive to deviate from contributing their amounts to the common pool. Moreover, if the punishment for not respecting the rules would be to exit the transfer scheme, the region would not be able to profit from possible future welfare gains.

3.3.4 Market clearing conditions

International risk sharing

Financial markets are assumed to be complete and households in all regions can trade in state contingent claims denominated in the home currency. Therefore, the perfect risk sharing condition holds, which states that the ratio of consumer price levels (or the real exchange rate) equals the ratio of marginal utilities of consumption across regions in every state of the world. The real exchange rate is defined as:

$$Q^i_{i*,t} = \frac{E^i_{i*,t} P^{i*}_{C,t}}{P^i_{C,t}} \tag{3.62}$$

The perfect risk-sharing condition for the monetary union is then[9]:

$$Q^i_{i*,t} = \kappa \frac{U'(C^{i*}_t)}{U'(C^i_t)} = \kappa \frac{\varepsilon^{i*}_{C,t}(C^{i*}_t - h^* C^{i*}_{t-1})^{-\sigma^*}}{\varepsilon^i_{C,t}(C^i_t - hC^i_{t-1})^{-\sigma}} \tag{3.63}$$

where κ is a constant that depends on the initial conditions and is defined as $\kappa = \frac{E^i_{i*,0} P^{i*}_{C,0} U'(C^i_0)}{P^i_{C,0} U'(C^{i*}_0)}$.

The terms of trade is defined as the ratio of producer prices of both economies, or put differently, the ratio of the import prices of a region relative to the export

[9]For the full derivation of the perfect risk-sharing condition, see Chari et al. (2002).

prices of that region:

$$T^i_{i*,t} = \frac{E^i_{i*,t} P^{i*}_{D,t}}{P^i_{D,t}} = \frac{P^i_{M,t}}{P^i_{D,t}} \tag{3.64}$$

The internal exchange rates are defined as $X^i_t = \frac{P^i_{N,t}}{P^i_{T,t}}$ and $X^{i*}_t = \frac{P^{i*}_{N,t}}{P^{i*}_{T,t}}$. Since both regions are in a monetary union with a single currency, the nominal exchange rate equals one which simplifies the notation to $Q^i_{i*,t} = \frac{P^{i*}_{C,t}}{P^i_{C,t}}$ and $T^i_{i*,t} = \frac{P^{i*}_{D,t}}{P^i_{D,t}}$.

The law of one price holds on the national level if we assume that the elasticity of substitution among goods is the same within a given region, which implies that:

$$P^i_{D,t} = E^i_{i*,t} P^{i*}_{M,t} \qquad P^i_{M,t} = E^i_{i*,t} P^{i*}_{D,t} \tag{3.65}$$

Using these conditions, the price indexes derived above and the fact that with a shared currency the nominal exchange rate equals one, allows us to show a relationship between the real exchange rate and the terms of trade[10]:

$$Q^i_{i*,t} = (T^i_{i*,t})^{\alpha+\alpha^*-1} \frac{\left(X^{i*}_t\right)^{1-\gamma^*_c}}{\left(X^i_t\right)^{1-\gamma_c}} \tag{3.66}$$

The real exchange rate is thus allowed to deviate from purchasing power parity, because of changes in relative prices of tradables versus nontradables in both regions and changes in the terms of trade, as long as there is a home bias. When there is no home bias, the terms of trade cannot be determined by the perfect risk sharing condition anymore.

Goods market

The goods market clears when total output in the economy equals total demand. Therefore, the output of nontradable goods has to be equal to the sum of consumption, investment and government purchases of nontradables in Home:

$$Y^i_{N,t} = (1-\gamma_C)\frac{P^i_{C,t}}{P^i_{N,t}} C^i_t + (1-\gamma_I)\frac{P^i_{I,t}}{P^i_{N,t}} I^i_t + G^i_t \tag{3.67}$$

Goods market clearance also implies that the output of tradable goods must be equal to the sum of domestic consumption and investment of tradables and tradables exported for consumption and investment abroad. As the export of

[10] The derivation of this relationship can be found in the appendix.

home produced consumption and investment goods to region i^* is defined as $M^{i*}_{C,t}$ and $M^{i*}_{I,t}$, the goods market clearance condition for tradables is given by:

$$\begin{aligned} Y^i_{D,t} = \gamma_C \alpha \frac{P^i_{C,t}}{P^i_{D,t}} C^i_t + \gamma_I \alpha \frac{P^i_{I,t}}{P^i_{D,t}} I^i_t + \frac{1-n}{n} \gamma^*_C (1-\alpha^*) \frac{P^{i*}_{C,t}}{P^{i*}_{M,t}} C^{i*}_t \\ + \frac{1-n}{n} \gamma^*_I (1-\alpha^*) \frac{P^{i*}_{I,t}}{P^{i*}_{M,t}} I^{i*}_t \end{aligned} \tag{3.68}$$

Total output is given by:

$$Y^i_t = Y^i_{N,t} + Y^i_{D,t} \tag{3.69}$$

Factor markets

Equilibrium in the factor markets requires that the labor and capital market both clear. For the labor market, this implies that:

$$L^i_t = L^i_{D,t} + L^i_{N,t} = \int_0^n L^i_{D,t}(j)dj + \int_0^n L^i_{N,t}(j)dj \tag{3.70}$$

Similarly, capital market clearing is defined as:

$$K^i_t = K^i_{D,t} + K^i_{N,t} = \int_0^n K^i_{D,t}(j)dj + \int_0^n K^i_{N,t}(j)dj \tag{3.71}$$

3.3.5 Solving the model

Because of the size of the model, there is no closed-form solution. Therefore, we will log-linearize the model around the steady state. The complete model in log-linearized form can be found in the appendix. The model is then solved numerically by running Dynare in Matlab using the log-linearized model.[11]

The two-region model of the monetary union is captured in a system of 72 equations[12] and 21 exogenous shocks. The shocks to productivity ($u^i_{a,D,t}$, $u^i_{a,N,t}$, $u^{i*}_{a,D,t}$, $u^{i*}_{a,N,t}$), the shocks to preferences in consumption and labor supply ($u^i_{C,t}$, $u^{i*}_{C,t}$,$u^i_{L,t}$, $u^{i*}_{L,t}$) and the shocks to investment efficiency ($u^i_{I,t}$, $u^{i*}_{I,t}$) are assumed to follow an AR(1) process in the log-linearized model. The shocks to government spending and tax rates ($u^i_{G,t}$, $u^{i*}_{G,t}$, $u^i_{Z,t}$, $u^{i^*}_{Z,t}$, $u^i_{\tau C,t}$, $u^{i^*}_{\tau C,t}$, $u^i_{\tau K,t}$, $u^{i^*}_{\tau K,t}$, $u^i_{\tau L,t}$, $u^{i^*}_{\tau L,t}$) and the monetary policy shock to the interest rate ($u_{R,t}$) are assumed to be i.i.d. shocks.

[11] The Matlab codes for running the Dynare program are available upon request.

[12] Equations for the transfer mechanism are not included in the estimated version of the model. If these equations were to be included the model entails a system of 77 equations.

3.3.6 Welfare measure

To evaluate the normative aspects of a fiscal transfer mechanism, we will use a welfare measure based on a second-order Taylor series expansion of the utility function around the steady state, following Benigno and Woodford (2005) and Jondeau and Sahuc (2008). Welfare is based on the expected discounted value of the sum of utilities, which gives the following second-order approximation[13]:

$$\begin{aligned} U_0^i = \sum_{t=0}^{\infty} \beta^t \Big(& \bar{U}^i + ((1-h)\bar{C}^i)^{-\sigma}\bar{C}^i \Big[(\mathrm{E}_0(\hat{c}_t^i) - h\mathrm{E}_0(\hat{c}_{t-1}^i)) \\ & + \frac{1}{2}\left(\mathrm{E}_0((\hat{c}_t^i)^2) - h\mathrm{E}_0((\hat{c}_{t-1}^i)^2)\right) - \frac{\sigma}{2(1-h)}\left(\mathrm{E}_0((\hat{c}_t^i)^2) + h^2\mathrm{E}_0((\hat{c}_{t-1}^i)^2)\right) \\ & + \frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t^i\hat{c}_{t-1}^i)\Big] - (\bar{L}^i)^{1+\phi}\left[\mathrm{E}_0(\hat{l}_t^i) + \frac{1}{2}(1+\phi)\mathrm{E}_0((\hat{l}_t^i)^2)\right] + \mathcal{O}\left(\|\zeta\|^3\right)\Big) \end{aligned}$$

The welfare effect of a fiscal transfer mechanism is evaluated using the consumption equivalent welfare measure in the tradition of Lucas (2003). The welfare compensation is measured as the permanent relative change in consumption compared to the steady state that will make the representative household indifferent between the current situation and the steady state, indicated by λ. The welfare loss or gain associated with the introduction of a transfer mechanism is then measured by the increase or decrease in the welfare compensation relative to the situation before introduction of the transfer scheme. Therefore, an increase in λ due to the introduction of the transfer mechanism implies a welfare gain. In this situation the representative household would require a higher steady state consumption in order to be equally well off in the steady state, as compared to the required steady state consumption level before introduction of the transfer mechanism.

The consumption equivalence λ is defined such that:

$$\begin{aligned} U_0^i = \sum_{t=0}^{\infty} \beta^t \mathrm{E}_0 U(C_t^i, C_{t-1}^i, L_t^i) &= \sum_{t=0}^{\infty} \beta^t U((1+\lambda)\bar{C}^i, \bar{L}^i) \\ &= \sum_{t=0}^{\infty} \beta^t \left[\frac{((1+\lambda^i)(1-h)\bar{C}^i)^{1-\sigma}}{1-\sigma} - \frac{(\bar{L}^i)^{1+\phi}}{1+\phi} \right] \end{aligned}$$

Using a first-order Taylor approximation in λ^i we find the consumption equivalent

[13] Derivations can be found in the appendix.

welfare compensation measure:

$$
\begin{aligned}
\lambda^i = \frac{1}{1-h}\Big[&(\mathrm{E}_0(\hat{c}_t^i) - h\mathrm{E}_0(\hat{c}_{t-1}^i)) + \frac{1}{2}(\mathrm{E}_0((\hat{c}_t^i)^2) - h\mathrm{E}_0((\hat{c}_{t-1}^i)^2)) \\
&-\frac{\sigma}{2(1-h)}\left(\mathrm{E}_0((\hat{c}_t^i)^2) + h^2\mathrm{E}_0((\hat{c}_{t-1}^i)^2)\right) + \frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t^i\hat{c}_{t-1}^i)\Big] \\
&-(\bar{L}^i)^{1+\phi}((1-h)\bar{C}^i)^{\sigma-1}\left[\mathrm{E}_0(\hat{l}_t^i) + \frac{1}{2}(1+\phi)\mathrm{E}_0((\hat{l}_t^i)^2)\right]
\end{aligned}
$$

The welfare compensation λ^i can be further decomposed into components reflecting the means as well as the variances of consumption and labor, denoted respectively by λ^i_M and λ^i_V. The overall welfare compensation is given by $(1+\lambda^i) = (1+\lambda^i_M)(1+\lambda^i_V)$. Moreover, the change in the means can be attributed to both consumption and labor, which leads to the decomposition $(1+\lambda^i_M) = (1+\lambda^i_{M,c})(1+\lambda^i_{M,l})$. Likewise, the change in the variance can be decomposed into its consumption and labor component, such that $(1+\lambda^i_V) = (1+\lambda^i_{V,c})(1+\lambda^i_{V,l})$. The second-order approximation of welfare as well as the formula for the consumption equivalent welfare measure are similar for the foreign region denoted with i^*. The parameter values and steady state values used for welfare analysis are heterogeneous across regions.

3.4 Bayesian Estimation

The model presented in the previous section is estimated with Bayesian estimation techniques using 21 macroeconomic time series as observable variables. Data on GDP, consumption, investment, internal exchange rate, CPI, real wage rate, government debt, total government expenditures, consumption tax revenues and capital income tax revenues is gathered for both a northern and a southern block of countries, as well as data on the nominal interest rate set by the ECB. South represents the so-called PIGS-countries that have experienced dramatic economic troubles during the recent European sovereign debt crisis, i.e. Portugal, Italy, Greece and Spain. The North block contains the other Eurozone countries that are a member of the EMU from the start of the currency union, these are Austria, Belgium, Finland, France, Germany, Ireland, Luxembourg and the Netherlands.[14] All variables are seasonally adjusted and first-differenced prior to estimation. For most variables, the data comes from Eurostat, except for the

[14] Ireland could also have been included in the South-block of countries, then representing the PIIGS-countries. Since Ireland is relatively small in both blocks, it is most likely that the parameter estimates would not have been very different.

data on CPI, internal exchange rate and real wage rate, for which the source is the OECD database. A complete description of the data used is given in the appendix.

The Metropolis-Hastings algorithm is used in order to obtain estimates of the complete posterior distribution. Estimation is done on a quarterly basis, with an estimation period from the second quarter of 2000 until the fourth quarter of 2013. Lack of data availability, especially for Greece, limits the estimation sample to 55 periods.

3.4.1 Calibrated parameters

In this section, we present some parameters that are calibrated in the Bayesian estimation of the model. Some of the structural parameters of the model are directly related to the steady state values of variables, such as β, and therefore, these need to be estimated from the means of observable variables. The data used in the estimation is in first differences, however, and hence these structural parameters cannot be pinned down in the estimation. Therefore, some of the structural parameters as well as the steady state values are calibrated, at values that can be found in table 3.4.1. For these parameter values, we follow mostly Smets and Wouters (2003), Kolasa (2009) and Hollmayr (2012).

Table 3.4.1: Calibrated parameters for symmetric regions

Parameter	North	South
	Structural parameters	
n	0.66	0.34
β	0.99	0.99
σ	2	2
h	0.75	0.75
γ_C	0.51	0.57
γ_I	0.51	0.57
α	0.96	0.88
δ	0.025	0.025
η	0.33	0.33
	Monetary policy parameters	
ρ	0.7	
ψ_Y	0.3	
ψ_π	0.8	

	Steady state values	
$\frac{\bar{C}}{\bar{Y}}$	0.54	0.58
$\frac{\bar{I}}{\bar{Y}}$	0.24	0.24
$\frac{\bar{G}}{\bar{Y}}$	0.22	0.18
$\frac{\bar{R}}{\bar{D}}$	0.01	0.01
$\frac{T\bar{A}X_C}{\bar{D}}$	0.0462	0.0353
$\frac{T\bar{A}X_K}{\bar{D}}$	0.015	0.015
$\frac{T\bar{A}X_L}{\bar{D}}$	0.0435	0.0338
$\frac{\bar{G}}{\bar{D}}$	0.0404	0.0321
$\frac{\bar{Z}}{\bar{D}}$	0.0372	0.0214
$\frac{R\bar{E}C}{\bar{D}} = \psi_{PAY} \cdot \frac{\bar{Y}}{\bar{D}}$	$\psi_{PAY} \cdot 0.35$	$\psi_{PAY} \cdot 0.27$
$\frac{P\bar{A}Y}{\bar{D}} = \psi_{PAY} \cdot \frac{\bar{Y}}{\bar{D}}$	$\psi_{PAY} \cdot 0.35$	$\psi_{PAY} \cdot 0.27$
$\frac{\bar{Y}}{\bar{Y}^{EMU}}$	0.66	0.34

According to OECD statistics on population, the relative size of the northern block is 66%. The discount factor β, the intertemporal elasticity of substitution σ and the output elasticity with respect to capital η are parameterized at values that are commonly used in the DSGE literature. The depreciation rate of capital δ equals 2.5% which implies a yearly capital depreciation of approximately 10%. The parameter of habit formation is given by 0.75 for both blocks of countries, which is close to the estimate of Kolasa (2009) for Europe. From OECD statistics, we calculate the share of tradable goods and services in GDP to approximate the share of tradables in consumption and investment. Here, tradables consists of agriculture, industry, construction, transport, distributive trade and communications. Nontradables are financial activities, real estate activities, scientific and administrative activities, public administration and other service activities. Hollmayr (2012) estimates the home bias of each member country of the EMU, and when converting this into the home bias of the North and the South, we find that the North has a larger home bias than the South, mostly because the northern countries trade a lot with Germany. The southern countries also trade a lot with Germany, but for these Germany is the foreign block.

For monetary policy, a Taylor-type rule is used for the interest rate in which the AR(1) coefficient for smoothing is the same as the priors for the persistence parameters in the estimation. Furthermore, the weight on inflation is larger than the weight on the output gap, which is reasonable for the monetary policy of the European Central Bank.

Some of the log-linearized equations contain steady state values of variables due to additive terms in the original equations. These steady state values are approximated using long-run averages of the variables provided by the OECD statistics database. Private consumption is assumed to be around 54% of national GDP in North and 58% of GDP in South, private investment 24% in both regions and therefore government expenditures are approximated at 22% and 18% in North and South. The steady state values for the fiscal variables are long-run averages on government debt, tax revenues and government expenditures taken from Eurostat.

3.4.2 Priors and parameter estimates

The first columns of table 3.4.2 show our assumptions regarding the prior distribution of the structural parameters that will be estimated. Prior means are typically set close to values that are found in other studies in this literature. The priors of the standard errors are chosen in such a way that the domain covers reasonable values of the parameter. The parameter for the inverse elasticity of labor supply ϕ is assumed to have a gamma distribution, which guarantees a positive range. The prior mean is set equal to 2 as is also done by Smets and Wouters (2003). The parameter for capital adjustment costs has a normal prior distribution with mean 4 as in Kolasa (2009). The parameters for the degree of indexation of wages and prices, which is expressed in percentages, are assumed to have a beta distribution, which covers the range between 0 and 1. Moreover, the Calvo probability parameters have a prior mean of either 0.7 and 0.8 and are assumed to have a beta distribution, for the same reason as the indexation parameters.

Setting the prior distribution for the regional fiscal policy parameters is more difficult, as the largest part of the fiscal policy sector in our model is an extension to the common models in which these parameters do not exist. Hence, economic intuition is key in providing the parameters with reasonable prior means. As can be seen in table 3.4.3, the persistence parameters in the policy rules for tax rates and expenditures are beta distributed, since we assume they are naturally between zero and one. A reasonable prior for the mean of these AR(1) coefficients is 0.7, a value also used for the shock persistence parameters as well as the monetary policy parameter. Economic theory would suggest that the parameter for the responsiveness of government transfers to the state of the economy is negative, since transfers such as unemployment insurance usually increase whenever the economy is in a bad state. Hence, we assume that ϕ_Z is negative such that it is normally distributed with prior mean -0.1. In a similar fashion, the parameter for the responsiveness of government consumption to debt γ_G is normally distributed with mean -0.2, as it seems likely that the government tightens its belt

Table 3.4.2: Estimation results: Structural parameters

	Prior distribution			Posterior distribution		
	Type	Mean	St. Error	Mean	10%	90%
ϕ	gamma	2.0	0.4	2.4725	1.8039	3.2210
ϕ^*	gamma	2.0	0.4	1.4489	1.2118	1.6466
S''	normal	4.0	1.0	9.1392	7.6770	10.3141
S''^*	normal	4.0	1.0	9.5634	8.9370	10.2580
δ_D	beta	0.5	0.1	0.3143	0.2482	0.3909
δ_D^*	beta	0.5	0.1	0.7268	0.6277	0.7941
δ_N	beta	0.5	0.1	0.3940	0.3260	0.4973
δ_N^*	beta	0.5	0.1	0.4731	0.3851	0.5533
δ_W	beta	0.5	0.1	0.1902	0.1335	0.2392
δ_W^*	beta	0.5	0.1	0.4192	0.3104	0.4934
θ_D	beta	0.7	0.1	0.8184	0.7910	0.8473
θ_D^*	beta	0.7	0.1	0.8746	0.8516	0.9071
θ_N	beta	0.7	0.1	0.5832	0.5290	0.6580
θ_N^*	beta	0.7	0.1	0.6716	0.6402	0.6953
θ_W	beta	0.8	0.1	0.9894	0.9870	0.9916
θ_W^*	beta	0.8	0.1	0.9788	0.9769	0.9808

when government debt is increasing. Tax rates move positively with government debt, therefore we assume that the γ-parameters for the tax rates have a normal distribution with a positive prior. Furthermore, we allow for correlation between tax rates by assuming a normal distribution with prior zero, in order not to impose any thought on whether the correlation should be positive or negative.

The variances of the 21 shocks are assumed to follow an inverted gamma distribution with prior means mainly equal to 5, as reported in table 3.4.4. Exceptions are the variance of consumer preference and labor preference shocks as well as shocks in capital income tax rates, investment efficiency and the interest rate. Moreover, shocks might be correlated across the two blocks of countries, therefore we estimate this correlation for all shocks, except for a shock to consumer preferences and investment efficiency for which we assume no correlation. The prior on this correlation is set equal to 0.5, as we expect shocks between the two regions in the Euro area to be positively correlated.

In addition to the prior distribution, tables 3.4.2, 3.4.3 and 3.4.4 reports the parameter estimates resulting from the Bayesian estimation with the Metropolis-Hastings algorithm. The results stress the importance of considering the two blocks of countries, North and South, as heterogeneous blocks, since the parameter estimates can differ substantially. The inverse elasticity of labor supply is

Table 3.4.3: Estimation results: Regional fiscal policy parameters

	Prior distribution			Posterior distribution		
	Type	Mean	St. Error	Mean	10%	90%
ρ_G	beta	0.7	0.1	0.7895	0.7020	0.8501
ρ_G^*	beta	0.7	0.1	0.7892	0.7343	0.8246
ρ_{τ_C}	beta	0.7	0.1	0.7292	0.6746	0.7858
$\rho_{\tau_C}^*$	beta	0.7	0.1	0.7887	0.7418	0.8550
ρ_{τ_K}	beta	0.7	0.1	0.5151	0.4446	0.5706
$\rho_{\tau_K}^*$	beta	0.7	0.1	0.5738	0.4850	0.6402
ρ_{τ_L}	beta	0.7	0.1	0.8330	0.7878	0.8901
$\rho_{\tau_L}^*$	beta	0.7	0.1	0.7914	0.7387	0.8373
ρ_Z	beta	0.7	0.1	0.8604	0.7810	0.9500
ρ_Z^*	beta	0.7	0.1	0.9132	0.8954	0.9297
ϕ_Z	normal	-0.1	0.1	-0.0451	-0.0696	-0.0312
ϕ_Z^*	normal	-0.1	0.1	-0.0592	-0.1236	-0.0164
γ_G	normal	-0.2	0.1	0.0845	0.0576	0.1174
γ_G^*	normal	-0.2	0.1	0.0787	0.0336	0.1265
γ_{τ_C}	normal	0.2	0.1	0.0960	0.0675	0.1309
$\gamma_{\tau_C}^*$	normal	0.2	0.1	0.0687	0.0359	0.1005
γ_{τ_K}	normal	0.2	0.1	0.2064	0.1027	0.3081
$\gamma_{\tau_K}^*$	normal	0.2	0.1	0.2416	0.1406	0.3488
γ_{τ_L}	normal	0.2	0.1	0.0763	0.0439	0.1154
$\gamma_{\tau_L}^*$	normal	0.2	0.1	0.1286	0.1013	0.1589
$\phi_{\tau_C\tau_K}$	normal	0	0.1	0.0026	-0.0000	0.0072
$\phi_{\tau_C\tau_K}^*$	normal	0	0.1	0.0021	-0.0032	0.0089
$\phi_{\tau_C\tau_L}$	normal	0	0.1	-0.0305	-0.0898	0.0558
$\phi_{\tau_C\tau_L}^*$	normal	0	0.1	-0.0511	-0.1259	0.0499
$\phi_{\tau_K\tau_C}$	normal	0	0.1	-0.0590	-0.1884	0.0718
$\phi_{\tau_K\tau_C}^*$	normal	0	0.1	-0.1578	-0.2515	-0.0462
$\phi_{\tau_K\tau_L}$	normal	0	0.1	-0.0185	-0.1102	0.1405
$\phi_{\tau_K\tau_L}^*$	normal	0	0.1	-0.0660	-0.1648	0.0584
$\phi_{\tau_L\tau_C}$	normal	0	0.1	-0.0111	-0.2098	0.1492
$\phi_{\tau_L\tau_C}^*$	normal	0	0.1	-0.0649	-0.1600	0.0416
$\phi_{\tau_L\tau_K}$	normal	0	0.1	-0.0002	-0.0070	0.0066
$\phi_{\tau_L\tau_K}^*$	normal	0	0.1	-0.0286	-0.0408	-0.0165

Table 3.4.4: Estimation results: Shock parameters

	Prior distribution			Posterior distribution		
	Type	Mean	St. Error	Mean	10%	90%
ρ_D	beta	0.7	0.1	0.9706	0.9588	0.9789
ρ_D^*	beta	0.7	0.1	0.9818	0.9741	0.9904
ρ_N	beta	0.8	0.1	0.9199	0.8991	0.9495
ρ_N^*	beta	0.8	0.1	0.8647	0.8199	0.9004
ρ_C	beta	0.7	0.1	0.8072	0.7782	0.8340
ρ_C^*	beta	0.7	0.1	0.7687	0.7281	0.7990
ρ_L	beta	0.7	0.1	0.5541	0.4758	0.6321
ρ_L^*	beta	0.7	0.1	0.2545	0.2058	0.3081
ρ_I	beta	0.7	0.1	0.7755	0.7479	0.7945
ρ_I^*	beta	0.7	0.1	0.8049	0.7887	0.8203
σ_D	inv. gamma	5	inf	2.6231	2.3019	3.0484
σ_D^*	inv. gamma	5	inf	2.9002	2.4211	3.3976
σ_N	inv. gamma	5	inf	2.1465	1.6224	2.6255
σ_N^*	inv. gamma	5	inf	2.6567	2.2713	3.4427
σ_C	inv. gamma	50	inf	48.6332	38.8198	59.6492
σ_C^*	inv. gamma	50	inf	53.1573	48.2783	56.4603
σ_L	inv. gamma	150	inf	172.4156	130.1887	206.3316
σ_L^*	inv. gamma	150	inf	347.4467	291.9749	409.5791
σ_G	inv. gamma	5	inf	0.9943	0.9083	1.0911
σ_G^*	inv. gamma	5	inf	1.2500	1.0816	1.4728
σ_I	inv. gamma	50	inf	46.3276	40.5957	51.7512
σ_I^*	inv. gamma	50	inf	43.4307	41.2986	45.8492
σ_R	inv. gamma	15	inf	16.9330	15.5673	19.1302
σ_{TC}	inv. gamma	5	inf	0.8158	0.7567	0.8912
σ_{TC}^*	inv. gamma	5	inf	1.1631	1.0601	1.2686
σ_{TK}	inv. gamma	30	inf	35.8199	30.6624	40.4097
σ_{TK}^*	inv. gamma	30	inf	28.5387	23.9674	32.7126
σ_{TL}	inv. gamma	5	inf	1.1178	1.0049	1.2343
σ_{TL}^*	inv. gamma	5	inf	1.4885	1.2497	1.7540
σ_Z	inv. gamma	5	inf	1.1839	0.998305	1.3717
σ_Z^*	inv. gamma	5	inf	1.5146	1.3826	1.6596
$corr_{D,D^*}$	normal	0.5	0.4	0.7236	0.6643	0.7997
$corr_{N,N^*}$	normal	0.5	0.4	0.9021	0.8839	0.9311
$corr_{L,L^*}$	normal	0.5	0.4	0.0140	−0.1471	0.2064
$corr_{G,G^*}$	normal	0.5	0.4	0.3610	0.0861	0.5046
$corr_{TC,TC^*}$	normal	0.5	0.4	0.4889	0.3051	0.6329
$corr_{TK,TK^*}$	normal	0.5	0.4	0.5617	0.4715	0.6832
$corr_{TL,TL^*}$	normal	0.5	0.4	0.4100	0.2713	0.5456
$corr_{Z,Z^*}$	normal	0.5	0.4	0.3879	0.0810	0.5736

estimated to be higher in South, in contrast to the indexation of prices and wages. These estimates are in line with the estimates of Jondeau and Sahuc (2008). The Calvo parameters do not differ as much. Capital adjustment costs are lower in North than in South, which is in line with evidence that these costs are low in Germany, the biggest country of the northern block (Pytlarczyk (2005)).

The most interesting results for the purpose of this chapter are the estimates on the regional fiscal policy parameters. The smoothing parameters for the policy rules do not show very large discrepancies between the two blocks. Except for capital income tax rates, the other fiscal policy variables are quite persistent. Surprisingly, the coefficient γ_G is significantly positive, suggesting that government expenditures react positively to an increase in government debt, in both the North as well as the South. Moreover, ϕ_Z is estimated to be negative, hence government transfers to households increase during recessions, and decrease during economic booms, suggesting that fiscal policy does act as an automatic stabilizer. Tax rates respond positively to government debt, meaning that tax rates increase whenever government debt increases. Since the expenditures side of the government fiscal policy is increasing with government debt, it is necessary to have a positive response of tax rates to debt for fiscal solvency. The correlations of the tax rates are not often significantly different from zero.

The posterior estimates on the AR(1) parameters of the shocks in table 3.4.4 suggest that the persistence of most shocks is larger in the North than in the South, except for a shock on domestic tradables and investment efficiency. Especially a shock to labor supply preferences is not as lasting in the South, a fact that might be related to the higher indexation of wages in the region. Estimates on the volatilities of shocks differ in size, indicating that shocks to consumer preferences, labor supply preferences and investment efficiency have much larger standard deviations than other shocks. In particular, the shock to labor supply preferences is significantly more volatile in South. Evidence is found that there are positive cross-region correlations of shocks, especially in the case of productivity shocks.

3.4.3 Robustness analysis

In order to establish the robustness of the posterior estimates of the model, we have run robustness checks on the priors chosen for the estimation. The priors for both parameters for the North and the South are altered at the same time, to keep a symmetric setting for the prior distribution in the estimation of the model.

Most of the parameters stay within or close to the confidence interval of the benchmark estimation, even for quite distant prior values. The general impression from the structural parameters is that the estimate is quite robust even to large changes in the prior, especially for the Calvo parameters of prices and wages. Similarly, the estimates of the AR(1) parameters of the shocks are also close to the benchmark estimate for any prior between 0 and 1.

With regard to the regional fiscal policy parameters, the response of government lump-sum transfers to households ϕ_Z as well as the responsiveness of the capital income tax rate to debt γ_{τ_K} are less robust to changing prior values of the mean. The sign of ϕ_Z is not necessarily negative in all robustness checks, which means that government transfers to households might respond positively to an increase in output, which is not in line with our expectations. However, for most priors this parameter will be negative for both the North and the South. Furthermore, we find that the parameter γ_G, which turned out to be surprisingly positive in the benchmark estimation, is also positive for different negative and positive priors. Hence, we are confident to claim that government consumption responds positively to the debt level, in both the North and the South.

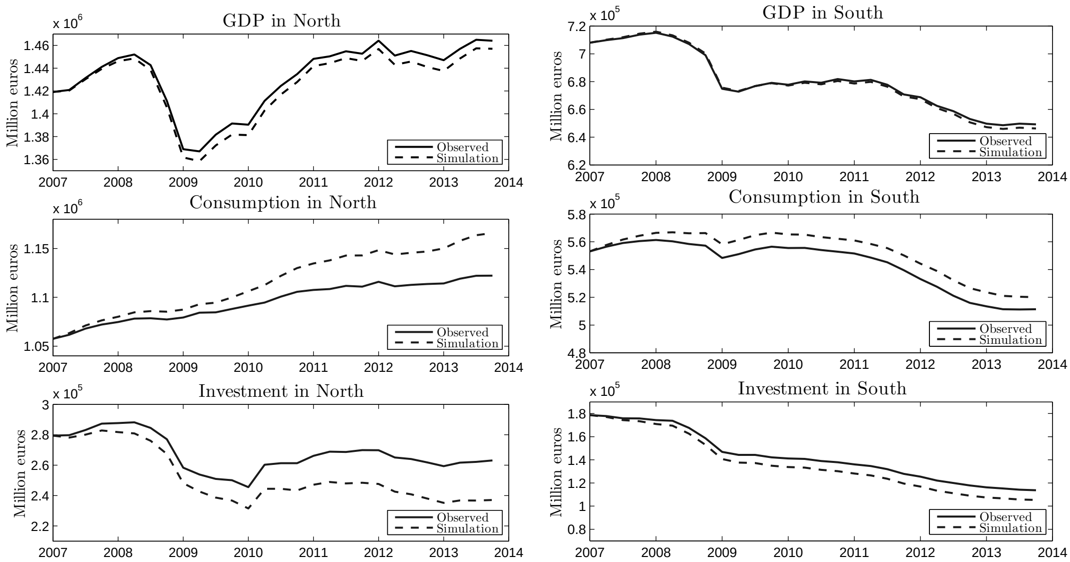
3.4.4 Fitting the model to the data

In order to say something valuable about the effectiveness of a transfer scheme in the Euro area using our model, we need to make sure that the estimated model fits the data quite well. Figure 3.1 plots the observed time series and the simulations for real GDP, real consumption and real investment from the first quarter of 2007 until the last quarter of 2013.

The simulations of the main macroeconomic variables are based on the policy functions and the exogenous shocks estimated by the model. The Bayesian estimation method reports the processes of the 21 shocks which we will use as the basis of the simulations. The economies start in the steady state and from then the economy responds to the exogenous shocks according to the policy functions that were estimated in the Bayesian estimation, using the estimated parameters for the North and the South. The model can reproduce the main behavior of the observed time series quite well. Although the levels do differ for some variables, the main peaks and drops are reflected well by the estimated model.

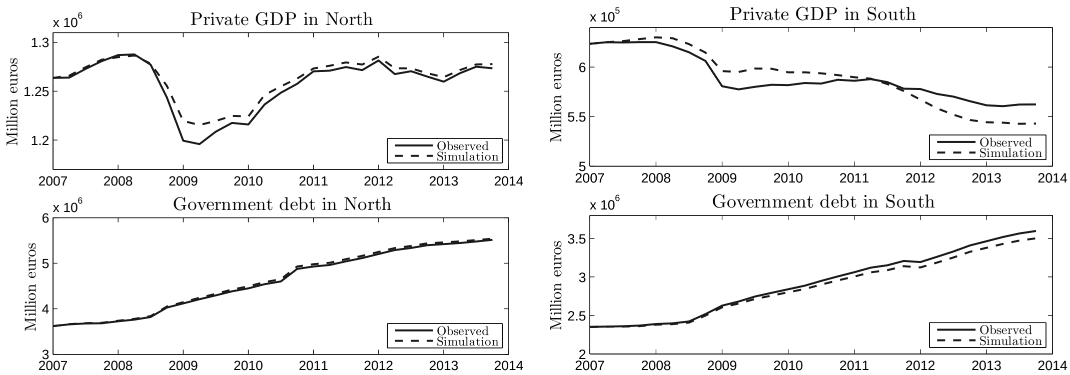
Moreover, the model simulations of private GDP and the government debt level are shown in figure 3.2. Private GDP contains both private consumption and private investment, and is effectively GDP minus government consumption. The model is doing quite well in reproducing the observed behavior of private GDP in the North, but is doing slightly worse for private GDP in the South.

Figure 3.1: Model simulations of GDP, consumption and investment



The new aspect of this model is the extensive fiscal policy sector, and hence one would expect that this model does well in reproducing the time series of fiscal variables. As figure 3.2 shows, the simulated series of government debt closely resembles the observed time series for the North and the South.

Figure 3.2: Model simulations of private GDP and government debt



3.5 Policy experiments

The Bayesian estimation of our DSGE model for the northern and southern region of the EMU has revealed significant heterogeneity in the structural parameters, as well as in the fiscal policy functions. The parameter estimates from the Bayesian estimation are used to simulate the behavior of the main macroeconomic variables for multiple purposes. Firstly, we will address the first main research question of this chapter, that asks to what extent a fiscal transfer mechanism would have helped to stabilize the economies of the North and the South during the last years of the crisis. Welfare analysis is performed to show how welfare is affected in case a transfer mechanism is introduced. Moreover, we will have a look into the optimal size of the transfer for this period considering multiple objectives. Secondly, we will analyze the introduction of a transfer mechanism at the start of the Economic and Monetary Union in Europe, to give an answer to the question how the transfer scheme would work in that situation. Lastly, we will answer the second research question of this chapter, namely whether the transfer mechanism would ex ante be beneficial for both regions.

3.5.1 Would a transfer mechanism have helped the South during the crisis?

In this section, we use the estimated DSGE model for the Euro area to analyze the effectiveness of the introduction of an automatic fiscal transfer mechanism just before the start of the most recent financial crisis. The automatic fiscal transfer mechanism is introduced in 2007, which is assumed to be the starting point for the determination of the percentage that a block receives from the common pool, implying that the net transfer equals zero in the first quarter of 2007. From then onwards, for South, the amount received from the common pool is larger than the amount paid to the common pool, so the South receives a net transfer from the North.

The fiscal transfer enters the economy through the fiscal policy rules, as it lightens the government budget by the amounted difference between the receipt from the common pool and the payment to the common pool. Let us first have a look at the effect of the transfer on the fiscal policy variables. As the coefficient γ_G is estimated to be positive for both the North and the South, we observe that government consumption increases in the North and decreases in the South as a result of the transfer. The lump-sum transfers from the government to households will decrease in the South and increase in the North, as these respond negatively to the GDP gap. The transfer makes the tax rates in North increase, whereas the tax rates on consumption, labor income as well as capital income will decrease in South. Government debt in North increases due to the payment of the transfer, an effect that is reinforced by the positive response of the government expenditures on the debt. In South, the government is receiving a net transfer and can therefore lower the amount of debt outstanding, which will lead them to lower their consumption as well with a further decreasing debt level as a result.

In North, the higher consumption tax rate will lead to a decrease in consumption, and the increase in the labor income tax rate causes a decrease in the net real wage, hence labor input goes down since the substitution effect of a drop in the real wage dominates the income effect. The opposite happens in South, where the drop in the tax rate on labor income leads to an increase in labor input. The lower tax rate on consumption leads to an increase in consumption in the South.

The output in the domestic tradables sector goes down in North because of the decrease in both consumption and investment. In South, the output in domestic tradables increases which comes from the increase in consumption and investment, although for the latter only until the beginning in 2012. In South, the nontradables output goes up, in spite of the decrease in government consumption, that is part of nontradables output since the government is assumed to only spend resources in the domestic nontradables sector. A striking result from the Bayesian estimation is that government expenditures increase with government debt, so the effect of the transfer on consumption and investment is reduced by the decrease in government consumption in South. Hence, if we would look at the effect of the introduction of a fiscal transfer mechanism on GDP when corrected for government expenditures[15], see table 3.5.1, then the transfer would have a significantly larger impact on both the North and the South.

The fiscal transfer mechanism is designed in such a way that the region with a relatively worse position compared to the starting point or steady state will receive a net transfer from the other region. Specifically, if the southern GDP is lower compared to its steady state than the ratio of last year's GDP to the steady state GDP of the North, then the South will receive a net transfer from the North. The size of the transfer will depend on the difference in the stance of the economy in both regions. If the South is experiencing a severe downturn and the North is doing rather well, the transfer will be bigger than in the case where both regions are suffering from a recession or are experiencing a boom.

[15]We will use the term 'private GDP' for output or GDP corrected for government consumption, as this reflects private consumption and private investment in the economy.

Regions pay 10% of their real GDP[16] of last year to the common pool, from which the money will be redistributed according to the levels of their share of GDP in the union's GDP at the introduction of the transfer mechanism. Even though the percentage paid to the common pool is quite high, the transfer is at maximum 5642 million euro in the last quarter of 2013, which is 0.39% of the GDP of the North. The South will receive this transfer which is 0.87% of southern GDP. The average size of the transfer over the period 2007-2013, being paid or received every quarter, is 1990 million euro which is 0.14% of GDP for the North and 0.31% of the South. However, the effect of the transfer is only slightly smaller in terms of the main macroeconomic variables, as can be seen in table 3.5.1.

Table 3.5.1: Effectiveness of transfer mechanism on main variables

Variable	Average effect	Maximum effect
GDP in North	-0.09%	-0.26%
GDP in South	+0.16%	+0.50%
Consumption in North	-0.19%	-0.27%
Consumption in South	+0.31%	+0.49%
Investment in North	-0.18%	-0.45%
Investment in South	+0.22%	+0.80%
Private GDP in North	-0.12%	-0.31%
Private GDP in South	+0.22%	+0.58%

The introduction of an automatic fiscal transfer mechanism in 2007 would have helped the southern countries to dampen the effects of the financial crisis on their economies. Consumption would have been 0.31% higher on average due to a transfer from the North which is on average 0.31% of GDP in the South. The northern countries would have had lower levels of GDP, consumption, investment and private GDP due to the transfer, however, the negative effect for the North is smaller than the positive effect for the South if we look at these main macroeconomic variables.[17]

[16] The contribution to the common pool is set arbitrarily to 10% of GDP. The average size of the transfer is much smaller however. Changing the size of the contribution to the common pool will lead to larger transfers, and in general also to larger effects of the transfer mechanism. In section 5.1.2, we discuss briefly the implications of changing the size of the transfer by looking at the optimal size of the transfer for different objectives.

[17] We realize that these quantitative results depend on the assumption that the values for the

Welfare

In order to assess the impact of the fiscal transfer mechanism on the consumers in both regions, we will use the consumption-equivalent welfare measure that can tell us how consumption should be affected in order to have the same utility level as without the introduction. This welfare measure is based on the utility function in which consumption affects utility positively and for which we assume that consumers dislike labor input. From the simulation results, it becomes clear that welfare in South would have increased if a transfer mechanism was introduced in 2007, since consumption has increased, and the volatility of both consumption and labor have decreased. In North, consumption has decreased and the variance of consumption and labor over the simulation have increased, leading to a welfare loss for the consumers in North. These welfare changes can be expressed in terms of steady state consumption, where a negative value means that a lower level of steady state consumption would be needed to make the North indifferent between the situation with transfer scheme compared to the steady state. For the South, the opposite reasoning applies, so that consumers would like to receive more steady state consumption than in the situation without the transfer mechanism in order to be equally well off as in the steady state. The results for the change in the consumption equivalent welfare measure λ, as well as for the decomposition of λ, are presented in table 3.5.2 in both percentages and in terms of steady state consumption level.

Table 3.5.2: Consumption-equivalent welfare measure (2007-2013)

	North		South	
	In percentages	In steady state consumption	In percentages	In steady state consumption
$\Delta\lambda$	-3.02%	-29296 m euro	+3.48%	+16521 m euro
$\Delta\lambda_M$	+0.02%	-194 m euro	-0.04%	+190 m euro
$\Delta\lambda_V$	-3.04%	-29490 m euro	+3.51%	+16663 m euro
$\Delta\lambda_{M,c}$	-0.04%	-388 m euro	+0.08%	+380 m euro
$\Delta\lambda_{M,l}$	+0.07%	+679 m euro	-0.11%	-522 m euro
$\Delta\lambda_{V,c}$	-0.19%	-1843 m euro	+0.27%	+1282 m euro
$\Delta\lambda_{V,l}$	-2.85%	-27647 m euro	+3.25%	+15429 m euro

fiscal policy parameters do not change when a fiscal transfer mechanism is introduced. However, the results on the effectiveness of this transfer scheme are qualitatively robust and respond quantitatively only very little to changes in values of these parameters within their confidence interval. If a decrease in the responsiveness of one tax rate to government debt is compensated with the increase of this parameter for another tax rate, the results are particularly robust.

The table reports the welfare measure λ over the period 2007 until 2013 for both the North and the South, which has the expected sign. The second column shows that consumption in the North should have been 3.02% higher in order to experience the same welfare level as without the transfer mechanism. The minus sign thus indicates that the North would experience a welfare loss if the mechanism would be introduced. Since South benefits from this mechanism, consumption should have been 3.48% lower in order for South to attain the level of welfare that it would have had without the transfers, hence the welfare gain is 3.48%. If we would express the welfare gains and losses in terms of steady state consumption, we find that the North should have had 29296 million euro in order to have the same welfare as without the transfers, which is the welfare loss. On the other hand, for the South, the welfare gain is equal to 16521 million euro. The welfare gain is lower than the welfare loss indicating that for the union as a whole the effect of a transfer scheme on welfare would be negative.

Optimal size of the transfer

Depending on the objective, we could determine the optimal size of the transfer if such a mechanism would have been introduced just before the start of the crisis. The size of the transfer would then be determined by the amount paid by each region to the common pool, i.e. ψ_{PAY}.[18] If policymakers take into consideration only the absolute welfare gains and losses, the transfer mechanism would not have been introduced. However, if the objective would to minimize the weighted sum of the variance of output, the optimal ψ_{PAY} would be 0.2. Each region should pay 40% of its GDP to the common pool to minimize the weighted variance of consumption, whereas ψ_{PAY} should be equal to 0.1 in order to minimize the weighted variance of private GDP. Hence, a high transfer might work better for stabilizing consumption fluctuations. However, taking into account the considerable welfare loss for the North, a transfer of smaller size might be more attainable.

3.5.2 Who will receive the transfer?

Rather than introducing the fiscal transfer mechanism in 2007, one could also imagine the implementation of such a transfer mechanism from the start of the EMU. When we introduce the fiscal transfer mechanism at the start of our simu-

[18]Here, the maximum amount of transfer that is still feasible within the model is constructed with $\psi_{PAY} = 0.475$.

lation period[19], the simulations depict an interesting result. Based on the share of GDP of both North and South in the second quarter of 2000, the net transfer will go from South to North, hence the South will actually be paying to the North until 2010.

The design of the transfer mechanism implemented in our model, with payments proportional to GDP and receipts on the basis of the share of GDP in the GDP of the union at the introduction of the mechanism, implies that the North as well as the South can become the one profiting from the transfer mechanism. The South has grown faster than the North from 2000 until 2004, which is the reason that the North has become a net receiver. Afterwards, it still takes time for the North to catch up with the South, which is the reason why the transfer goes in the direction of the northern countries until 2010.

In terms of political feasibility, this aspect of the fiscal transfer mechanism can help in convincing countries that the system will not be a one-way street. Depending on the starting year, which is also an important factor to play with in the public debate, the transfers could go in either the northern or the southern direction. But most importantly, upfront there are no clear winners or losers, since the transfer will be based on the growth of GDP that economies experience after the start. As the above mentioned aspects are reasons for mainly the northern countries not to head towards deeper fiscal integration, this result might increase the support for an automatic fiscal transfer mechanism or any other type of fiscal integration.

3.5.3 Would a transfer mechanism be beneficial for the future?

In order to assess whether an automatic fiscal transfer scheme could actually be implemented in the Euro area, it is important to gain knowledge about the ex ante implications of such a mechanism. Without clear ex ante benefits to both regions, there would be no common ground for the North and the South of Europe to take off with such an initiative. For this purpose, the model has been simulated for 200 periods in the future, equal to 50 years, using random shocks[20]

[19] Please note that the start of our simulation period, i.e. the second quarter of 2000, is not the same as the official start of the EMU, or the effective start with the introduction of the euro. However, this is the closest one could get to this, since we would like to have the transfer mechanism starting with a zero net transfer in the first period to make sure that the system is able to get political support.

[20] We only take into account the main shocks of the model, i.e. shocks to productivity and investment efficiency. Shocks to consumer and labor supply preferences affect both the behavior of the economy as well as the welfare function itself, which makes identification of the welfare

occurring every period in both the North and the South.[21] A transfer scheme would be deemed valuable to regions involved if the transfer would be expected to lead to increased welfare.[22] The average results over 10.000 simulations show us what countries could expect of a transfer system in terms of long run welfare effects.

Table 3.5.3: Simulation for the future: welfare effect of transfer mechanism

	North		South	
	In percentages	In steady state consumption	In percentages	In steady state consumption
$\Delta\lambda$	+2.37%	+22990 m euro	+3.08%	+14622 m euro
$\Delta\lambda_M$	+0.02%	+194 m euro	-0.06%	-285 m euro
$\Delta\lambda_V$	+2.35%	+22796 m euro	+3.14%	+14907 m euro
$\Delta\lambda_{M,c}$	-0.08%	-776 m euro	+0.14%	+665 m euro
$\Delta\lambda_{M,l}$	+0.10%	+970 m euro	-0.20%	-950 m euro
$\Delta\lambda_{V,c}$	+0.29%	+2813 m euro	+0.03%	+142 m euro
$\Delta\lambda_{V,l}$	+2.06%	+19983 m euro	+3.11%	+14765 m euro

Table 3.5.3 depicts the average change in welfare over the 10.000 simulations, including a decomposition of the welfare components, caused by the presence of a fiscal transfer mechanism. The transfer mechanism is expected to be beneficial for both North and South, as there are substantial welfare gains for both regions. On average over the simulations, the welfare benefit would be equivalent to 22990 million euro in the North and 14622 million euro in the South.

The welfare decomposition shows that the transfer mechanism is expected to do well in terms of stabilizing the economy, as both the welfare component related to the variance of labor input and the variance of consumption are, on average over the simulations, positive for both regions. Although there is a negative average level effect for the mean of consumption in the North and for the mean of labor input in the South, these numbers are negligible compared to

effects of the transfer hardly possible. Fiscal policy shocks are ignored else these shocks might interfere with the working of the transfer scheme, and identification of the effect of the transfer scheme would be hindered.

[21] The distribution of shocks is given by the estimated mean and variance of the shocks, estimated over the period 2000-2013 by the model. Both the North and the South can experience a shock every period. However, there is also the possibility that a region is not affected by a shock in a certain period.

[22] For welfare, we use the consumption equivalent measure λ as explained in section 3.6. In the table we report the percentage welfare change due to the transfer scheme in terms of steady state consumption.

the positive welfare components. Hence, a transfer mechanism would ex ante be beneficial for both the North and the South in terms of welfare projections.

The direction of the transfer during the simulated future period of 50 years will also matter for the attainability of a fiscal transfer scheme, since a region is not willing to participate in such a scheme if there is a possibility that the transfer will always go in the direction of the other region. In our 10.000 simulations, it does not happen once that the transfer only goes into one direction during the course of 200 periods. Hence, ex ante, regions can expect that in the future the transfer will go both from the North to South and vice versa. Moreover, it is almost as likely that the North is receiving a transfer from the South as the other way around. In the simulations, on average the North is receiving the transfer in 48.1% of the future periods and the South is receiving it 51.9% of the periods. Therefore, we can conclude that the design of the transfer mechanism does not have clear winners and losers ex ante.

3.6 Risk sharing

3.6.1 Variance decomposition of shocks to output

To relate the analysis in this chapter to the empirical literature on the channels of risk sharing, we will decompose the variance of GDP into three different channels of risk sharing and compare these with the empirical estimates for existing monetary unions. The most influential empirical paper on this topic is Asdrubali et al. (1996), who estimate that around 10% of a shock to regional GDP on the state level is insured by the US federal fiscal system. Sorensen and Yosha (1998) use the same methods to estimate the regional income insurance also in European countries, and find that there is hardly any risk sharing through the federal government. We will use these methods to measure the fraction of shocks to output that are smoothened via the transfer mechanism.

The approach by Asdrubali et al. (1996) decomposes cross-country variance in GDP into several components to identify the amount of capital market smoothing, credit market smoothing and federal government smoothing. The following identity for GDP is used[23]:

$$gdp_t = \frac{gdp_t}{ni_t} \cdot \frac{ni_t}{dni_t} \cdot \frac{dni_t}{c_t} \cdot c_t \tag{3.72}$$

[23]Instead of GDP and the sum of private and public consumption, we will use private GDP and private consumption in order to identify the risk sharing channels beyond the disturbing behavior of government consumption.

where gdp_t is the output level in either one of the regions at time t, ni_t denotes real national income, dni_t denotes real disposable national income and c_t is the sum of private consumption expenditures. The difference between GDP and national income consists of factor payments across regions as well as capital depreciation, but we do not observe any factor payments across the border in our model. Smoothing via factor payments or capital depreciation is called capital market smoothing. Disposable national income is national income corrected for the payment or receipt of federal fiscal transfers, and thus measures the scope of risk sharing through the federal budget. The third channel of inter-country risk sharing is the savings channel, as the difference between disposable national income and the private consumption expenditures is given by the savings in a country.

Asdrubali et al. (1996) express the identity in equation (3.72) in terms of log-deviations from the steady state, multiply both sides by the log-deviation of GDP and then take expectations of both sides to get the following expression:

$$\begin{aligned} \mathrm{var}(\hat{gdp}_t) = {} & \mathrm{cov}(\hat{gdp}_t - \hat{ni}_t, \hat{gdp}_t) + \mathrm{cov}(\hat{ni}_t - \hat{dni}_t, \hat{gdp}_t) \\ & + \mathrm{cov}(\hat{dni}_t - \hat{c}_t, \hat{gdp}_t) + \mathrm{cov}(\hat{c}_t, \hat{gdp}_t) \end{aligned} \tag{3.73}$$

If we now divide the equation by the variance of GDP, we find the coefficients that indicate the size of the risk sharing channels:

$$1 = \beta_K + \beta_F + \beta_S + \beta_U \tag{3.74}$$

where for example $\beta_F = \frac{\mathrm{cov}(\hat{ni}_t - \hat{dni}_t, \hat{gdp}_t)}{\mathrm{var}(\hat{gdp}_t)}$ is the amount of a shock that is smoothened by the federal budget. The same holds for β_K with capital market smoothing and β_S with smoothing by savings, and β_U represents the amount that is unsmoothened. Full risk sharing between the two regions in the monetary union would thus mean that $\beta_U = 0$, and the larger β_F, the more smoothing of asymmetric shocks to GDP is achieved by federal fiscal arrangements. The estimation of the model in Dynare will give us information on the variance and covariance of these variables, and the results will be presented in the next section.

3.6.2 Channels of risk sharing between regions

Using the method explained in section 6.1, we will quantitatively analyze the amount of risk sharing by the fiscal transfer mechanism for shocks to GDP. The results of the variance decomposition of output are presented for the situation without and with a transfer mechanism.[24] Table 3.6.1 shows the results of the variance decomposition for the estimated model for productivity shocks that affect GDP.[25]

Table 3.6.1: Channels of risk sharing for productivity shocks

Scenario	Capital market β_K	Transfer mechanism β_F	Savings β_S	Unsmoothened β_U
North no transfer	32.3%	0.0%	32.3%	35.4%
South no transfer	30.9%	0.0%	35.3%	33.8%
North with transfer	22.6%	29.9%	21.3%	26.3%
South with transfer	22.0%	28.0%	24.3%	25.7%

When there is no transfer mechanism, there is no risk sharing through the federal channel in the North and the South since only the transfer would affect disposable national income in the model. In reality, the federal government in the EU also has regional programs for structural inequalities that would affect disposable national income, but these programs are not included in our model. The transfer mechanism in this monetary union will smooth 29.9% of a productivity shock in North and 28.0% of a shock in South. This means that ex ante the transfer mechanism has larger benefits in terms of interregional risk sharing for North than for South, as the simulations for the future in section 5.3 also showed. The amount of smoothing via the capital market is reduced, and the savings channel becomes less important due to the fiscal transfer mechanism. Apparently, the fiscal transfers crowd out private savings such that savings do not co-move as much with shocks to GDP. The benefit of the introduction of the transfer mechanism is clear from the last column in table 3.6.1, which shows that the amount of risk that is unsmoothened decreases in both North and South when a transfer scheme is introduced. Hence, a consumer is less affected by a shock to the GDP of its country in case fiscal transfers exist. This quantitative assessment of the channels of interregional risk sharing in our two-region model of the Euro area is relatively close to the estimates of Asdrubali et al. (1996) for the United States. The main difference is that the capital market channel

[24]The parameter ψ_{PAY} for the size of the transfer is set to $\psi_{PAY} = 0.1$.

[25]In the analysis here, we disregard government expenditures in order to have a clear idea of what a transfer mechanism could mean in terms of risk sharing for consumers in the North and the South of the EMU.

appears to be much more important in the United States, whereas the effect that federal fiscal arrangements, and in our model the fiscal transfers, have on interregional risk sharing is potentially larger for the EMU.

3.7 Conclusion

This chapter provides both a qualitative and a quantitative analysis of the effectiveness of a transfer mechanism in the Economic and Monetary Union, for the past and the future. A DSGE model with two asymmetric regions is estimated using Bayesian methods for a northern and southern block of countries within the Euro area, and the simulations of this model follow the observed data quite closely. The estimated model is used to simulate the hypothetical introduction of an automatic fiscal transfer mechanism in 2007 in the EMU. Moreover, the ex ante implications for the future are studied, by running 10.000 simulations over 50 years in order to get a clear picture on stabilization and welfare consequences.

The design of the transfer scheme is innovative with regard to the implementability of the mechanism in the Euro area. Due to the dependence of the transfer on the relative growth rate in GDP, moral hazard is eliminated as much as possible. Moreover, there are no clear winners or losers upfront, which will make policymakers more eager to implement such a scheme. When introduced in 2007, the transfer scheme would have resulted in a transfer from the North to the South. However, if such a mechanism was introduced in 2000, the South would have been paying a transfer to the North for almost 10 years. The simulations for the future with random shocks show that over all simulations with 200 periods, the transfer will never go in one way and both regions are equally likely to become net recipient, underlining the political feasibility of this specific transfer mechanism compared to other schemes proposed in the literature.

The analysis of the estimated model and simulations suggests that a transfer mechanism would have been effective in stabilizing the southern economy in the financial crisis. Over the period between 2007 and 2013, consumption and private GDP would have been, respectively, 0.31% and 0.22% higher, achieved by a transfer of 0.31% of southern GDP. This mechanism would have led to a welfare loss for the North that is larger than the welfare gain for the South in absolute terms. The decision for policymakers on whether to introduce a transfer scheme, and if so, then to what extent, depends largely on the objective chosen. If the objective would be to maximize the weighted sum of welfare in absolute terms no transfer would have been introduced in 2007, whereas a large transfer scheme would have been introduced if the objective function would entail the weighted variance of consumption.

The discussion about the implementation of a fiscal transfer scheme will depend on policymakers' expectations for the future. The simulations for the future using random shocks show that the transfer scheme would be ex ante beneficial for both the North and the South, as the introduction would imply an average welfare gain of 2.37% for the North and 3.08% for the South. These positive welfare expectations for the future might increase the support for such a way of deeper fiscal integration within the Euro area.

There are several interesting directions along which future research could be extended. More countries could be introduced in the model in order to give a clear representation of the whole EMU and what a transfer mechanism could mean for all countries involved. Furthermore, as there are also discussions about whether there should be even more integration in the form of a fiscal union, one could compare the transfer mechanism as designed here with a common fiscal authority that decides on government expenditures and taxes for all member countries. Besides, the question on how the optimal fiscal transfer rule would look like is one that is stimulated to be answered in the future by the findings in this chapter. Finally, monetary policy is left untouched in this chapter, but an interesting dimension for future research would be the interaction between monetary policy and fiscal policy integration in Europe.

3.A Appendix

3.A.1 Log-linearized model

This section contains the log-linearized equations of the model. The variables in small letters with a hat denote the log deviations from the steady state. The constant terms with bar and without time subscript are the steady state values of the corresponding variables.
Market-clearing conditions

$$\hat{y}^i_{N,t} = \frac{\bar{C}}{\bar{Y}_N}(1-\gamma_C)\left(\hat{c}^i_t - \gamma_C \hat{x}^i_t\right) + \frac{\bar{I}}{\bar{Y}_N}(1-\gamma_I)\left(\hat{i}^i_t - \gamma_I \hat{x}^i_t\right) + \frac{\bar{G}}{\bar{Y}_N}\hat{g}^i_t \quad (3.A.1)$$

$$\hat{y}^{i*}_{N,t} = \frac{\bar{C}^*}{\bar{Y}^*_N}(1-\gamma^*_C)\left(\hat{c}^{i*}_t - \gamma^*_C \hat{x}^{i*}_t\right) + \frac{\bar{I}^*}{\bar{Y}^*_N}(1-\gamma^*_I)\left(\hat{i}^{i*}_t - \gamma^*_I \hat{x}^{i*}_t\right) + \frac{\bar{G}^*}{\bar{Y}^*_N}\hat{g}^{i*}_t \quad (3.A.2)$$

$$\begin{aligned} \hat{y}^i_{D,t} = & \frac{\bar{C}}{\bar{Y}_D}\gamma_C \alpha \left(\hat{c}^i_t + (1-\gamma_C)\hat{x}^i_t + (1-\alpha)\hat{t}^i_{i*,t}\right) \\ & + \frac{\bar{I}}{\bar{Y}_D}\gamma_I \alpha \left(\hat{i}^i_t + (1-\gamma_I)\hat{x}^i_t + (1-\alpha)\hat{t}^i_{i*,t}\right) \\ & + \frac{\bar{C}^*}{\bar{Y}_D}\frac{1-n}{n}\gamma^*_C(1-\alpha^*)\left(\hat{c}^{i*}_t + (1-\gamma^*_C)\hat{x}^{i*}_t + \alpha^*\hat{t}^i_{i*,t}\right) \\ & + \frac{\bar{I}^*}{\bar{Y}_D}\frac{1-n}{n}\gamma^*_I(1-\alpha^*)\left(\hat{i}^{i*}_t + (1-\gamma^*_I)\hat{x}^{i*}_t + \alpha^*\hat{t}^i_{i*,t}\right) \end{aligned} \quad (3.A.3)$$

$$\begin{aligned} \hat{y}^{i*}_{D,t} = & \frac{\bar{C}^*}{\bar{Y}^*_D}\gamma^*_C \alpha^* \left(\hat{c}^{i*}_t + (1-\gamma^*_C)\hat{x}^{i*}_t - (1-\alpha^*)\hat{t}^i_{i*,t}\right) \\ & + \frac{\bar{I}^*}{\bar{Y}^*_D}\gamma^*_I \alpha^* \left(\hat{i}^{i*}_t + (1-\gamma^*_I)\hat{x}^{i*}_t - (1-\alpha^*)\hat{t}^i_{i*,t}\right) \\ & + \frac{\bar{C}}{\bar{Y}^*_D}\frac{n}{1-n}\gamma_C(1-\alpha)\left(\hat{c}^i_t + (1-\gamma_C)\hat{x}^i_t - \alpha\hat{t}^i_{i*,t}\right) \\ & + \frac{\bar{I}}{\bar{Y}^*_D}\frac{n}{1-n}\gamma_I(1-\alpha)\left(\hat{i}^i_t + (1-\gamma_I)\hat{x}^i_t - \alpha\hat{t}^i_{i*,t}\right) \end{aligned} \quad (3.A.4)$$

$$\hat{y}^i_t = \frac{\bar{Y}_D}{\bar{Y}}\hat{y}^i_{D,t} + \frac{\bar{Y}_N}{\bar{Y}}\hat{y}^i_{N,t} \quad (3.A.5)$$

$$\hat{y}^{i*}_t = \frac{\bar{Y}^*_D}{\bar{Y}^*}\hat{y}^{i*}_{D,t} + \frac{\bar{Y}^*_N}{\bar{Y}^*}\hat{y}^{i*}_{N,t} \quad (3.A.6)$$

Consumption (Euler) equations

$$\begin{aligned}\hat{c}_t^i - h\hat{c}_{t-1}^i = \mathrm{E}_t\left(\hat{c}_{t+1}^i - h\hat{c}_t^i\right) - \frac{1-h}{\sigma}\left(\hat{r}_t - \mathrm{E}_t\hat{\pi}_{C,t+1}^i\right) \\ + \frac{1-h}{\sigma}\mathrm{E}_t(\varepsilon_{C,t}^i - \varepsilon_{C,t+1}^i) - \frac{1-h}{\sigma}\left(\hat{\tau}_{C,t}^i - \hat{\tau}_{C,t+1}^i\right)\end{aligned} \tag{3.A.7}$$

$$\begin{aligned}\hat{c}_t^{i*} - h^*\hat{c}_{t-1}^{i*} = \mathrm{E}_t\left(\hat{c}_{t+1}^{i*} - h^*\hat{c}_t^{i*}\right) - \frac{1-h^*}{\sigma^*}\left(\hat{r}_t - \mathrm{E}_t\hat{\pi}_{C,t+1}^{i*}\right) \\ + \frac{1-h^*}{\sigma^*}\mathrm{E}_t(\varepsilon_{C,t}^{i*} - \varepsilon_{C,t+1}^{i*}) - \frac{1-h^*}{\sigma^*}\left(\hat{\tau}_{C,t}^{i*} - \hat{\tau}_{C,t+1}^{i*}\right)\end{aligned} \tag{3.A.8}$$

International risk sharing condition

$$\hat{q}_{i*,t}^i = \varepsilon_{C,t}^{i*} - \varepsilon_{C,t}^i - \frac{\sigma^*}{1-h^*}\cdot\left(\hat{c}_t^{i*} - h^*\hat{c}_{t-1}^{i*}\right) + \frac{\sigma}{1-h}\cdot\left(\hat{c}_t^i - h\hat{c}_{t-1}^i\right) \tag{3.A.9}$$

Capital accumulation

$$\hat{k}_{t+1}^i = (1-\delta)\hat{k}_t^i + \delta(\varepsilon_{I,t}^i + \hat{i}_t^i) \tag{3.A.10}$$

$$\hat{k}_{t+1}^{i*} = (1-\delta^*)\hat{k}_t^{i*} + \delta^*(\varepsilon_{I,t}^{i*} + \hat{i}_t^{i*}) \tag{3.A.11}$$

Real cost of capital

$$\hat{r}_{K,t}^i = \hat{w}_t^i + \hat{l}_t^i - \hat{k}_t^i \tag{3.A.12}$$

$$\hat{r}_{K,t}^{i*} = \hat{w}_t^{i*} + \hat{l}_t^{i*} - \hat{k}_t^{i*} \tag{3.A.13}$$

Investment demand

$$\hat{i}_t^i - \hat{i}_{t-1}^i = \beta\mathrm{E}_t\left(\hat{i}_{t+1}^i - \hat{i}_t^i\right) + \frac{1}{S''}\left(\hat{q}_{T,t}^i + \varepsilon_{I,t}^i\right) + \frac{\gamma_I - \gamma_C}{S''}\hat{x}_t^i \tag{3.A.14}$$

$$\hat{i}_t^{i*} - \hat{i}_{t-1}^{i*} = \beta^*\mathrm{E}_t\left(\hat{i}_{t+1}^{i*} - \hat{i}_t^{i*}\right) + \frac{1}{S''*}\left(\hat{q}_{T,t}^{i*} + \varepsilon_{I,t}^{i*}\right) + \frac{\gamma_I^* - \gamma_C^*}{S''*}\hat{x}_t^{i*} \tag{3.A.15}$$

Price of installed capital

$$\begin{aligned}\hat{q}_{T,t}^i = \beta(1-\delta)\mathrm{E}_t\hat{q}_{T,t+1}^i - \left(\hat{r}_t - \mathrm{E}_t\hat{\pi}_{C,t+1}^i\right) \\ + (1-\beta(1-\delta))\mathrm{E}_t\left(\hat{r}_{K,t+1}^i - \hat{\tau}_{K,t}^i\right)\end{aligned} \tag{3.A.16}$$

$$\begin{aligned}\hat{q}_{T,t}^{i*} = \beta^*(1-\delta^*)\mathrm{E}_t\hat{q}_{T,t+1}^{i*} - \left(\hat{r}_t - \mathrm{E}_t\hat{\pi}_{C,t+1}^{i*}\right) \\ + (1-\beta^*(1-\delta^*))\mathrm{E}_t\left(\hat{r}_{K,t+1}^{i*} - \hat{\tau}_{K,t}^{i*}\right)\end{aligned} \tag{3.A.17}$$

Labor input

$$\hat{l}_t^i = \eta \left(\hat{r}_{K,t}^i - \hat{w}_t^i\right) + \frac{\bar{Y}_D}{\bar{Y}} \left(\hat{y}_{D,t}^i - a_{D,t}^i\right) + \frac{\bar{Y}_N}{\bar{Y}} \left(\hat{y}_{N,t}^i - a_{N,t}^i\right) \tag{3.A.18}$$

$$\hat{l}_t^{i*} = \eta^* \left(\hat{r}_{K,t}^{i*} - \hat{w}_t^{i*}\right) + \frac{\bar{Y}_D^*}{\bar{Y}^*} \left(\hat{y}_{D,t}^{i*} - a_{D,t}^{i*}\right) + \frac{\bar{Y}_N^*}{\bar{Y}^*} \left(\hat{y}_{N,t}^{i*} - a_{N,t}^{i*}\right) \tag{3.A.19}$$

Real wage rate

$$\begin{aligned} \hat{w}_t^i = & \frac{\beta}{1+\beta} \mathrm{E}_t \hat{w}_{t+1}^i + \frac{1}{1+\beta} \hat{w}_{t-1}^i + \frac{\beta}{1+\beta} \mathrm{E}_t \hat{\pi}_{C,t+1}^i - \frac{1+\beta\delta_W}{1+\beta} \hat{\pi}_{C,t}^i \\ & + \frac{\delta_W}{1+\beta} \hat{\pi}_{C,t-1}^i - \frac{(1-\theta_W)(1-\beta\theta_W)}{\theta_W(1+\beta)} (M\hat{R}S_t^i - \tau_{L,t}^i) \end{aligned} \tag{3.A.20}$$

$$\begin{aligned} \hat{w}_t^{i*} = & \frac{\beta^*}{1+\beta^*} \mathrm{E}_t \hat{w}_{t+1}^{i*} + \frac{1}{1+\beta^*} \hat{w}_{t-1}^{i*} + \frac{\beta^*}{1+\beta^*} \mathrm{E}_t \hat{\pi}_{C,t+1}^{i*} - \frac{1+\beta^*\delta_W^*}{1+\beta^*} \hat{\pi}_{C,t}^{i*} \\ & + \frac{\delta_W^*}{1+\beta^*} \hat{\pi}_{C,t-1}^{i*} - \frac{(1-\theta_W^*)(1-\beta^*\theta_W^*)}{\theta_W^*(1+\beta^*)} (M\hat{R}S_t^{i*} - \tau_{L,t}^{i*}) \end{aligned} \tag{3.A.21}$$

Marginal rate of substitution between consumption and labor

$$M\hat{R}S_t^i = \varepsilon_{L,t}^i - \varepsilon_{C,t}^i + \phi \cdot \hat{l}_t^i + \frac{\sigma}{1-h} \left(\hat{c}_t^i - h\hat{c}_{t-1}^i\right) \tag{3.A.22}$$

$$M\hat{R}S_t^{i*} = \varepsilon_{L,t}^{i*} - \varepsilon_{C,t}^{i*} + \phi^* \cdot \hat{l}_t^{i*} + \frac{\sigma^*}{1-h^*} \left(\hat{c}_t^{i*} - h^*\hat{c}_{t-1}^{i*}\right) \tag{3.A.23}$$

Domestic tradable goods Phillips curves

$$\hat{\pi}_{D,t}^i = \frac{\beta}{1+\beta\delta_D} \mathrm{E}_t \hat{\pi}_{D,t+1}^i + \frac{\delta_D}{1+\beta\delta_D} \hat{\pi}_{D,t-1}^i + \frac{(1-\theta_D)(1-\theta_D\beta)}{\theta_D(1+\beta\delta_D)} \hat{MC}_{D,t}^i \tag{3.A.24}$$

$$\hat{\pi}_{D,t}^{i*} = \frac{\beta^*}{1+\beta^*\delta_D^*} \mathrm{E}_t \hat{\pi}_{D,t+1}^{i*} + \frac{\delta_D^*}{1+\beta^*\delta_D^*} \hat{\pi}_{D,t-1}^{i*} + \frac{(1-\theta_D^*)(1-\theta_D^*\beta^*)}{\theta_D^*(1+\beta^*\delta_D^*)} \hat{MC}_{D,t}^{i*} \tag{3.A.25}$$

Nontradable goods Phillips curves

$$\hat{\pi}^{i}_{N,t} = \frac{\beta}{1+\beta\delta_N}\mathrm{E}_t\hat{\pi}^{i}_{N,t+1} + \frac{\delta_N}{1+\beta\delta_N}\hat{\pi}^{i}_{N,t-1} + \frac{(1-\theta_N)(1-\theta_N\beta)}{\theta_N(1+\beta\delta_N)}\hat{MC}^{i}_{N,t} \tag{3.A.26}$$

$$\hat{\pi}^{i*}_{N,t} = \frac{\beta^*}{1+\beta^*\delta^*_N}\mathrm{E}_t\hat{\pi}^{i*}_{N,t+1} + \frac{\delta^*_N}{1+\beta^*\delta^*_N}\hat{\pi}^{i*}_{N,t-1} + \frac{(1-\theta^*_N)(1-\theta^*_N\beta^*)}{\theta^*_N(1+\beta^*\delta^*_N)}\hat{MC}^{i*}_{N,t} \tag{3.A.27}$$

Real marginal cost for domestic tradable goods

$$\hat{MC}^{i}_{D,t} = (1-\eta)\hat{w}^i_t + \eta\hat{r}^i_{K,t} - a^i_{D,t} + (1-\gamma_C)\hat{x}^i_t + (1-\alpha)\hat{t}^i_{i*,t} \tag{3.A.28}$$

$$\hat{MC}^{i*}_{D,t} = (1-\eta^*)\hat{w}^{i*}_t + \eta^*\hat{r}^{i*}_{K,t} - a^{i*}_{D,t} + (1-\gamma^*_C)\hat{x}^{i*}_t - (1-\alpha^*)\hat{t}^{i*}_{i*,t} \tag{3.A.29}$$

Real marginal cost for nontradable goods

$$\hat{MC}^{i}_{N,t} = (1-\eta)\hat{w}^i_t + \eta\hat{r}^i_{K,t} - a^i_{N,t} - \gamma_C\hat{x}^i_t \tag{3.A.30}$$

$$\hat{MC}^{i*}_{N,t} = (1-\eta^*)\hat{w}^{i*}_t + \eta^*\hat{r}^{i*}_{K,t} - a^{i*}_{N,t} - \gamma^*_C\hat{x}^{i*}_t \tag{3.A.31}$$

Relative inflation of nontradable consumption goods

$$\Delta\hat{x}^i_t = \hat{\pi}^i_{N,t} - \hat{\pi}^i_{T,t} \tag{3.A.32}$$

$$\Delta\hat{x}^{i*}_t = \hat{\pi}^{i*}_{N,t} - \hat{\pi}^{i*}_{T,t} \tag{3.A.33}$$

Inflation of tradable consumption goods

$$\hat{\pi}^i_{T,t} = \hat{\pi}^i_{D,t} + (1-\alpha)\Delta\hat{t}^i_{i*,t} \tag{3.A.34}$$

$$\hat{\pi}^{i*}_{T,t} = \hat{\pi}^{i*}_{D,t} - (1-\alpha^*)\Delta t^i_{i*,t} \tag{3.A.35}$$

CPI inflation

$$\hat{\pi}^i_{C,t} = \gamma_C\hat{\pi}^i_{T,t} + (1-\gamma_C)\hat{\pi}^i_{N,t} \tag{3.A.36}$$

$$\hat{\pi}^{i*}_{C,t} = \gamma^*_C\hat{\pi}^{i*}_{T,t} + (1-\gamma^*_C)\hat{\pi}^{i*}_{N,t} \tag{3.A.37}$$

Real exchange rate

$$\hat{q}^i_{i*,t} = (\alpha + \alpha^* - 1) \cdot \hat{t}^i_{i*,t} + (1 - \gamma^*_C)\hat{x}^{i*}_t - (1 - \gamma_C)\hat{x}^i_t \tag{3.A.38}$$

Monetary policy rule

$$\hat{i}_t = \rho \cdot \hat{r}^{EMU}_{t-1} + (1 - \rho) \cdot \left[\psi_y \cdot \hat{y}^{EMU}_{t-1} + \psi_\pi \hat{\pi}^{EMU}_{C,t-1}\right] + u_{R,t} \tag{3.A.39}$$

Real interest rate

$$\hat{r}^i_t = \hat{i}_t - \mathrm{E}_t \hat{\pi}^i_{C,t+1} \tag{3.A.40}$$

$$\hat{r}^{i*}_t = \hat{i}_t - \mathrm{E}_t \hat{\pi}^{i*}_{C,t+1} \tag{3.A.41}$$

Union-wide real interest rate, output and inflation

$$\hat{r}^{EMU}_t = n \cdot \hat{r}^i_t + (1 - n) \cdot \hat{r}^{i*}_t \tag{3.A.42}$$

$$\hat{y}^{EMU}_t = n \cdot \hat{y}^i_t + (1 - n) \cdot \hat{y}^{i*}_t \tag{3.A.43}$$

$$\hat{\pi}^{EMU}_t = n \cdot \hat{\pi}^i_t + (1 - n) \cdot \hat{\pi}^{i*}_t \tag{3.A.44}$$

Government consumption

$$\hat{g}^i_t = \rho_G \cdot \hat{g}^i_{t-1} + \gamma_G \cdot \hat{d}^i_{t-1} + u^i_{G,t} \tag{3.A.45}$$

$$\hat{g}^{i*}_t = \rho^*_G \cdot \hat{g}^{i*}_{t-1} + \gamma^*_G \cdot \hat{d}^{i^*}_{t-1} + u^{i*}_{G,t} \tag{3.A.46}$$

Lump-sum transfers from government to households

$$\hat{z}^i_t = \rho_Z \cdot \hat{z}^i_{t-1} + \phi_Z \cdot \hat{y}^i_{t-1} + u^i_{Z,t} \tag{3.A.47}$$

$$\hat{z}^{i*}_t = \rho^*_Z \cdot \hat{z}^{i*}_{t-1} + \phi^*_Z \cdot \hat{y}^{i^*}_{t-1} + u^{i*}_{Z,t} \tag{3.A.48}$$

Consumption tax rate

$$\hat{\tau}^i_{C,t} = \rho_{\tau_C} \cdot \hat{\tau}^i_{C,t-1} + \gamma_{\tau_C} \cdot \hat{d}^i_{t-1} + \phi_{\tau_C \tau_K} \cdot u^i_{\tau_K,t} + \phi_{\tau_C \tau_L} \cdot u^i_{\tau_L,t} + u^i_{\tau_C,t} \tag{3.A.49}$$

$$\hat{\tau}^{i^*}_{C,t} = \rho^*_{\tau_C} \cdot \hat{\tau}^{i^*}_{C,t-1} + \gamma^*_{\tau_C} \cdot \hat{d}^{i^*}_{t-1} + \phi^*_{\tau_C \tau_K} \cdot u^{i^*}_{\tau_K,t} + \phi^*_{\tau_C \tau_L} \cdot u^{i^*}_{\tau_L,t} + u^{i^*}_{\tau_C,t} \tag{3.A.50}$$

Capital income tax rate

$$\hat{\tau}^i_{K,t} = \rho_{\tau_K} \cdot \hat{\tau}^i_{K,t-1} + \gamma_{\tau_K} \cdot \hat{d}^i_{t-1} + \phi_{\tau_K \tau_C} \cdot u^i_{\tau_C,t} + \phi_{\tau_K \tau_L} \cdot u^i_{\tau_L,t} + u^i_{\tau_K,t} \tag{3.A.51}$$

$$\hat{\tau}^{i^*}_{K,t} = \rho^*_{\tau_K} \cdot \hat{\tau}^{i^*}_{K,t-1} + \gamma^*_{\tau_K} \cdot \hat{d}^{i^*}_{t-1} + \phi^*_{\tau_K \tau_C} \cdot u^{i^*}_{\tau_C,t} + \phi^*_{\tau_K \tau_L} \cdot u^{i^*}_{\tau_L,t} + u^{i^*}_{\tau_K,t} \quad (3.A.52)$$

Labor income tax rate

$$\hat{\tau}^{i}_{L,t} = \rho_{\tau_L} \cdot \hat{\tau}^{i}_{L,t-1} + \gamma_{\tau_L} \cdot \hat{d}^{i}_{t-1} + \phi_{\tau_L \tau_C} \cdot u^{i}_{\tau_C,t} + \phi_{\tau_L \tau_K} \cdot u^{i}_{\tau_K,t} + u^{i}_{\tau_L,t} \quad (3.A.53)$$

$$\hat{\tau}^{i^*}_{L,t} = \rho^*_{\tau_L} \cdot \hat{\tau}^{i^*}_{L,t-1} + \gamma^*_{\tau_L} \cdot \hat{d}^{i^*}_{t-1} + \phi^*_{\tau_L \tau_C} \cdot u^{i^*}_{\tau_C,t} + \phi^*_{\tau_L \tau_K} \cdot u^{i^*}_{\tau_K,t} + u^{i^*}_{\tau_L,t} \quad (3.A.54)$$

Consumption tax revenues

$$ta\hat{x}C^{i}_{t} = \hat{\tau}^{i}_{C,t} + \hat{c}^{i}_{t} \quad (3.A.55)$$

$$ta\hat{x}C^{i*}_{t} = \hat{\tau}^{i*}_{C,t} + \hat{c}^{i*}_{t} \quad (3.A.56)$$

Capital income tax revenues

$$ta\hat{x}K^{i}_{t} = \hat{\tau}^{i}_{K,t} + \hat{r}^{i}_{K,t} + \hat{k}^{i}_{t} \quad (3.A.57)$$

$$ta\hat{x}K^{i*}_{t} = \hat{\tau}^{i*}_{K,t} + \hat{r}^{i*}_{K,t} + \hat{k}^{i*}_{t} \quad (3.A.58)$$

Labor income tax revenues

$$ta\hat{x}L^{i}_{t} = \hat{\tau}^{i}_{L,t} + \hat{w}^{i}_{t} + \hat{l}^{i}_{t} \quad (3.A.59)$$

$$ta\hat{x}L^{i*}_{t} = \hat{\tau}^{i*}_{L,t} + \hat{w}^{i*}_{t} + \hat{l}^{i*}_{t} \quad (3.A.60)$$

Government debt

$$\begin{aligned} \hat{d}^{i}_{t} = {} & \frac{\bar{R}}{\bar{D}} \cdot \hat{r}^{i}_{t} + \hat{d}^{i}_{t-1} + \frac{\bar{G}}{\bar{D}} \cdot \hat{g}^{i}_{t} + \frac{\bar{Z}}{\bar{D}} \cdot \hat{z}^{i}_{t} - \frac{T\bar{AX}C}{\bar{D}} \cdot t\hat{a}x^{i}_{C,t} \\ & - \frac{T\bar{AX}K}{\bar{D}} \cdot t\hat{a}x^{i}_{K,t} - \frac{T\bar{AX}L}{\bar{D}} \cdot t\hat{a}x^{i}_{L,t} - \left(\frac{R\bar{E}C}{\bar{D}} \cdot r\hat{e}c^{i}_{t} - \frac{P\bar{A}Y}{\bar{D}} \cdot p\hat{a}y^{i}_{t} \right) \end{aligned} \quad (3.A.61)$$

$$\begin{aligned} \hat{d}^{i^*}_{t} = {} & \frac{\bar{R}^*}{\bar{D}^*} \cdot \hat{r}^{i^*}_{t} + \hat{d}^{i^*}_{t-1} + \frac{\bar{G}^*}{\bar{D}^*} \cdot \hat{g}^{i^*}_{t} + \frac{\bar{Z}^*}{\bar{D}^*} \cdot \hat{z}^{i^*}_{t} - \frac{T\bar{AX}C^*}{\bar{D}^*} \cdot t\hat{a}x^{i^*}_{C,t} \\ & - \frac{T\bar{AX}K^*}{\bar{D}^*} \cdot t\hat{a}x^{i^*}_{K,t} - \frac{T\bar{AX}L^*}{\bar{D}^*} \cdot t\hat{a}x^{i^*}_{L,t} - \left(\frac{R\bar{E}C^*}{\bar{D}^*} \cdot r\hat{e}c^{i^*}_{t} - \frac{P\bar{A}Y^*}{\bar{D}^*} \cdot p\hat{a}y^{i^*}_{t} \right) \end{aligned} \quad (3.A.62)$$

Transfer mechanism

$$p\hat{a}y^{i}_{t} = \hat{y}^{i}_{t} \quad (3.A.63)$$

$$p\hat{a}y_t^{i^*} = \hat{y}_t^{i^*} \tag{3.A.64}$$

$$r\hat{e}c_t^{i} = \hat{c}p_t \tag{3.A.65}$$

$$r\hat{e}c_t^{i^*} = \hat{c}p_t \tag{3.A.66}$$

$$\hat{c}p_t = \frac{\bar{Y}}{\bar{Y}^{EMU}} \cdot p\hat{a}y_t^{i} + \frac{\bar{Y}^*}{\bar{Y}^{EMU}} \cdot p\hat{a}y_t^{i^*} \tag{3.A.67}$$

Productivity shocks in tradable sectors

$$\hat{a}_{D,t}^{i} = \rho_{a,D} \cdot \hat{a}_{D,t-1}^{i} + u_{a,D,t}^{i} \tag{3.A.68}$$

$$\hat{a}_{D,t}^{i*} = \rho_{a,D}^{*} \cdot \hat{a}_{D,t-1}^{i*} + u_{a,D,t}^{i*} \tag{3.A.69}$$

Productivity shocks in nontradable sectors

$$\hat{a}_{N,t}^{i} = \rho_{a,N} \cdot \hat{a}_{N,t-1}^{i} + u_{a,N,t}^{i} \tag{3.A.70}$$

$$\hat{a}_{N,t}^{i*} = \rho_{a,N}^{*} \cdot \hat{a}_{N,t-1}^{i*} + u_{a,N,t}^{i*} \tag{3.A.71}$$

Consumption preference shocks

$$\hat{\varepsilon}_{C,t}^{i} = \rho_{C} \cdot \hat{\varepsilon}_{C,t-1}^{i} + u_{C,t}^{i} \tag{3.A.72}$$

$$\hat{\varepsilon}_{C,t}^{i*} = \rho_{C}^{*} \cdot \hat{\varepsilon}_{C,t-1}^{i*} + u_{C,t}^{i*} \tag{3.A.73}$$

Labor supply shocks

$$\hat{\varepsilon}_{L,t}^{i} = \rho_{L} \cdot \hat{\varepsilon}_{L,t-1}^{i} + u_{L,t}^{i} \tag{3.A.74}$$

$$\hat{\varepsilon}_{L,t}^{i*} = \rho_{L}^{*} \cdot \hat{\varepsilon}_{L,t-1}^{i*} + u_{L,t}^{i*} \tag{3.A.75}$$

Investment efficiency shocks

$$\hat{\varepsilon}_{I,t}^{i} = \rho_{I} \cdot \hat{\varepsilon}_{I,t-1}^{i} + u_{I,t}^{i} \tag{3.A.76}$$

$$\hat{\varepsilon}_{I,t}^{i*} = \rho_{I}^{*} \cdot \hat{\varepsilon}_{I,t-1}^{i*} + u_{I,t}^{i*} \tag{3.A.77}$$

Monetary shocks

$$u_{R,t} \tag{3.A.78}$$

Government consumption shocks

$$u_{G,t}^{i}, \; u_{G,t}^{i*} \tag{3.A.79}$$

Government transfer shocks

$$u^{i}_{Z,t},\; u^{i*}_{Z,t} \tag{3.A.80}$$

Consumption tax rate shocks

$$u^{i}_{\tau_C,t},\; u^{i*}_{\tau_C,t} \tag{3.A.81}$$

Capital income tax rate shocks

$$u^{i}_{\tau_K,t},\; u^{i*}_{\tau_K,t} \tag{3.A.82}$$

Labor income tax rate shocks

$$u^{i}_{\tau_L,t},\; u^{i*}_{\tau_L,t} \tag{3.A.83}$$

3.A.2 Model derivations

Household optimization: Derivation of first-order conditions

The optimization problem of the household j is to maximize lifetime utility subject to the budget constraint and the capital accumulation function. The corresponding Lagrangian is given by:

$$\begin{aligned}\mathcal{L}_t(j) = {} & \varepsilon^{i}_{C,t}\frac{(C^{i}_{t}(j) - hC^{i}_{t-1})^{1-\sigma}}{1-\sigma} - \varepsilon^{i}_{L,t}\frac{(L^{i}_{t}(j))^{1+\phi}}{1+\phi} \\ & + \lambda_{C,t}(j)\Big[D^{i}_{t}(j) + (1-\tau^{i}_{L,t})W^{i}_{t}(j)L^{i}_{t}(j) + (1-\tau^{i}_{K,t})R^{i}_{K,t}K^{i}_{t}(j) \\ & + \Pi^{i}_{t}(j) - (1+\tau^{i}_{C,t})P_{C,t}C^{i}_{t}(j) - P^{i}_{I,t}I^{i}_{t}(j) - \frac{\mathrm{E}_t D^{i}_{t+1}(j)}{R_t}\Big] \\ & + \lambda_{K,t}(j)\left[-K^{i}_{t+1}(j) + (1-\delta)K^{i}_{t}(j) + \varepsilon^{i}_{I,t}\left(1 - S\left(\frac{I^{i}_{t}}{I^{i}_{t-1}}\right)\right)I^{i}_{t}\right]\end{aligned}$$

where $\lambda_{C,t}(j)$ is the Lagrange multiplier on the household's budget constraint and $\lambda_{K,t}(j)$ is the Lagrange multiplier on the capital accumulation function. The first-order conditions are as follows:

$$\frac{\partial \mathcal{L}_t(j)}{\partial C_t(j)} = 0 \Rightarrow \varepsilon^{i}_{C,t}(C^{i}_{t}(j) - hC^{i}_{t-1})^{-\sigma} = \lambda_{C,t}(j)P^{i}_{C,t}$$

$$\frac{\partial \mathcal{L}_t(j)}{\partial D_{t+1}(j)} = 0 \Rightarrow \lambda_{C,t}(j) = \lambda_{C,t+1}(j)\beta R_t$$

which together give the well-known Euler equation:

$$\frac{1}{R_t} = \beta \mathrm{E}_t \left[\frac{\varepsilon^i_{C,t+1}}{\varepsilon^i_{C,t}} \frac{(C^i_{t+1}(j) - hC^i_t)^{-\sigma}}{(C^i_t(j) - hC^i_{t-1})^{-\sigma}} \frac{P^i_{C,t}}{P^i_{C,t+1}} \frac{(1+\tau^i_{C,t})}{(1+\tau^i_{C,t+1})} \right]$$

The first-order conditions with respect to $I^i_t(j)$ is given by:

$$\frac{\partial \mathcal{L}_t(j)}{\partial I_t(j)} = 0 \Rightarrow$$

$$\lambda_{C,t}(j) P^i_{I,t} = \lambda_{K,t}(j) \varepsilon^i_{I,t} \left(1 - S\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) - \frac{I^i_t(j)}{I^i_{t-1}(j)} S'\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) \right)$$
$$+ \beta \mathrm{E}_t \lambda_{K,t+1}(j) \varepsilon^i_{I,t+1} \left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)^2 S'\left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)$$

The relative price of installed capital is defined as $Q_{T,t}(j) \equiv \frac{\lambda_{K,t}(j)}{\lambda_{C,t}(j) P_{C,t}}$ (with subscript T for Tobin). If we substitute for $\lambda_{K,t}(j) = Q^i_{T,t}(j)\lambda_{C,t}(j)P^i_{C,t}$, then the first-order condition with respect to I_t(j) results in:

$$\lambda_{C,t}(j) P^i_{I,t} = Q^i_{T,t}(j)\lambda_{C,t}(j) P^i_{C,t} \varepsilon^i_{I,t} \left(1 - S\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) - \frac{I^i_t(j)}{I^i_{t-1}(j)} S'\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) \right)$$
$$+ \beta \mathrm{E}_t Q^i_{T,t+1}(j) \lambda_{C,t+1}(j) P^i_{C,t+1} \varepsilon^i_{I,t+1} \left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)^2 S'\left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)$$

$$\Leftrightarrow \frac{P^i_{I,t}}{P^i_{C,t}} = Q^i_{T,t}(j) \varepsilon^i_{I,t} \left(1 - S\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) - \frac{I^i_t(j)}{I^i_{t-1}(j)} S'\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) \right)$$
$$+ \beta \mathrm{E}_t Q^i_{T,t+1}(j) \frac{\lambda_{C,t+1}(j)}{\lambda_{C,t}(j)} \frac{P^i_{C,t+1}}{P^i_{C,t}} \varepsilon^i_{I,t+1} \left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)^2 S'\left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)$$

Using from the first order condition with respect to $D_{t+1}(j)$ that $\frac{\lambda_{C,t+1}(j)}{\lambda_{C,t}(j)} = \frac{1}{\beta R_t}$ defines investment demand:

$$\frac{P^i_{I,t}}{P^i_{C,t}} = Q^i_{T,t}(j) \varepsilon^i_{I,t} \left(1 - S\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) - \frac{I^i_t(j)}{I^i_{t-1}(j)} S'\left(\frac{I^i_t(j)}{I^i_{t-1}(j)} \right) \right)$$
$$+ \mathrm{E}_t \left[Q^i_{T,t+1}(j) \frac{P^i_{C,t+1}}{P^i_{C,t} R_t} \varepsilon^i_{I,t+1} \left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right)^2 S'\left(\frac{I^i_{t+1}(j)}{I^i_t(j)} \right) \right]$$

The first-order condition with respect to $K^i_{t+1}(j)$ is given by:

$$
\begin{aligned}
&\frac{\partial \mathcal{L}_t(j)}{\partial K_{t+1}(j)} = 0 \Rightarrow \\
&\lambda_{K,t}(j) = \beta \mathrm{E}_t[\lambda_{C,t+1}(j)(1-\tau^i_{K,t})R^i_{K,t+1}] + \beta(1-\delta)\mathrm{E}_t[\lambda_{K,t+1}(j)]
\end{aligned}
$$

Using again the definition of Tobin's Q gives us:

$$
\begin{aligned}
Q^i_{T,t}(j)\lambda_{C,t}(j)P^i_{C,t} = {}& \beta \mathrm{E}[\lambda_{C,t+1}(j)(1-\tau^i_{K,t})R^i_{K,t+1}] \\
&+ \beta(1-\delta)\mathrm{E}_t[Q^i_{T,t+1}(j)\lambda_{C,t+1}(j)P^i_{C,t+1}]
\end{aligned}
$$

$$
\begin{aligned}
\Leftrightarrow Q^i_{T,t}(j) = {}& \beta \mathrm{E}_t\left[\frac{\lambda_{C,t+1}(j)}{\lambda_{C,t}(j)}\frac{(1-\tau^i_{K,t})R^i_{K,t+1}}{P^i_{C,t}}\right] \\
&+ \beta(1-\delta)\mathrm{E}_t\left[Q^i_{T,t+1}(j)\frac{\lambda_{C,t+1}(j)}{\lambda_{C,t}(j)}\frac{P^i_{C,t+1}}{P^i_{C,t}}\right] \\
\Leftrightarrow Q^i_{T,t}(j) = {}& \mathrm{E}_t\left[\frac{(1-\tau^i_{K,t})R^i_{K,t+1}}{P^i_{C,t}R_t}\right] + (1-\delta)\mathrm{E}_t\left[Q^i_{T,t+1}(j)\frac{P^i_{C,t+1}}{P^i_{C,t}R_t}\right]
\end{aligned}
$$

Household optimization: Wage setting

The household maximizes the following equation to find the optimal wage:

$$
\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \left[\frac{\varepsilon^i_{C,t+k}}{1-\sigma}\left(\frac{(1-\tau^i_{L,t+k})\tilde{W}^i_t(j)L^i_{t+k}(j)}{P^i_{C,t+k}}\right)^{1-\sigma} - \frac{\varepsilon^i_{L,t+k}}{1+\phi}(L_{t+k}(j)^i)^{1+\phi}\right]
$$

subject to

$$
L^i_{t+k}(j) = \frac{1}{n}\left[\frac{\tilde{W}^i_t(j)}{W^i_{t+k}}\left(\frac{P^i_{C,t+k-1}}{P^i_{C,t-1}}\right)^{\delta_W}\right]^{-\phi_W} L^i_{t+k}
$$

Substituting the constraint in the expression to maximize and defining $x^i_{t,t+k} = \left(\frac{P^i_{C,t+k-1}}{P^i_{C,t-1}}\right)^{\delta_W}$ gives:

$$\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \left[\frac{\varepsilon^i_{C,t+k}}{1-\sigma} \left(\frac{(1-\tau^i_{L,t+k})\tilde{W}^i_t(j) \left(\frac{\tilde{W}^i_t(j)}{W^i_{t+k}} x^i_{t,t+k}\right)^{-\phi_W} L^i_{t+k}}{P^i_{C,t+k}} \right)^{1-\sigma} \right.$$
$$\left. - \frac{\varepsilon^i_{L,t+k}}{1+\phi} \left(\left(\frac{\tilde{W}^i_t(j)}{W^i_{t+k}} x^i_{t,t+k} \right)^{-\phi_W} L^i_{t+k} \right)^{1+\phi} \right]$$

The first-order condition with respect to $\tilde{W}_t(j)$ is then derived:

$$\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \left[\varepsilon^i_{C,t+k} (1-\phi_W) \left(\frac{(1-\tau^i_{L,t+k})\tilde{W}^i_t(j) \left(\frac{\tilde{W}^i_t(j)}{W^i_{t+k}} x^i_{t,t+k}\right)^{-\phi_W} L^i_{t+k}}{P^i_{C,t+k}} \right)^{1-\sigma} \right.$$
$$\left. \frac{1}{\tilde{W}^i_t(j)} + \varepsilon^i_{L,t+k} \cdot \phi_W \left(\left(\frac{\tilde{W}^i_t(j)}{W^i_{t+k}} x^i_{t,t+k} \right)^{-\phi_W} L^i_{t+k} \right)^{1+\phi} \frac{1}{\tilde{W}^i_t(j)} \right] = 0$$

$$\Leftrightarrow \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \left[\varepsilon^i_{C,t+k} (1-\phi_W) \frac{(1-\tau^i_{L,t+k})\tilde{W}^i_t(j) \left(\frac{\tilde{W}^i_t(j)}{W^i_{t+k}} x^i_{t,t+k}\right)^{-\phi_W} L^i_{t+k}}{P^i_{C,t+k}} \right.$$
$$\left. \frac{1}{\tilde{W}^i_t(j)} C^i_{t+k}(j)^{-\sigma} + \varepsilon^i_{L,t+k} \cdot \phi_W \left(\left(\frac{\tilde{W}^i_t(j)}{W^i_{t+k}} x^i_{t,t+k} \right)^{-\phi_W} L^i_{t+k} \right)^{1+\phi} \frac{1}{\tilde{W}^i_t(j)} \right] = 0$$

$$\Leftrightarrow \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \left[\varepsilon^i_{C,t+k} (1-\phi_W) \frac{(1-\tau^i_{L,t+k})\tilde{W}^i_t(j) L^i_{t+k}(j)}{P^i_{C,t+k}} \right.$$
$$\left. \frac{1}{\tilde{W}^i_t(j)} C^i_{t+k}(j)^{-\sigma} + \varepsilon^i_{L,t+k} \cdot \phi_W \left(L^i_{t+k}(j) \right)^{1+\phi} \frac{1}{\tilde{W}^i_t(j)} \right] = 0$$

$$\Leftrightarrow \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \left[(1-\phi_W) \frac{(1-\tau^i_{L,t+k})\tilde{W}^i_t(j)}{P^i_{C,t+k}} \frac{1}{\tilde{W}^i_t(j)} \right.$$
$$\left. + \phi_W \cdot \frac{\varepsilon^i_{L,t+k}}{\varepsilon^i_{C,t+k}} \frac{L^i_{t+k}(j)^{\phi}}{C^i_{t+k}(j)^{-\sigma}} \frac{1}{\tilde{W}^i_t(j)} \right] \cdot \varepsilon^i_{C,t+k} \cdot L^i_{t+k}(j) \cdot C^i_{t+k}(j)^{-\sigma} = 0$$

$$\Leftrightarrow \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \left[(1-\phi_W) \frac{(1-\tau^i_{L,t+k})}{P^i_{C,t+k}} + \phi_W MRS^i_{t+k}(j) \frac{1}{\tilde{W}^i_t(j)} \right]$$
$$\cdot \varepsilon^i_{C,t+k} \cdot L^i_{t+k}(j) \cdot C^i_{t+k}(j)^{-\sigma} = 0$$
$$\Leftrightarrow (1-\phi_W)\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \frac{(1-\tau^i_{L,t+k})}{P^i_{C,t+k}} \cdot \varepsilon^i_{C,t+k} \cdot L^i_{t+k}(j) \cdot C^i_{t+k}(j)^{-\sigma}$$
$$= -\phi_W \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k MRS^i_{t+k}(j) \frac{1}{\tilde{W}^i_t(j)} \cdot \varepsilon^i_{C,t+k} \cdot L^i_{t+k}(j) \cdot C^i_{t+k}(j)^{-\sigma}$$

where the marginal rate of substitution of consumption for leisure is:

$$MRS^i_t(j) = \frac{\varepsilon^i_{L,t} L^i_t(j)^{\phi}}{\varepsilon^i_{C,t}(C^i_t(j) - hC_{t-1})^{-\sigma}} = -\frac{U_{L,t}}{U_{C,t}}$$

As a result, we have:

$$\tilde{W}^i_t(j) = \frac{\phi_W}{\phi_W - 1} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k MRS^i_{t+k}(j) \varepsilon^i_{C,t} L^i_{t+k}(j) C^i_{t+k}(j)^{-\sigma}}{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_W \beta)^k \frac{(1-\tau^i_{L,t+k})}{P^i_{C,t+k}} \varepsilon^i_{C,t} L^i_{t+k}(j) C^i_{t+k}(j)^{-\sigma}}$$

Firm optimization: Price setting

To find the optimal price, firms maximize the following expression with respect to $\tilde{P}^i_{D,t}$:

$$\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k}(z) \left[\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} \left(\frac{P^i_{D,t+k-1}}{P^i_{D,t-1}} \right)^{\delta_D} - MC^i_{D,t+k} \right] \quad (3.A.84)$$

subject to

$$Y^i_{D,t+k}(z) = \frac{1}{n} \left[\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} \left(\frac{P^i_{D,t+k-1}}{P^i_{D,t-1}} \right)^{\delta_D} \right]^{-\phi_D} Y^i_{D,t+k}$$
$$= \frac{1}{n} \left[\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right]^{-\phi_D} Y^i_{D,t+k} \quad (3.A.85)$$

where we define $X^i_{t,t+k} = \left(\frac{P^i_{D,t+k-1}}{P^i_{D,t-1}} \right)^{\delta_D}$. The term $\Lambda_{t,t+k} = \frac{U^i_C(C_{t+k})}{U^i_C(C_t)}$ is the ratio of marginal utilities of consumption as part of the firm's stochastic discount factor.

Substituting the constraint in the expression to maximize gives:

$$\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} \left[\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} - MC^i_{D,t+k} \right] \left[\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right]^{-\phi_D}$$

$$\Leftrightarrow \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} \left[\left(\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right)^{1-\phi_D} - MC^i_{D,t+k} \left(\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right)^{-\phi_D} \right]$$

The first-order condition related to the profit-maximization problem of the firms that are re-optimizing their prices is given by:

$$\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} \left[(1-\phi_D) \left(\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right)^{1-\phi_D} \frac{1}{\tilde{P}^i_{D,t}} + \phi_D MC^i_{D,t+k} \left(\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right)^{-\phi_D} \frac{1}{\tilde{P}^i_{D,t}} \right] = 0$$

$$\Leftrightarrow \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} \frac{1}{\tilde{P}^i_{D,t}} (1-\phi_D) \left(\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right)^{1-\phi_D}$$
$$= -\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} \frac{1}{\tilde{P}^i_{D,t}} \phi_D MC^i_{D,t+k} \left(\frac{\tilde{P}^i_{D,t}}{P^i_{D,t+k}} X^i_{t,t+k} \right)^{-\phi_D}$$

$$\Leftrightarrow (1-\phi_D) \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} (\tilde{P}^i_{D,t})^{-\phi_D} \left(\frac{X^i_{t,t+k}}{P^i_{D,t+k}} \right)^{1-\phi_D}$$
$$= -\phi_D \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} (\tilde{P}^i_{D,t})^{-1-\phi_D} MC^i_{D,t+k} \left(\frac{X^i_{t,t+k}}{P^i_{D,t+k}} \right)^{-\phi_D}$$

$$\Leftrightarrow (1-\phi_D) \tilde{P}^i_{D,t} \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} \left(\frac{X^i_{t,t+k}}{P^i_{D,t+k}} \right)^{1-\phi_D}$$
$$= -\phi_D \mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} MC^i_{D,t+k} \left(\frac{X^i_{t,t+k}}{P^i_{D,t+k}} \right)^{-\phi_D}$$

$$\Leftrightarrow \tilde{P}^i_{D,t} = \frac{\phi_D}{\phi_D - 1} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} MC^i_{D,t+k} \left(\frac{X^i_{t,t+k}}{P^i_{D,t+k}} \right)^{-\phi_D}}{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \Lambda^i_{t,t+k} Y^i_{D,t+k} \left(\frac{X^i_{t,t+k}}{P^i_{D,t+k}} \right)^{1-\phi_D}}$$

Using the definitions of $X_{t,t+k}$ and $\Lambda_{t,t+k}$ gives us the optimal price for the re-optimizing firms:

$$\tilde{P}^i_{D,t} = \frac{\phi_D}{\phi_D - 1} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \frac{U^i_C(C_{t+k})}{U^i_C(C_t)} Y^i_{D,t+k} MC^i_{D,t+k} \left(\frac{P^i_{D,t+k}}{\left(\frac{P^i_{D,t+k-1}}{P^i_{D,t-1}} \right)^{\delta_D}} \right)^{\phi_D}}{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_D \beta)^k \frac{U^i_C(C_{t+k})}{U^i_C(C_t)} Y^i_{D,t+k} \left(\frac{P^i_{D,t+k}}{\left(\frac{P^i_{D,t+k-1}}{P^i_{D,t-1}} \right)^{\delta_D}} \right)^{\phi_D - 1}}$$

Given the optimization process for the firms that are forward-looking, the evolution of the price index for the domestic tradable goods is given by:

$$P^i_{D,t} = \left(\theta_D \left(P^i_{D,t-1} \left(\frac{P^i_{D,t-1}}{P^i_{D,t-2}} \right)^{\delta_D} \right)^{1-\phi_D} + (1-\theta_D)(\tilde{P}^i_{D,t})^{1-\phi_D} \right)^{\frac{1}{1-\phi_D}}$$

Similarly, for the nontradables sector, the optimal price for the forward-looking firms and the evolution of the price index are respectively:

$$\tilde{P}^i_{N,t} = \frac{\phi_N}{\phi_N - 1} \frac{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_N \beta)^k \frac{U^i_C(C_{t+k})}{U^i_C(C_t)} Y^i_{N,t+k} MC^i_{N,t+k} \left(\frac{P^i_{N,t+k}}{\left(\frac{P^i_{N,t+k-1}}{P^i_{N,t-1}} \right)^{\delta_N}} \right)^{\phi_N}}{\mathrm{E}_t \sum_{k=0}^{\infty} (\theta_N \beta)^k \frac{U^i_C(C_{t+k})}{U^i_C(C_t)} Y^i_{N,t+k} \left(\frac{P^i_{N,t+k}}{\left(\frac{P^i_{N,t+k-1}}{P^i_{N,t-1}} \right)^{\delta_N}} \right)^{\phi_N - 1}}$$

$$P^i_{N,t} = \left(\theta_N \left(P^i_{N,t-1} \left(\frac{P^i_{N,t-1}}{P^i_{N,t-2}} \right)^{\delta_N} \right)^{1-\phi_N} + (1-\theta_N)(\tilde{P}^i_{N,t})^{1-\phi_N} \right)^{\frac{1}{1-\phi_N}}$$

Derivation of the relationship between real exchange rate and terms of trade

The relationship between the real exchange rate and the terms of trade can be derived as follows:

$$Q^i_{i*,t} = \frac{E^i_{i*,t} P^{i*}_{C,t}}{P^i_{C,t}} = \frac{P^{i*}_{C,t}}{P^i_{C,t}} = \frac{(P^{i*}_{T,t})^{\gamma^*_c}(P^{i*}_{N,t})^{1-\gamma^*_c}}{(P^i_{T,t})^{\gamma_c}(P^i_{N,t})^{1-\gamma_c}}$$

$$\Leftrightarrow Q^i_{i*,t} = \frac{\left(\frac{P^{i*}_{N,t}}{P^{i*}_{T,t}}\right)^{1-\gamma^*_c} P^{i*}_{T,t}}{\left(\frac{P^i_{N,t}}{P^i_{T,t}}\right)^{1-\gamma_c} P^i_{T,t}} = \frac{P^{i*}_{T,t}}{P^i_{T,t}} \frac{\left(\frac{P^{i*}_{N,t}}{P^{i*}_{T,t}}\right)^{1-\gamma^*_c}}{\left(\frac{P^i_{N,t}}{P^i_{T,t}}\right)^{1-\gamma_c}}$$

$$\Leftrightarrow Q^i_{i*,t} = \frac{(P^{i*}_{D,t})^{\alpha^*}(P^{i*}_{M,t})^{1-\alpha^*}}{(P^i_{D,t})^{\alpha}(P^i_{M,t})^{1-\alpha}} \frac{\left(\frac{P^{i*}_{N,t}}{P^{i*}_{T,t}}\right)^{1-\gamma^*_c}}{\left(\frac{P^i_{N,t}}{P^i_{T,t}}\right)^{1-\gamma_c}} = \frac{(P^{i*}_{D,t})^{\alpha^*}(P^i_{D,t})^{1-\alpha^*}}{(P^i_{D,t})^{\alpha}(P^i_{D,t})^{1-\alpha}} \frac{\left(\frac{P^{i*}_{N,t}}{P^{i*}_{T,t}}\right)^{1-\gamma^*_c}}{\left(\frac{P^i_{N,t}}{P^i_{T,t}}\right)^{1-\gamma_c}}$$

$$\Leftrightarrow Q^i_{i*,t} = \frac{(P^{i*}_{D,t})^{\alpha+\alpha^*-1}}{(P^i_{D,t})^{\alpha+\alpha^*-1}} \frac{\left(\frac{P^{i*}_{N,t}}{P^{i*}_{T,t}}\right)^{1-\gamma^*_c}}{\left(\frac{P^i_{N,t}}{P^i_{T,t}}\right)^{1-\gamma_c}} = (T^i_{i*,t})^{\alpha+\alpha^*-1} \frac{\left(\frac{P^{i*}_{N,t}}{P^{i*}_{T,t}}\right)^{1-\gamma^*_c}}{\left(\frac{P^i_{N,t}}{P^i_{T,t}}\right)^{1-\gamma_c}}$$

$$\Leftrightarrow Q^i_{i*,t} = (T^i_{i*,t})^{\alpha+\alpha^*-1} \frac{\left(X^{i*}_t\right)^{1-\gamma^*_c}}{\left(X^i_t\right)^{1-\gamma_c}}$$

3.A.3 Welfare measure

Welfare measure

Welfare is measured using a second-order Taylor series expansion around the steady state. The expected discounted value of the sum of the utilities of the households is approximated by

$$U_0 = \sum_{t=0}^{\infty} \beta^t \, \mathrm{E}_0 \, U(C_t, C_{t-1}, L_t, \varepsilon_{C,t}, \varepsilon_{L,t})$$

for both blocks of countries.[26] The period utility function is given by[27]

$$U(C_t, C_{t-1}, L_t) = \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\phi}}{1+\phi}$$

The second-order Taylor expansion of the period utility function around the steady state is defined as

$$\begin{aligned} U(C_t, C_{t-1}, L_t) &\approx \bar{U} + \bar{U}_C \tilde{C}_t + \bar{U}_C \tilde{C}_{t-1} + \bar{U}_L \tilde{L}_t + \frac{1}{2}\bar{U}_{CC}\tilde{C}_t^2 + \frac{1}{2}\bar{U}_{CC}\tilde{C}_{t-1}^2 \\ &\quad + \frac{1}{2}\bar{U}_{LL}\tilde{L}_t^2 + \bar{U}_{CC}\tilde{C}_t\tilde{C}_{t-1} + \bar{U}_{CL}\tilde{C}_t\tilde{L}_t + \bar{U}_{CL}\tilde{C}_{t-1}\tilde{L}_t + \mathcal{O}(\|\zeta\|^3) \\ &= \bar{U} + ((1-h)\bar{C})^{-\sigma}\tilde{C}_t - h((1-h)\bar{C})^{-\sigma}\tilde{C}_{t-1} - \bar{L}^{\phi}\tilde{L}_t \\ &\quad - \frac{\sigma}{2}((1-h)\bar{C})^{-\sigma-1}\tilde{C}_t^2 - \frac{\sigma}{2}h^2((1-h)\bar{C})^{-\sigma-1}\tilde{C}_{t-1}^2 - \frac{\phi}{2}\bar{L}^{\phi-1}\tilde{L}_t^2 \\ &\quad + \sigma h((1-h)\bar{C})^{-\sigma-1}\tilde{C}_t\tilde{C}_{t-1} + \mathcal{O}(\|\zeta\|^3) \end{aligned}$$

where the last term denotes the higher order exogenous disturbances. Here, a tilde refers to the deviation of the variable from the steady state, i.e. $\tilde{C}_t = C_t - \bar{C}$. However, our log-linearized model requires log deviations of variables from their steady state value. Using the Taylor expansion

$$\frac{C_t}{\bar{C}} = 1 + \hat{c}_t + \frac{1}{2}\hat{c}_t^2 + \mathcal{O}(\|\zeta\|^3)$$

which in fact gives us

$$\tilde{C}_t = C_t - \bar{C} = \bar{C}\left(\hat{c}_t + \frac{1}{2}\hat{c}_t^2\right) + \mathcal{O}(\|\zeta\|^3)$$

[26]We suppress the region index since the welfare measure is the same for the two regions, except for the estimated parameters and steady state values in the function. Union-wide welfare is given by the weighted average of welfare in both regions: $U_t^{EMU} = n \cdot U_t^i + (1-n) \cdot U_t^{i^*}$.

[27]Here we leave out the ε-terms for simplicity. In fact, leaving both $\varepsilon_{C,t}$ and $\varepsilon_{L,t}$ out of the second-order Taylor series approximation would not affect the numerical values of the welfare measure, since the mean and the covariance with both consumption and labor are almost equal to zero.

we obtain the following approximation of utility around the steady state

$$\begin{aligned}
U(C_t, C_{t-1}, L_t) \approx\ & \bar{U} + ((1-h)\bar{C})^{-\sigma}\bar{C}\left(\hat{c}_t + \frac{1}{2}\hat{c}_t^2\right) \\
& - h((1-h)\bar{C})^{-\sigma}\bar{C}\left(\hat{c}_{t-1} + \frac{1}{2}\hat{c}_{t-1}^2\right) - \bar{L}^{\phi}\bar{L}\left(\hat{l}_t + \frac{1}{2}\hat{l}_t^2\right) \\
& - \frac{\sigma}{2}((1-h)\bar{C})^{-\sigma-1}\bar{C}^2\hat{c}_t^2 - \frac{\sigma}{2}h^2((1-h)\bar{C})^{-\sigma-1}\bar{C}^2\hat{c}_{t-1}^2 \\
& - \frac{\phi}{2}\bar{L}^{\phi-1}\bar{L}^2\hat{l}_t^2 + \sigma h((1-h)\bar{C})^{-\sigma-1}\bar{C}^2\hat{c}_t\hat{c}_{t-1} + \mathcal{O}(\|\zeta\|^3) \\
=\ & \bar{U} + ((1-h)\bar{C})^{\sigma}\bar{C}\left[(\hat{c}_t - h\hat{c}_{t-1}) + \frac{1}{2}(\hat{c}_t^2 - h\hat{c}_{t-1}^2)\right. \\
& \left. - \frac{\sigma}{2(1-h)}(\hat{c}_t^2 + h^2\hat{c}_{t-1}^2) + \frac{\sigma h}{1-h}(\hat{c}_t\hat{c}_{t-1})\right] \\
& - \bar{L}^{1+\phi}\left[\hat{l}_t + \frac{1}{2}(1+\phi)\hat{l}_t^2\right] + \mathcal{O}(\|\zeta\|^3)
\end{aligned}$$

Expected lifetime utility at time zero is hence given by

$$\begin{aligned}
U_0 =\ & \sum_{t=0}^{\infty}\beta^t\ \mathrm{E}_0\ \left(\bar{U} + ((1-h)\bar{C})^{-\sigma}\bar{C}\left[(\hat{c}_t - h\hat{c}_{t-1}) + \frac{1}{2}(\hat{c}_t^2 - h\hat{c}_{t-1}^2)\right.\right. \\
& \left. - \frac{\sigma}{2(1-h)}(\hat{c}_t^2 + h^2\hat{c}_{t-1}^2) + \frac{\sigma h}{1-h}(\hat{c}_t\hat{c}_{t-1})\right] - \bar{L}^{1+\phi}\left[\hat{l}_t + \frac{1}{2}(1+\phi)\hat{l}_t^2\right] + \\
& \left.\mathcal{O}(\|\zeta\|^3)\right) \\
=\ & \sum_{t=0}^{\infty}\beta^t\ \left(\bar{U} + ((1-h)\bar{C})^{-\sigma}\bar{C}\left[(\mathrm{E}_0(\hat{c}_t) - h\mathrm{E}_0(\hat{c}_{t-1}))\right.\right. \\
& + \frac{1}{2}(\mathrm{E}_0((\hat{c}_t^2) - h\mathrm{E}_0(\hat{c}_{t-1}^2)) - \frac{\sigma}{2(1-h)}(\mathrm{E}_0(\hat{c}_t^2) + h^2\mathrm{E}_0(\hat{c}_{t-1}^2)) \\
& \left.\left. + \frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t\hat{c}_{t-1})\right] - \bar{L}^{1+\phi}\left[\mathrm{E}_0(\hat{l}_t) + \frac{1}{2}(1+\phi)\mathrm{E}_0(\hat{l}_t^2)\right] + \mathcal{O}(\|\zeta\|^3)\right)
\end{aligned}$$

The welfare effect of a fiscal transfer mechanism is evaluated using the consumption equivalent welfare measure in the tradition of Lucas (2003). This measure defines the welfare gain as the permanent percentage change in steady state consumption that will make the representative household indifferent between situation A and the steady state:

$$\begin{aligned}
U^A &= \sum_{t=0}^{\infty} \beta^t \mathrm{E}_0 U(C_t^A, C_{t-1}^A, L_t^A) \\
&= \sum_{t=0}^{\infty} \beta^t U((1+\lambda)\bar{C}, \bar{L}) \\
&= \sum_{t=0}^{\infty} \beta^t \left[\frac{((1-h)(1+\lambda)\bar{C})^{1-\sigma}}{1-\sigma} - \frac{\bar{L}^{1+\phi}}{1+\phi} \right]
\end{aligned}$$

Using a first-order Taylor approximation in consumption equivalence

$$\begin{aligned}
\frac{((1-h)(1+\lambda)\bar{C})^{1-\sigma}}{1-\sigma} - \frac{\bar{L}^{1+\phi}}{1+\phi} &\approx \frac{((1-h)\bar{C})^{1-\sigma}}{1-\sigma} - \frac{\bar{L}^{1+\phi}}{1+\phi} + ((1-h)\bar{C})^{1-\sigma} \cdot \lambda \\
&= \bar{U} + ((1-h)\bar{C})^{1-\sigma} \cdot \lambda
\end{aligned}$$

we obtain a solution for λ:

$$\begin{aligned}
& \sum_{t=0}^{\infty} \beta^t U((1+\lambda)\bar{C}, \bar{L}) = \sum_{t=0}^{\infty} \beta^t \mathrm{E}_0 U(C_t, C_{t-1}, L_t) \\
\Rightarrow\quad & \sum_{t=0}^{\infty} \beta^t \left(\bar{U} + ((1-h)\bar{C})^{1-\sigma} \cdot \lambda \right) \\
& = \sum_{t=0}^{\infty} \beta^t \ \Big(\bar{U} + ((1-h)\bar{C})^{-\sigma}\bar{C} \Big[(\mathrm{E}_0(\hat{c}_t) - h\mathrm{E}_0(\hat{c}_{t-1})) + \frac{1}{2}(\mathrm{E}_0(\hat{c}_t^2) \\
& -h\mathrm{E}_0(\hat{c}_{t-1}^2)) - \frac{\sigma}{2(1-h)}(\mathrm{E}_0(\hat{c}_t^2) + h^2\mathrm{E}_0(\hat{c}_{t-1}^2)) + \frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t\hat{c}_{t-1}) \Big] \\
& -\bar{L}^{1+\phi} \left[\mathrm{E}_0(\hat{l}_t) + \frac{1}{2}(1+\phi)\mathrm{E}_0(\hat{l}_t^2) \right] \Big) \\
\Rightarrow\quad & ((1-h)\bar{C})^{1-\sigma} \cdot \lambda \\
& = ((1-h)\bar{C})^{-\sigma}\bar{C} \Big[(\mathrm{E}_0(\hat{c}_t) - h\mathrm{E}_0(\hat{c}_{t-1})) + \frac{1}{2}(\mathrm{E}_0(\hat{c}_t^2) - h\mathrm{E}_0(\hat{c}_{t-1}^2)) \\
& - \frac{\sigma}{2(1-h)}(\mathrm{E}_0(\hat{c}_t^2) + h^2\mathrm{E}_0(\hat{c}_{t-1}^2)) + \frac{\sigma h}{1-h}(\mathrm{E}_0(\hat{c}_t\hat{c}_{t-1}) \Big] \\
& - \bar{L}^{1+\phi} \left[\mathrm{E}_0(\hat{l}_t) + \frac{1}{2}(1+\phi)\mathrm{E}_0(\hat{l}_t^2) \right] \\
\Rightarrow\quad & \lambda = \frac{1}{1-h} \Big[(\mathrm{E}_0(\hat{c}_t) - h\mathrm{E}_0(\hat{c}_{t-1})) + \frac{1}{2}(\mathrm{E}_0(\hat{c}_t^2) - h\mathrm{E}_0(\hat{c}_{t-1}^2)) \\
& - \frac{\sigma}{2(1-h)}(\mathrm{E}_0(\hat{c}_t^2) + h^2\mathrm{E}_0(\hat{c}_{t-1}^2)) + \frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t\hat{c}_{t-1}) \Big] \\
& - \bar{L}^{1+\phi}((1-h)\bar{C})^{\sigma-1} \left[\mathrm{E}_0(\hat{l}_t) + \frac{1}{2}(1+\phi)\mathrm{E}_0(\hat{l}_t^2) \right]
\end{aligned}$$

Hence, the consumption equivalent welfare measure is given by:

$$
\begin{aligned}
\lambda = \frac{1}{1-h}\Big[&(\mathrm{E}_0(\hat{c}_t) - h\mathrm{E}_0(\hat{c}_{t-1})) + \frac{1}{2}(\mathrm{E}_0(\hat{c}_t^2) - h\mathrm{E}_0(\hat{c}_{t-1}^2)) \\
&-\frac{\sigma}{2(1-h)}(\mathrm{E}_0(\hat{c}_t^2) + h^2\mathrm{E}_0(\hat{c}_{t-1}^2)) + \frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t\hat{c}_{t-1})\Big] \\
&- \bar{L}^{1+\phi}((1-h)\bar{C})^{\sigma-1}\Big[\mathrm{E}_0(\hat{l}_t) + \frac{1}{2}(1+\phi)\mathrm{E}_0(\hat{l}_t^2)\Big]
\end{aligned}
$$

Steady state

The relative weight of the means and variances of consumption and labor within this consumption equivalent welfare measure are determined by the steady state values of variables in the utility function. The steady state values of $\varepsilon_{C,t}$ and $\varepsilon_{L,t}$ are given by $\bar{\varepsilon}_C = 1$ and $\bar{\varepsilon}_L = 1$. The steady state values of consumption and labor have to be calculated throughout the theoretical model[28] and are approximated with numerical methods given the estimated parameters of the model. Steady state consumption is calculated to be $\bar{C} = 2.6232$, $\bar{C}^* = 2.8107$, $\bar{L} = 1.2840$ and $\bar{L}^* = 1.2990$. The parameters in this welfare measure are the parameters for the different regions as they are estimated using Bayesian methods.

Decomposition

A decomposition of the welfare measure yields the following welfare compensations for the means and variances of labor and consumption, and on an overall basis:

$$
\lambda_M = \frac{1}{1-h}\left[\mathrm{E}_0(\hat{c}_t) - h\mathrm{E}_0(\hat{c}_{t-1})\right] - \bar{L}^{1+\phi}((1-h)\bar{C})^{\sigma-1}\mathrm{E}_0(\hat{l}_t)
$$

$$
\begin{aligned}
\lambda_V = \frac{1}{1-h}\Big[&\frac{1}{2}(\mathrm{E}_0(\hat{c}_t^2) - h\mathrm{E}_0(\hat{c}_{t-1}^2)) - \frac{\sigma}{2(1-h)}(\mathrm{E}_0(\hat{c}_t^2) + h^2\mathrm{E}_0(\hat{c}_{t-1}^2)) \\
&+\frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t\hat{c}_{t-1})\Big] - \bar{L}^{1+\phi}((1-h)\bar{C})^{\sigma-1}\cdot\frac{1}{2}(1+\phi)\mathrm{E}_0(\hat{l}_t^2)
\end{aligned}
$$

$$
\lambda_{M,c} = \frac{1}{1-h}\left[\mathrm{E}_0(\hat{c}_t) - h\mathrm{E}_0(\hat{c}_{t-1})\right]
$$

$$
\lambda_{M,l} = -\bar{L}^{1+\phi}((1-h)\bar{C})^{\sigma-1}\mathrm{E}_0(\hat{l}_t)
$$

[28]The steady state equations can be found in the appendix.

$$\lambda_{V,c} = \frac{1}{1-h}\left[\frac{1}{2}(\mathrm{E}_0(\hat{c}_t^2) - h\mathrm{E}_0(\hat{c}_{t-1}^2)) - \frac{\sigma}{2(1-h)}(\mathrm{E}_0(\hat{c}_t^2) + h^2\mathrm{E}_0(\hat{c}_{t-1}^2)) \right.$$
$$\left. + \frac{\sigma h}{1-h}\mathrm{E}_0(\hat{c}_t\hat{c}_{t-1})\right]$$
$$\lambda_{V,l} = -\bar{L}^{1+\phi}((1-h)\bar{C})^{\sigma-1} \cdot \frac{1}{2}(1+\phi)\mathrm{E}_0(\hat{l}_t^2)$$

3.A.4 Steady state

In this appendix, the steady state equations of the model are presented. Given the non-linearity of the equations, the solution is not explicitly stated, but can be solved for numerically. As before, steady state variables are denoted with a bar.

Real interest rate

$$\bar{R}^i = \bar{R}^{i^*} = \frac{1}{\beta} \tag{3.A.86}$$

Real wage rate

$$\bar{W}^i = \bar{\tilde{W}}^i = \frac{\phi_W}{\phi_W - 1}\frac{(\bar{L}^i)^\phi}{((1-h)\bar{C}^i)^{-\sigma}} \tag{3.A.87}$$

$$\bar{W}^{i^*} = \bar{\tilde{W}}^{i^*} = \frac{\phi_W^*}{\phi_W^* - 1}\frac{(\bar{L}^{i^*})^{\phi^*}}{((1-h^*)\bar{C}^{i^*})^{-\sigma^*}} \tag{3.A.88}$$

Labor demand

$$\frac{\bar{W}^i\bar{L}^i}{\bar{R_K}^i\bar{K}^i} = \frac{1-\eta}{\eta} \tag{3.A.89}$$

$$\frac{\bar{W}^{i^*}\bar{L}^{i^*}}{\bar{R_K}^{i^*}\bar{K}^{i^*}} = \frac{1-\eta^*}{\eta^*} \tag{3.A.90}$$

Marginal cost

$$\left(\frac{\bar{W}^i}{1-\eta}\right)^{1-\eta} = \frac{\phi_D - 1}{\phi_D}\left(\frac{\bar{R_K}^i}{\eta}\right)^{-\eta} \tag{3.A.91}$$

$$\left(\frac{\bar{W}^{i^*}}{1-\eta^*}\right)^{1-\eta^*} = \frac{\phi_D^* - 1}{\phi_D^*}\left(\frac{\bar{R_K}^{i^*}}{\eta^*}\right)^{-\eta^*} \tag{3.A.92}$$

Capital accumulation

$$\bar{I}^i = \delta \bar{K}^i \tag{3.A.93}$$

$$\bar{I}^{i^*} = \delta^* \bar{K}^{i^*} \tag{3.A.94}$$

Production function

$$\bar{Y}^i = (\bar{K}^i)^{\eta} (\bar{L}^i)^{1-\eta} \tag{3.A.95}$$

$$\bar{Y}^{i^*} = (\bar{K}^{i^*})^{\eta^*} (\bar{L}^{i^*})^{1-\eta^*} \tag{3.A.96}$$

Market equilibrium

$$\begin{aligned} \bar{Y}^i = \bar{Y_N}^i + \bar{Y_D}^i = (1-\gamma_C)\bar{C}^i + (1-\gamma_I)\bar{I}^i + \gamma_C \alpha \bar{C}^i \\ + \gamma_I \alpha \bar{I}^i + \frac{1-n}{n}\gamma_C^*(1-\alpha^*)\bar{C}^{i^*} + \frac{1-n}{n}\gamma_I^*(1-\alpha^*)\bar{I}^{i^*} \end{aligned} \tag{3.A.97}$$

$$\begin{aligned} \bar{Y}^{i^*} = \bar{Y_N}^{i^*} + \bar{Y_D}^{i^*} = (1-\gamma_C^*)\bar{C}^{i^*} + (1-\gamma_I^*)\bar{I}^{i^*} + \gamma_C^* \alpha^* \bar{C}^{i^*} \\ + \gamma_I^* \alpha^* \bar{I}^{i^*} + \frac{n}{1-n}\gamma_C(1-\alpha)\bar{C}^i + \frac{n}{1-n}\gamma_I(1-\alpha)\bar{I}^i \end{aligned} \tag{3.A.98}$$

3.A.5 Data description

The structural parameters of the model and the processes that govern the 21 shocks of the model are estimated using Bayesian estimation. Data on 21 key macroeconomic and fiscal policy variables in the two blocks of the Euro area is used. Only first generation members of the Economic and Monetary Union are taken into account because of data availability. The northern block consists of Austria, Belgium, Finland, France, Germany, Ireland, Luxembourg and the Netherlands. Greece, Italy, Portugal and Spain constitute the South. The data is quarterly and taken from 2000:Q2 until 2013:Q4, due to a lack of data availability before 2000 for certain variables for Greece.

The key macroeconomic variables are real GDP, real consumption, real investment, consumer price index, real wage rate, the internal exchange rate and the nominal interest rate set in the Euro area by the ECB. Furthermore, we observe data on fiscal variables as government debt, government expenditures and the revenues from consumption taxes and capital income taxes. The source of the time series is explained in more detail below:

- **Real GDP**: Data on 'GDP at market prices' is taken from the Eurostat database. The series is expressed in chain-linked volumes, where the reference year is 2005. The series of all countries are expressed in the same currency, in euros.

- **Real consumption**: Data on 'Final consumption expenditure' is taken from the Eurostat database. The series is expressed in chain-linked volumes, where the reference year is 2005.

- **Real investment**: Investment is approximated by 'Gross fixed capital formation', taken from the Eurostat database. The series is expressed in chain-linked volumes, where the reference year is 2005.

- **Consumer price index**: The 'Harmonised Consumer Price Index' (HICP) is calculated by the OECD with index 2010 = 100.

- **Real wages**: The nominal wage is given by 'Labour compensation per employed person' with index 2010 = 100, as recorded in the OECD database. To account for price changes, the real wage is obtained by dividing the index for labor compensation by the consumer price index.

- **Internal exchange rate**: The internal exchange rate is determined using data on prices from the OECD database. The internal exchange rate is defined as the price of nontradables over the price of tradables. Here the consumer price index of nontradables is used which is the average of the CPI in 'Services' and 'Energy', and the CPI of tradables consists of the CPI of 'Food' and 'Non-food non-energy'. Data on the CPI in services is missing for Germany, Greece and the Netherlands, hence this variable is not taken into account when calculating the internal exchange rate for these countries.

- **Nominal interest rate**: The nominal interest rate in this model is given by the 3-month money market rate, documented in the Eurostat database. Since the two blocks in our model have been in the monetary union since the start, the nominal interest rate is the same for both.

- **Consumption taxes**: The tax revenues on consumption taxes are approximated by 'Taxes on production and imports' from the Eurostat database. The series is expressed in millions of euros.

- **Capital income taxes**: The tax revenues on capital income taxes are approximated by 'Capital taxes' from the Eurostat database. The series is expressed in millions of euros.

- **Government debt**: Government debt is given by 'Gross consolidated government debt', which is available from the Eurostat database. The series is expressed in millions of euros.

- **Wage income taxes**: The tax revenues on wage income taxes are approximated by 'Current taxes on income, wealth, etc..', which is available from the Eurostat database. The series is expressed in millions of euros.

- **Government consumption**: Government consumption (both expenditures and transfer) are approximated by 'Final consumption expenditure' by the general government, which is available from the Eurostat database. The series is expressed in millions of euros. Data is available from 2000 onwards for all countries.

Furthermore, we use data on labor input for the welfare analysis, however, this is not used in the estimation process. To approximate labor input, we take actual weekly hours worked from the Eurostat database. Data points are missing for Germany, France and Luxembourg at the beginning of the time series, here we use interpolation as yearly data is available.

The data is summed up to get series for North and South. For inflation, internal exchange rate and the real wage rate, the series for North and South are averaged using as a weight the share of GDP of the country in total GDP of the block of countries. Seasonal adjustment of the time series is done by the program Demetra+, which is often used by official statistical offices. The TramoSeats method[29] is used with specification RSA3. This specification tests for the log/level specification, it automatically detects outliers and it identifies and estimates the best ARIMA model for the seasonal adjustment.[30] Then, the variables are expressed in 100*log differences to match with the measurement equations of the model.

An important remark has to be made about the data on government debt of Greece, as Martin and Philippon (2014) argue: "Greece benefited from a debt relief that reduced its public debt by around 50% in 2012, and from a reduction in interest rates and an extension in the repayment period for the EU and IMF rescue package in 2011". In the time series for Greece, there is a significant drop in government debt from the last quarter of 2011 to the first quarter of 2012. However, because the data is summed for South, there is no significant drop in the data for South as a whole, as Greece is relatively small within this block of countries.

[29]The TramoSeats method is also used by the OECD to seasonally adjust the data series.
[30]More information can be found in the Demetra+ User Manual (Grudkowska (2011)).

The data is mapped onto the model via the observation equations, which is as follows for output:

$$y_t^{obs} = \hat{y}_t^i - \hat{y}_{t-1}^i \tag{3.A.99}$$

where y_t^{obs} is the observable time series for output, adjusted in the manner described above. The model can give us a simulation of $\hat{y}_t^i$, based on the estimated parameters, which is the log deviation of output from the steady state. The measurement equations for c_t^{obs}, i_t^{obs}, x_t^{obs}, w_t^{obs}, $taxC_t^{obs}$, $taxL_t^{obs}$, d_t^{obs}, $(g+z)_t^{obs}$ and r_t^{obs}[31] are of the same type, and these are similar for both regions. The only exception is the measurement equation for the observable of inflation:

$$\pi_t^{obs} = \hat{\pi}_t^i \tag{3.A.100}$$

For inflation, data on the level of CPI is used. In the model, π_C^i is the deviation of the growth rate of log CPI from the steady state growth rate of log CPI. Hence, the observation equation does not have a lagged term in it as well, since the data is in CPI levels rather than inflation rates.

[31] The observable time series for the nominal interest rate (set by the ECB) is r_t^{obs} only because the notation i_t^{obs} was already taken for investment. However, the observable r_t^{obs} does represent the nominal interest rate.

CHAPTER 4

The Implications of a European Unemployment Benefit Scheme:

A DSGE Model for the North and South of the Euro Area

4.1 Introduction

The Great Recession and the European debt crisis exposed a critical gap in the design of the Economic and Monetary Union, and have revived the debate on fiscal integration in the Euro area. When the EMU was founded, it was thought that countries in the Euro area would face only moderate country-specific shocks. Besides, commitment to the fiscal rules in the Stability and Growth Pact was thought to limit the severity of the impact of these shocks. However, the EMU members have been hit by quite substantial shocks that were also able to spread across the Euro area. National automatic stabilizers have not been able to provide sufficient insurance, and hence some observers conclude that a common risk sharing mechanism is necessary to make the EMU sustainable and perhaps even to prevent countries from exiting the EMU (Bertola (2013)). Deeper fiscal integration could correct the architectural weakness in the system, and hence potentially reduce the severity of future crises.

How could a risk sharing mechanism be designed to insure the Euro area countries against asymmetric macroeconomic shocks? The former President of the European Council, Herman van Rompuy, made some suggestions on this in the Four Presidents' report: *"An EMU fiscal capacity with a limited asymmetric shock* *absorption function could take the form of an insurance-type system between euro area countries. [...] The specific design of such a function could follow two broad approaches. The first would be a macroeconomic approach, where contributions and disbursements would be based on fluctuations in cyclical revenue and expenditure items [...]. The second could be based on a microeconomic approach, and be more directly linked to a specific public function sensitive to the economic cycle, such as unemployment insurance."* (Van Rompuy (2012)). In this chapter, I will focus on a risk sharing mechanism that takes the form of an EMU-wide unemployment insurance.

An EMU-wide unemployment insurance scheme has some advantages compared to other fiscal risk sharing mechanisms. Because of the focus on unemployment, there is an automatic link between payments and the business cycle. This limits the problem of moral hazard and makes the system more robust to political manipulation than, for example, a European compensation fund with transfer payments based on the output gap. However, like with any risk sharing mechanism, there will be a chance that the European unemployment benefit scheme would lower the incentives of local governments to implement structural policies to correct labor market frictions. Potentially, participation in the scheme could be exclusively for those countries that comply with certain rules concerning labor market conditions. Furthermore, the financing of the scheme could be set up in such a way that the main objective is to insure member countries without starting off permanent redistribution between countries. Therefore, EMU members do not become systematic net recipients or net contributors and there is a low risk of permanent transfers from one region to the other. The EMU-wide unemployment benefit scheme, that will replace the existing regional systems, is meant for dampening the cyclical imbalances in the monetary union, and will not remove or eliminate the structural differences between countries.

The purpose of this chapter is to analyze the impact of a European unemployment benefit scheme (EUBS) on the northern and southern region of the EMU for both the past and the future. For that reason, I have incorporated a common unemployment insurance into a DSGE model for a currency area. Apart from several standard DSGE features, the model also contains a labor market with search and matching frictions. The setup of the financing of the EMU-wide unemployment insurance guarantees that no permanent transfers from one region to the other arise. Moreover, this model is estimated with Bayesian methods for a northern and southern block of countries in the Euro area. By taking into account the heterogeneity between these two regions, especially in terms of the labor market institutions, I specifically focus on the effectiveness of a common unemployment insurance in the Euro area. A third contribution of this chapter is that I focus on two main questions to give an extensive overview of the implications of an EUBS. Firstly, ex post, what would the European unemployment insurance have meant for the EMU had it been introduced in 2013? Secondly, would the EUBS be ex ante beneficial for both the North and the South of the Euro area? Finally, the setup and the estimation of the model allow me to quantify the effect on the main macroeconomic variables in both regions.

A European unemployment benefit scheme, if introduced in 2013 as a replacement for the existing regional schemes, would have been effective in raising GDP, consumption and employment in North, though it would have decreased GDP and employment in the South. The risk sharing aspect of the scheme is found to be positive for both regions, however, the higher level of the benefit is leading to higher unemployment in South. Furthermore, I will show that European unemployment insurance is ex ante beneficial for both the North and the South of the Euro area. Introducing the EUBS will lead to increased welfare and decreased volatility of employment in the future, an effect that is enhanced in the case of labor market harmonization across the EMU regions. This will increase the willingness to implement such a type of EMU-wide unemployment insurance in the future.

The chapter is structured as follows. In section 2, I discuss the relevant literature on this topic. Section 3 describes the model of two regions in a monetary union. In addition, I explain how the European unemployment benefit scheme is set up. The data, prior distribution and estimated parameters of the Bayesian estimation are presented in section 4. Section 5 shows the main results of different policy experiments, where a hypothetical introduction of the EUBS in 2013 is simulated. Moreover, the implications of the EUBS for the future are analyzed as well as the influence of harmonization of the labor markets in North and South on the effectiveness of the EUBS. Section 6 concludes.

4.2 Related literature

In the past, but also more recently, there were voices to complement the Economic and Monetary Union with a risk sharing mechanism. The discussion on whether the common currency should come along with an automatic stabilizer for the Euro area started already in the 1970s with reports from the European Commission such as the MacDougall Report (MacDougall and Commission of the European Communities (1977)). Though the vision in the MacDougall Report was that the European monetary union should become a full-fledged economic union, the arguments in these discussions for having common fiscal policy in the EMU apply to the general case of having more stabilization mechanisms. The first rationale is one of spillover effects. Avoiding negative spillover effects from an economic crisis in one region by a sound macroeconomic policy can have positive effects by increasing stability in the union. As Allard et al. (2013) show, next to important common shocks, there have been substantial country-specific shocks in the EMU. Another argument is related to current account imbalances in a monetary union that cannot be offset by exchange rate adjustments. As adjustment through the real economy is rather painful, an automatic stabilizer would be useful to offset differences between the different regions. Finally, the low degree of labor mobility and labor market flexibility can cause adverse shocks to have a large impact on real variables, which enhances the need for automatic stabilization as is explained in the Optimum Currency Area literature (for example, Mundell (1961)).

The experience of the Great Recession has led economists and politicians to reopen the debate on the need for a risk sharing mechanism in the EMU. In the Four Presidents' Report (Van Rompuy (2012)) the creation of an automatic stabilizer was advocated to tackle regional asymmetric shocks. There have been several proposals along the lines of "an insurance-type system between Euro area countries" (Van Rompuy (2012)). The former President of the European Council specifies two broad approaches for the design of a risk sharing mechanism. For the macroeconomic approach, one could think of a stabilization fund with contributions and disbursements based on fluctuations in output. In this chapter, I will take a stance on the microeconomic approach, which is linked to a specific public function that depends on the business cycle, namely EMU-wide unemployment insurance.

There are several studies that have analyzed the economic effects of an EMU-wide unemployment insurance system, both using macro-level data as well as using household micro data. The EUROMOD calculator is a tax-benefit calculator often used for these simulation exercises. Dolls et al. (2015) analyze different alternatives of a European unemployment insurance, and find that a significant fraction of an unemployment shock can be absorbed by this scheme. The authors use the static tax-benefit calculator EUROMOD, that is mainly based on cross-sectional micro data. Though the question that this chapter tries to answer is similar, the approach is fairly different. Their analysis does not take into account any general equilibrium effects of EMU-wide unemployment insurance or any individual behavioral responses of consumers or firms. As the authors stress, these results can only be interpreted as first-round effects of an

EUBS. This study finds interregional smoothing gains of on average 10% of the income fluctuations at the Euro area-level. In the paper by Jara and Sutherland (2014), this EUROMOD calculator is also exploited to estimate additionally the effect on poverty and income stabilization. They find that this effect depends to a large extent on the design of national unemployment insurance schemes, but also on the differences in labor force characteristics in EMU countries. Papers focusing on the macro-level data are, amongst others, Beblavý and Maselli (2014), Beblavý et al. (2015), Pisani-Ferry et al. (2013) and Dullien and Fichtner (2013). In the paper by Dullien and Fichtner (2013), the authors show that stabilization can be achieved even with a small budget. Furthermore, Beblavý and Maselli (2014) study two proposals for a European unemployment insurance scheme. In the first option, every eligible unemployed person would receive a harmonized unemployment benefit, whereas in the other option the national unemployment insurance fund would be financed by a supranational fund when unemployment in that country would be higher than normal. Though these empirical simulation studies are able to look at very detailed proposals on unemployment insurance, the key disadvantage is that general or even partial equilibrium effects are not taken into account.

The theoretical literature on this topic is not very extensive. The approach by Moyen et al. (2016) is closest to this chapter, as the authors set up a two-country business cycle model with frictional labor markets and cross-country unemployment insurance. The model is calibrated to Eurozone data and solved for the Ramsey-optimal stabilizing transfers. An important difference with my model is that workers need to consume their per-period income and do not have access to individual savings. In this way, one might overestimate the effectiveness of European unemployment insurance as one additional channel for insurance against shocks is shut down. The government sector is modeled relatively simplistic without any debt accumulation or taxes on capital income or consumption. Moreover, the model is calibrated for the core and periphery of the Euro area with symmetric parameters for important labor market parameters, thus not taking into account possible heterogeneity across these regions. Furthermore, the analysis is focused on the general optimal cross-country insurance policy, whereas in this chapter I focus on the effectiveness of an EUBS for the past and the future specifically.

In this chapter I use a full-fledged DSGE model with search and matching in the labor market to analyze a European unemployment benefit scheme (EUBS). For the modeling of the labor market, I rely on the models in Gertler et al. (2008), Blanchard and Gali (2008) and in particular Abbritti and Mueller (2013).

In the model of this last paper, labor market search frictions are integrated into a model of a monetary union. The model in this chapter also incorporates several established features in the DSGE literature such as Calvo price setting and capital adjustment costs. For this, the chapter builds on a larger history of DSGE models for monetary unions, or specifically for the EMU, written by Smets and Wouters (2003), Jondeau and Sahuc (2008) and Galí and Monacelli (2008). Several papers have also studied the effects of heterogeneity among labor market institutions and the influence of labor market harmonization in a monetary union, such as Poilly and Sahuc (2008) and Abbritti and Fahr (2013).

There are four directions in which my chapter contributes to the existing literature. Firstly, I have implemented a detailed labor market with search and matching and a common unemployment insurance into a DSGE model for a monetary union. The financing of this unemployment benefit scheme works in such a way that no continuous redistribution from one region to the other arises. A second contribution of this chapter is that the model is estimated for the Euro area and thus takes into account the heterogeneity between regions. This allows me to analyze the effectiveness of the EUBS specifically in light of the differences between the labor markets in the EMU. Thirdly, by looking at the effectiveness of European unemployment insurance in both the past and the future, I provide a comprehensive overview of the necessary information when making a decision on whether to implement this scheme. Finally, due to the setup and the estimation of the model I am able to quantify the effect on the main economic variables in both regions. Taking into account the asymmetry of regions within the EMU is important to genuinely analyze the implication of a European unemployment benefit scheme for the Euro area.

4.3 Two-Region DSGE Model with Search and Matching in the Labor Market

The DSGE model in this chapter considers two regions in a monetary union. A specific feature of the model is that it includes labor market search and matching frictions. The model most closely related to this model in terms of the labor market setup is discussed in Abbritti and Mueller (2013). The model includes several features to improve the empirical fit and make it more realistic, such as investment adjustment costs and Calvo staggered price setting. The main features of this model are in line with the conventional models in the literature, as in Christiano et al. (2005), Smets and Wouters (2003) and Galí and Monacelli

(2008). There are three types of agents in each region, namely households, intermediate goods firms and final goods firms. Besides, there is a common monetary authority and two independent fiscal authorities.

In what follows I will describe the model only for the home economy, as the general setup for the foreign economy is similar. Variables referring to the home region are indexed by i and foreign variables are indexed by i^*. Parameters can take a different value across regions, and foreign parameters are marked with an asterisk. The size of the home region H in terms of population is $[0, n]$ and the size of the foreign region is $[n, 1]$, such that the size of the union is normalized to 1.

4.3.1 Households

There is a representative household in each region, that has a continuum of members. Household members can be either employed or unemployed. The representative household in the home region maximizes a lifetime utility function that depends on the household's consumption as well as leisure time:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \Omega_t \left[\frac{(C_t^i)^{1-\sigma}}{1-\sigma} - \chi \frac{(N_t^H)^{1+\phi}}{1+\phi} \right] \tag{4.1}$$

The number of employed individuals within the representative household[1] in the home region is given by N_t^H, and Ω_t denotes the AR(1) preference shock process which can be interpreted as shocks to the household's discount factor. The consumption bundle of a household in the home region, C_t^i, is defined as:

$$C_t^i = \frac{(C_t^{H,i})^{1-\alpha}(C_t^{F,i})^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} \tag{4.2}$$

where $C_t^{j,i}$ is the quantity of the good produced in region j and consumed by the household in region i. The weight on the imported goods is given by α, such that $\alpha < 0.5$ implies a home bias in consumption.

The household maximizes lifetime utility subject to a sequence of budget con-

[1]Here I model variation in hours worked on the extensive margin rather than the intensive margin as is done in Gertler et al. (2008). The authors show that for the United States, most of the cyclical variation in hours worked is on the extensive margin. Besides, the estimates of their model including both the extensive and the intensive margin find no role for the intensive margin in the cyclical variation of hours worked.

straints of the form:

$$\begin{aligned}&(1+\tau_{C,t})\left[P_t^H C_t^H + P_t^F C_t^F\right] + P_t^H I_t^H + P_t^F I_t^F + \mathrm{E}_t\left\{Q_{t,t+1} V_{t+1}^H\right\}\\ &\leq V_t^H + (1-\tau_{L,t}) W_t^H N_t^H + (1-\tau_{K,t}) R_{K,t}^H K_t^H + UB_t^H u_t^H + \Pi_t^H\end{aligned} \tag{4.3}$$

which holds for all period $t = 0, 1, 2, ...$ The price of goods produced in region i is given by P_t^i and V_t^H is the nominal payoff in period t of the portfolio held at the end of period $t-1$. Investment in the home good and foreign good are given by respectively I_t^H and I_t^F. The households own the firms and hence they receive profits Π_t. The nominal wage is given by W_t^H that is earned by the N_t^H household members that are employed. The income on capital that is earned by households is determined by the rental rate of capital $R_{K,t}^H$. Households are taxed via the tax rate on consumption expenditures $\tau_{C,t}$ and capital and labor income are taxed by $\tau_{K,t}$ and $\tau_{L,t}$. The total amount of unemployed in the household are given by u_t^H and they receive an unemployment benefit UB_t^H paid for by the regional government. The level of the unemployment benefit is determined as a fraction of the wage in that region. The stochastic discount factor for one-period ahead nominal payoffs $Q_{t,t+1}$ is assumed to be common across regions.[2]

The production sectors are characterized by monopolistic competition. The index for consumption of a household in region i of the good produced in the home region is given by the CES aggregator:

$$C_t^{H,i} = \left(\frac{1}{n}\int_0^n (C_t^{H,i}(z))^{\frac{\varepsilon-1}{\varepsilon}} dz\right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{4.4}$$

where ε is the elasticity of substitution between varieties. The consumption demand for the goods produced at home is then given by:

$$C_t^{H,i}(z) = \frac{1}{n}\left(\frac{P_t^H(z)}{P_t^H}\right)^{-\varepsilon} C_t^{H,i} \tag{4.5}$$

The price index is defined as follows:

$$P_t^H = \left(\frac{1}{n}\int_0^n (P_t^H(z))^{1-\varepsilon} dz\right)^{\frac{1}{1-\varepsilon}} \tag{4.6}$$

As the law of one price holds, P_t^H represents both the price index for the bundle

[2]There are DSGE models that include rule-of-thumb consumers which can only consume their labor income in a certain period, and are not able to save. Though the inclusion of rule-of-thumb consumers in the model could be more realistic, I believe that the effects of the introduction of an EUBS would automatically be larger in size. Therefore, I exclude this feature as to be cautious on the effectiveness of the European unemployment benefit scheme.

of goods imported from the home region as well as the home region's domestic price index. Therefore, I can derive for the home region that:

$$\int_0^1 P_t^H(z)C_t^H(z)dz = P_t^H C_t^H \tag{4.7}$$

The home CPI index is given by:

$$P_t = (P_t^H)^{1-\alpha}(P_t^F)^{\alpha} \tag{4.8}$$

The optimal allocation of expenditures implies for the home region that $P_t^H C_t^H = (1-\alpha)P_t C_t$ and $P_t^F C_t^F = \alpha P_t C_t$, while for the foreign region $P_t^{F,*}C_t^{F,*} = (1-\alpha)P_t^* C_t^*$ and $P_t^{H,*}C_t^{H,*} = \alpha P_t^* C_t^*$. Due to the Cobb-Douglas preferences, a fixed proportion of income is allocated to each consumption bundle.

The law of one price holds for all goods, however, purchasing power parity does not need to hold at the aggregate level. It could be that $P_t \neq P_t^*$ due to the presence of a home bias in consumption.

Investment

Households rent out capital that is invested in a homogeneous investment good. The law of motion for capital accumulation is as follows:

$$K_{t+1}(z) = (1-\xi)K_t(z) + \varepsilon_{I,t}\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)I_t \tag{4.9}$$

Capital depreciates at a rate ξ and the variable $\varepsilon_{I,t}$ represents technological progress that is specific for investment. The investment adjustment cost function is given by $S(\cdot)$. It is assumed that the value of $S(\cdot)$ equals zero if $\frac{I_t}{I_{t-1}} = 1$. Hence, if investment stays at the same level, there are no adjustment costs.

The investment bundle of a household is given by:

$$I_t = \frac{(I_t^H)^{1-\alpha}(I_t^F)^{\alpha}}{(1-\alpha)^{1-\alpha}(\alpha)^{\alpha}} \tag{4.10}$$

The index for investment of a household of region i of the good produced in the home region is given by the following CES aggregator:

$$I_t^{H,i} = \left(\frac{1}{n}\int_0^n (I_t^{H,i}(z))^{\frac{\varepsilon-1}{\varepsilon}}dz\right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{4.11}$$

Domestic investment demand is given by:

$$I_t^{H,i}(z) = \frac{1}{n}\left(\frac{P_t^H(z)}{P_t^H}\right)^{-\varepsilon} I_t^{H,i} \tag{4.12}$$

The price indexes are the same for the consumption and investment goods. Due to the Cobb-Douglas preferences, the optimal allocation of expenditures to the investment bundles implies that $P_t^H I_t^H = (1-\alpha)P_t I_t$ and $P_t^F I_t^F = \alpha P_t I_t$. For the foreign region, the optimal allocation is given by $P_t^{F,*} I_t^{F,*} = (1-\alpha)P_t^* I_t^*$ and $P_t^{H,*} I_t^{H,*} = \alpha P_t^* I_t^*$.

Household optimization

The optimization problem of the household involves the maximization of its lifetime utility function subject to the sequence of budget constraints and the law of motion for capital. The first-order conditions of this optimization problem lead to the well-known Euler equation[3]:

$$\frac{1}{R_t} = \beta \mathrm{E}_t\left[\frac{\Omega_{t+1}}{\Omega_t}\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+1}}\frac{1+\tau_{C,t}}{1+\tau_{C,t+1}}\right] \tag{4.13}$$

the condition for labor supply:

$$\frac{\chi(N_t^H)^{\phi}}{C_t^{-\sigma}} = \frac{(1-\tau_{L,t})W_t^H}{(1+\tau_{C,t})P_t} \tag{4.14}$$

the equation for investment demand:

$$\begin{aligned} 1 = {} & Q_{T,t}^H \varepsilon_{I,t}\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] \\ & + \mathrm{E}_t\left[\frac{Q_{T,t+1}^H}{R_t}\frac{P_{t+1}}{P_t}\varepsilon_{I,t+1} S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_{t+1}}{I_t}\right] \end{aligned} \tag{4.15}$$

and the equation for the price of capital:

$$Q_{T,t}^H = \mathrm{E}_t\left[\frac{(1-\tau_{K,t+1})R_{K,t+1}^H}{P_t R_t} + (1-\xi)\frac{Q_{T,t+1}^H}{R_t}\frac{P_{t+1}}{P_t}\right] \tag{4.16}$$

[3] The derivation of the first-order conditions can be found in the appendix.

4.3.2 Terms of trade and international risk sharing

The terms of trade is defined as the ratio of the price of goods produced in the foreign region to the price of goods produced in the home region:

$$S_t = \frac{P_t^F}{P_t^H} \tag{4.17}$$

The law of one price is assumed to hold for all goods such that $P_t^H = P_t^{H,*}$ and $P_t^F = P_t^{F,*}$. Therefore, the following relationships between the domestic price index and the CPI in the two regions exist:

$$P_t = P_t^H (S_t)^{\alpha} \tag{4.18}$$

$$P_t^* = P_t^F (S_t)^{-\alpha} \tag{4.19}$$

The real exchange rate is the ratio between the foreign CPI and home CPI and relates to the terms of trade in the following way:

$$RER_t = \frac{P_t^*}{P_t} = (S_t)^{1-2\alpha} \tag{4.20}$$

where it is assumed that α is the same in both the home and the foreign economy.

Financial markets are assumed to be complete, which means that each household can access a complete set of contingent claims that is traded internationally. Therefore, the perfect risk-sharing condition holds:

$$RER_t = \kappa \frac{u'(C_t^*)}{u'(C_t)} = \kappa \left(\frac{C_t^*}{C_t}\right)^{-\sigma} \frac{\Omega_t^*}{\Omega_t} \tag{4.21}$$

where κ is a constant that depends on the initial conditions given by $\kappa = RER_0 \frac{u'(C_0)}{u'(C_0^*)}$. Movements in the real exchange rate will be reflected in different consumption rates.

4.3.3 Firms

Firms in the intermediate goods sector are perfectly competitive. Capital and labor input are required for production. The intermediate goods are sold to the final goods producers that are monopolistically competitive.

Intermediate goods producers

In the intermediate goods sector there is a continuum of firms indexed by z. Each firm produces this intermediate good z according to a constant-returns-to-scale production function with labor and capital as inputs:

$$X_t^i(z) = A_t^i N_t^i(z)^{1-\zeta} K_t^i(z)^{\zeta} \tag{4.22}$$

where A_t^i represents the state of technology in region i.

There is a fraction δ^i of the employed that loses its job and enters the unemployment pool in every period t. Employment in a firm z hence evolves according to:

$$N_t^i(z) = (1-\delta^i)N_{t-1}^i(z) + h_t^i(z) \tag{4.23}$$

where $h_t^i(z)$ is the new hires by firm z in region i. Employment at the aggregate level in the home region, $N_t \equiv \int_0^n N_t(z)dz$, is given by:

$$N_t^i = (1-\delta^i)N_{t-1} + h_t^i \tag{4.24}$$

where the aggregate hiring level is represented by $h_t \equiv \int_0^n h_t(z)dz$. In the foreign economy, aggregate employment equals $N_t^* \equiv \int_n^1 N_t^*(z)dz$ and aggregate hiring is equal to $h_t^* \equiv \int_n^1 h_t^*(z)dz$.

It is assumed that everyone who is unemployed looks for a job. Hence, the number of searching workers that are available for hire in region i, U_t^i, is equal to:

$$U_t^i = 1 - (1-\delta^i)N_{t-1} \tag{4.25}$$

and unemployment is defined as the fraction of population left without a job after the hiring took place:

$$u_t^i = 1 - N_t^i \tag{4.26}$$

The number of new hires is determined by a matching function of searching workers and vacancies posted by firms:

$$M_t^i = \sigma_M (U_t^i)^{\omega} (v_t^i)^{1-\omega} \tag{4.27}$$

where v_t^i is the total number of vacancies posted by firms to attract new workers.

The probability that a firm fills a vacancy is thus given by

$$q_t^i = \frac{M_t^i}{v_t^i} \tag{4.28}$$

and the probability that a searching worker finds a job is given by:

$$s_t^i = \frac{M_t^i}{U_t^i} \tag{4.29}$$

Both firms and workers take these probabilities q_t^i and s_t^i as given. The hiring of the firms in the economy thus equals $h_t^i = q_t^i v_t^i$.

The costly hiring of labor imposes another labor market friction in the model. The hiring cost per hire in region i is G_t^i, which is assumed to be given for the individual firm. Hence, total hiring cost for a firm in region i is given by $G_t^i h_t^i(z)$. The ratio of aggregate vacancies to the number of searching individuals is defined as the labor market tightness index, $x_t^i \equiv \frac{v_t^i}{U_t^i}$. The recruitment or hiring costs are an increasing function of the labor market tightness index:

$$G_t^i = A_t^i Z^i (x_t^i)^{\psi} \tag{4.30}$$

where $\psi > 0$ and Z^i is a positive constant.

Optimization problem of intermediate goods producers

The intermediate good produced at home is sold to retailers at the relative price $\mu_t^H = \frac{P_{I,t}^H}{P_t^H}$ as $P_{I,t}$ is the nominal price of the intermediate good. Then the intermediate good producers maximize their discounted expected future profits:

$$\begin{aligned} \max \mathrm{E}_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \Big[& P_{I,t+s}^H X_{t+s}^H(z) - P_{t+s}^H G_{t+s}^H h_{t+s}^H(z) \\ & - W_{t+s}^H N_{t+s}^H(z) - R_{K,t+s}^H K_{t+s}^H(z) \Big] \end{aligned} \tag{4.31}$$

where the profit of the firm equals its revenues minus the cost of hiring and the wage costs. Here the discount factor for nominal payoffs is given by $\Lambda_{t,t+s} = \beta^s \frac{\Omega_{t+s}}{\Omega_t} \left(\frac{C_{t+s}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+s}}$. The constraints on this maximization problem are the evolution of employment in the firm in equation (4.23) and the production function of firm z given by equation (4.22).

The first-order conditions of this optimization problem lead to the following equation[4]:

$$\mu_t^H(1-\zeta)A_t^H N_t^H(z)^{-\zeta}K_t^H(z)^{\zeta} = \frac{W_t^H}{P_t}(S_t)^{\alpha} + G_t^H - (1-\delta^H)\mathrm{E}_t\left[\beta\frac{\Omega_{t+1}}{\Omega_t}\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}}\frac{S_t^{\alpha}}{S_{t+1}^{\alpha}}G_{t+1}^H\right] \tag{4.32}$$

This relationship states that the marginal revenue of labor has to equal the marginal cost. This cost includes not only the real wage, but also the additional cost for hiring a new worker as well as the savings on future hiring cost as a result from increasing the amount of employees now.

Moreover, a relationship between the real cost of capital, the marginal cost and the use of the input factors is derived:

$$\frac{R_{K,t}^H}{P_t^H} = \mu_t^H\zeta A_t^H N_t^H(z)^{1-\zeta}K_t^H(z)^{\zeta-1} \tag{4.33}$$

Wage determination

Due to the hiring costs, there is a positive rent from existing employment relationships. Wages are bargained to split this rent between the firm and the employee, the share depending on their bargaining power. The value of a job for firm z, the firm's surplus as expressed in terms of consumption goods, is:

$$\frac{P_t^H G_t^H}{P_t} \tag{4.34}$$

For the worker, the marginal value of the employment relationship is:

$$\mathcal{W}_t^{H,E} = \frac{(1-\tau_{L,t})W_t^{H,Nash}}{P_t} - \chi C_t^{\sigma}(N_t^H)^{\phi} + \beta\mathrm{E}_t\left[\frac{\Omega_{t+1}}{\Omega_t}\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left[(1-\delta^H(1-x_{t+1}^H))\mathcal{W}_{t+1}^{H,E} + \delta^H(1-x_{t+1}^H)\mathcal{W}_{t+1}^{H,U}\right]\right] \tag{4.35}$$

The first term is the real wage of the worker, the second term is the disutility from work and the last term represents the discounted expected continuation value. The probability of being unemployed at time $t+1$ is given by $\delta^H(1-x_{t+1}^H)$. The

[4] The derivation of the first-order conditions can be found in the appendix.

value for a member who is unemployed (after hiring takes place) is:

$$\mathcal{W}_t^{H,U} = \frac{UB_t^H}{P_t} + \beta \mathrm{E}_t \left[\frac{\Omega_{t+1}}{\Omega_t} \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left[x_{t+1}^H \mathcal{W}_{t+1}^{H,E} + (1 - x_{t+1}^H) \mathcal{W}_{t+1}^{H,U} \right] \right] \tag{4.36}$$

Hence, for the household the surplus of an employment relationship is given by:

$$\begin{aligned} \mathcal{W}_t^{H,E} - \mathcal{W}_t^{H,U} &= \frac{(1-\tau_{L,t}) W_t^{H,Nash}}{P_t} - \chi C_t^{\sigma} (N_t^H)^{\phi} - \frac{UB_t^H}{P_t} \\ &+ \beta(1-\delta^H) \mathrm{E}_t \left[\frac{\Omega_{t+1}}{\Omega_t} \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \left[(1 - x_{t+1}^H) \left(\mathcal{W}_{t+1}^{H,E} - \mathcal{W}_{t+1}^{H,U} \right) \right] \right] \end{aligned} \tag{4.37}$$

The share of the surplus going to the worker is given by ζ, and therefore the bargaining solution is given by:

$$\mathcal{W}_t^{H,E} - \mathcal{W}_t^{H,U} = \frac{\zeta}{1-\zeta} \frac{P_t^H G_t^H}{P_t} = \eta G_t^H (S_t)^{-\alpha} \tag{4.38}$$

where $\eta = \frac{\zeta}{1-\zeta}$ is the relative weight of workers in the Nash bargaining reflecting the worker's bargaining power. Hence, the Nash wage schedule is given by:

$$\begin{aligned} &\frac{(1-\tau_{L,t}) W_t^{H,Nash}}{A_t^H P_t} (S_t)^{\alpha} = \frac{\chi C_t^{\sigma} (N_t^H)^{\phi} (S_t)^{\alpha}}{A_t^H} + \frac{UB_t^H (S_t)^{\alpha}}{A_t^H P_t} \\ &+ \eta \left(B(x_t^H)^{\psi} - (1-\delta^H) \mathrm{E}_t \left[\beta_{t,t+1} (1 - x_{t+1}^H) \frac{A_{t+1}^H}{A_t^H} B(x_{t+1}^H)^{\psi} \right] \right) \end{aligned} \tag{4.39}$$

where the first term denotes the marginal rate of substitution between consumption and leisure. Besides, the Nash wage schedule takes into account the outside option of the worker, which is the unemployment benefit. The latter term reflects the labor market conditions, and is taken into account in the wage bargaining if the workers have at least some bargaining power ($\eta > 0$) and there are hiring costs ($B > 0$). This term increases in current labor market tightness x_t^H, as this raises the surplus from an existing relationship for the firm. As the expected future hiring costs $A_{t+1}^H B(x_{t+1}^H)^{\psi}$ and the probability of not finding a job if unemployed next period, given by $(1 - x_{t+1})$, raise the continuation value of an employed worker, these reduce the Nash bargained wage.

Final goods sector

In each region, final goods producers face monopolistic competition in the production of a differentiated consumption good. There is imperfect substitutability across these goods, therefore the final goods producer faces a Dixit-Stiglitz type of demand function for his product:

$$Y_t(z) = \frac{1}{n}\left(\frac{P_t^H(z)}{P_t^H}\right)^{\varepsilon} Y_t \tag{4.40}$$

The final goods producers use one unit of the intermediate good as an input to produce one unit of final good, so that their production technology can be defined as $Y_t(z) = X_t(z)$. The final goods producers can purchase intermediate goods at price μ_t^H, which is the marginal cost for the final goods producer.

In the final goods sector, prices are set according to Calvo staggered price setting. A fraction $(1-\theta)$ of the firms has the chance to optimally set its price. The fraction θ of the firms will maintain the same price as in the previous period. The optimal price is chosen to maximize the present discounted value, taking into account that the firm might not be able to reset its price for a random amount of periods. The optimal price setting rule for firms in the home region is given by:

$$\mathrm{E}_t\left[\sum_{s=0}^{\infty}\theta^s Q_{t,t+s} Y_{t+s/t}\left(\tilde{P}_t^H - \frac{\varepsilon}{\varepsilon-1}P_{t+s}^H \mu_{t+s}^H\right)\right] = 0 \tag{4.41}$$

where $\tilde{P}_t^H$ is the optimal price chosen at time t. The evolution of the price index for production in the home region is given by:

$$P_t^H = \left[(1-\theta)(\tilde{P}_t^H)^{1-\varepsilon} + \theta(P_{t-1}^H)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{4.42}$$

Real wage rigidities

To account for the high wage rigidity that is especially apparent in the Euro area, a real wage rigidity as in Hall (2005) is used. There is a wage norm that arises because of social conventions that hinder wage adjustment for existing and newly hired workers.[5] The real wage $\frac{W_t^H}{P_t} \equiv w_t^{H,R}$ is a weighted average of the

[5] The introduction of a wage norm in a search and matching model is mostly for the sake of matching labor market fluctuations. As a wage norm limits adjustment via wages, it increases the adjustments on the quantity side of the labor market. In that sense, the model is better able to replicate the fluctuations in vacancies and unemployment. Though being a shortcut to a micro founded wage rigidity, the aggregate wage norm is a widely used method to incorporate

Nash bargained wage and the wage norm w^H, so that it is determined as:

$$w_t^{H,R} = \left(w_t^{H,Nash}\right)^{1-\gamma}\left(w^H\right)^{\gamma} \tag{4.43}$$

4.3.4 Common monetary authority and national fiscal authorities

The monetary authority of this currency union will follow an interest-rate feedback rule that takes into account both the union-wide inflation and output gap:

$$\hat{i}_t = \rho \cdot \hat{i}_{t-1} + (1-\rho)[\rho_\pi \hat{\pi}_t^{EMU} + \rho_y \hat{y}_t^{EMU}] + \hat{\varepsilon}_t \tag{4.44}$$

where $\hat{i}_t$ is the log deviation of the nominal interest rate from its steady state. The central bank reacts to the log deviation of inflation from the steady state $\hat{\pi}_t$ as well as $\hat{y}_t$, the deviation of GDP from its steady state level.

The government collects taxes on consumption expenditures and capital and labor income, which it spends on interest payments on government debt, government expenditures and total unemployment benefits. The government budget constraint for the home region is therefore:

$$B_t^H = (1+R_t)B_{t-1}^H + UB_t^H u_t^H + G_t - \tau_{C,t}P_tC_t - \tau_{K,t}R_{K,t}^H K_t^H - \tau_{L,t}W_t^H N_t^H \tag{4.45}$$

where $UB_t^H \times u_t^H$ represents total unemployment benefits in period t and G_t is government expenditures that follow an AR(1) process. The level of the unemployment benefit is a policy variable that depends on the regional real wage:

$$\log UB_t = \rho_{UB} \log w_{t-1} \tag{4.46}$$

Tax rates follow the following policy rule:

$$\log \tau_{C,t} = \rho_{\tau_C} \log \tau_{C,t-1} + \gamma_{\tau_C} \log B_{t-1} + u_{\tau_C,t} \tag{4.47}$$

$$\log \tau_{K,t} = \rho_{\tau_K} \log \tau_{K,t-1} + \gamma_{\tau_K} \log B_{t-1} + u_{\tau_K,t} \tag{4.48}$$

$$\log \tau_{L,t} = \rho_{\tau_L} \log \tau_{L,t-1} + \gamma_{\tau_L} \log B_{t-1} + u_{\tau_L,t} \tag{4.49}$$

The tax rates are expected to depend positively on government debt in order to ensure fiscal solvency.

wage rigidities in the model, see for example Christoffel and Linzert (2005) and Abbritti and Mueller (2013).

4.3.5 Market clearing

Besides labor market and capital market clearing, the goods market needs to be cleared. The market clearing condition for good z produced in the home region is:

$$Y_t(z) - G_t^H h_t^H(z) = C_t^H(z) + C_t^{H,*}(z) + I_t^H(z) + I_t^{H,*}(z) \tag{4.50}$$

The aggregate goods market clearing condition in the home region is obtained by aggregation across varieties:

$$Y_t - G_t^H h_t^H = (1-\alpha)S_t^{\alpha}C_t + \frac{1-n}{n}\alpha S_t^{1-\alpha}C_t^* + (1-\alpha)S_t^{\alpha}I_t + \frac{1-n}{n}\alpha S_t^{1-\alpha}I_t^* \tag{4.51}$$

4.3.6 European unemployment benefit scheme

The European unemployment benefit scheme is a system of benefits to all unemployed within the monetary union which is financed by the governments of the regions. The European unemployment benefit depends on the weighted average of the real wages in both economies:

$$\log UB_{EMU,t} = \psi_{EMU} \cdot \left(n \log W_{t-1}^i + (1-n)\log W_{t-1}^{i*}\right) \tag{4.52}$$

In the policy experiments, I will assume that the benefit paid to the unemployed should give the same replacement rate as a percentage of the real wage in each region for fairness reasons. Therefore, the European unemployment benefit that the unemployed in the home region ($ub_{EMU,t}^i$) and the foreign region ($ub_{EMU,t}^{i*}$) will receive is adjusted by a factor to ensure that the relative size rather than the absolute size of the benefit is the same.[6]

The total expenditures on this scheme are financed by both governments. The total expenditures Z_t are given by

$$Z_t = UB_{EMU,t}^i \cdot u_t^i + UB_{EMU,t}^{i*} \cdot u_t^{i*} \tag{4.53}$$

[6] To illustrate, the European unemployment benefit is given by $UB_{EMU,t}$. Each unemployed in North receives $UB_{EMU,t}^i$ and each unemployed worker in South receives $UB_{EMU,t}^{i*}$, such that the northern replacement rate, given by $\frac{UB_{EMU,t}^i}{W_t^i}$, equals the replacement rate in the South, which is $\frac{UB_{EMU,t}^{i*}}{W_t^{i*}}$. For that purpose, the unemployment benefits are adjusted by a factor υ in North and υ^* in South, hence $UB_{EMU,t}^i = UB_{EMU,t}^{\upsilon}$ and $UB_{EMU,t}^{i*} = UB_{EMU,t}^{\upsilon^*}$.

The contribution of each region to these expenditures is based on the relative share of unemployment in the union at the time of the introduction of the EUBS. Hence, I make sure that when the scheme is introduced, each region is effectively financing its own unemployed citizens. The region that is afterwards negatively affected by shocks leading to high unemployment rates will in this way be subsidized by the other region. The amount that the home region and the foreign region contribute to the scheme are respectively :

$$z_t^i = \frac{\bar{u}^i}{\bar{u}^i + \bar{u}^{i*}} \cdot Z_t \qquad \text{and} \qquad z_t^{i*} = \frac{\bar{u}^{i*}}{\bar{u}^i + \bar{u}^{i*}} \cdot Z_t \tag{4.54}$$

The total expenditures are covered by both governments, which implies that there is no accumulation of either funds or debt. Moreover, if I take $\bar{u}^i$ and $\bar{u}^{i*}$ to be the unemployment levels at the time of the introduction, one could easily see that in the first period each region pays only for its own unemployed people. The expenditures on the EUBS end up on the government budget constraint as any other expense, such that:

$$B_t^H = (1+R_t)B_{t-1}^H + UB_t^H u_t^H + G_t + Z_t - \tau_{C,t}P_tC_t - \tau_{K,t}R_{K,t}^H K_t^H - \tau_{L,t}W_t^H N_t^H \tag{4.55}$$

The idea behind this European unemployment benefit scheme is to provide temporary relief to a region with high unemployment which might be caused by adverse economic shocks. It is not the goal of this scheme to start off a continuous redistribution from one region to the other. If no clear paths for unemployment are expected in advance, then it is just as likely that the home region will be subsidizing the foreign region as the other way around. Moreover, one could also consider resettling the period on which the shares in expenditures are based, if structural growth in unemployment would have governed the financing dynamics too much into one direction.

4.3.7 Solving the model

The size of the model does not allow for a closed-form solution. Therefore, I will log-linearize the model around the steady state. The log-linearized model can be found in the appendix. Then the model is solved numerically by Dynare.[7]

The DSGE model of the monetary union is given by a system of 73 equations[8]

[7]The Matlab codes for running the Dynare programs are available upon request.

[8]The estimated version of the model does not include the equations for the European unemployment benefit scheme, and therefore it contains 65 equations.

and 15 exogenous shocks. There are shocks to productivity or technology ($u^i_{A,t}$, $u^{i*}_{A,t}$), shocks to investment efficiency ($u^i_{E,t}$, $u^{i*}_{E,t}$) and shocks to preferences ($u^i_{\Omega,t}$, $u^{i*}_{\Omega,t}$). Moreover, there are shocks to government spending and the tax rates ($u^i_{G,t}$, $u^{i*}_{G,t}$, $u^i_{\tau_C,t}$, $u^{i*}_{\tau_C,t}$, $u^i_{\tau_K,t}$, $u^{i*}_{\tau_K,t}$, $u^i_{\tau_L,t}$, $u^{i*}_{\tau_L,t}$) as well as a monetary policy shock to the interest rate ($u_{R,t}$).

4.3.8 Welfare measure

In order to evaluate how households are affected by the introduction of a European unemployment benefit scheme, I will use a welfare measure based on a second-order Taylor series expansion of the utility function around the steady state.[9] Here, I follow the approach of Benigno and Woodford (2005) and Jondeau and Sahuc (2008). The second-order approximation of the expected discounted sum of utility is given by:

$$\begin{aligned} U_0 = \sum_{t=0}^{\infty} \beta^t \Big[\bar{U} + (\bar{C})^{1-\sigma} \left(\mathrm{E}_0(\hat{c}_t) + \frac{1-\sigma}{2} \mathrm{E}_0(\hat{c}_t^2) \right) \\ -\chi(\bar{N})^{1+\phi} \left(\mathrm{E}_0(\hat{n}_t) + \frac{1+\phi}{2} \mathrm{E}_0(\hat{n}_t^2) \right) + \mathcal{O}(||\zeta||^3) \Big] \end{aligned}$$

The consumption equivalent welfare measure in the tradition of Lucas (2003) is used to evaluate the welfare effect of the policy experiments. The welfare compensation is measured as the permanent change in steady state consumption that will make the representative household indifferent between a situation A and the steady state. This welfare compensation is given by λ. The size of the welfare gain or welfare loss associated with the introduction of the EUBS is then given by the increase or decrease in the welfare compensation λ relative to the case without the introduction. As a result, an increase in λ due to the introduction of the EUBS implies a welfare gain. The household would require a higher steady state consumption to be just as well off in the steady state, whereas in the situation without EUBS a smaller amount would have been enough to make the representative household indifferent. Consumption equivalence is defined such that

$$\sum_{t=0}^{\infty} \beta^t U((1+\lambda)\bar{C}, \bar{N}) = \sum_{t=0}^{\infty} \beta^t \mathrm{E}_0 U(C_t, N_t)$$

[9] Derivations can be found in the appendix.

which leads to the consumption equivalent welfare measure:

$$\lambda = \left(\mathrm{E}_0(\hat{c}_t) + \frac{1-\sigma}{2}\mathrm{E}_0(\hat{c}_t^2)\right) - \chi(\bar{N})^{1+\phi}(\bar{C})^{\sigma-1}\left(\mathrm{E}_0(\hat{n}_t) + \frac{1+\phi}{2}\mathrm{E}_0(\hat{n}_t^2)\right)$$

4.4 Bayesian Estimation

Using Bayesian techniques, I estimate the two-region model presented in the previous section for the northern and southern region of the Euro area. As there are 15 shocks in the model, 15 macroeconomic time series are used as observable variables in the estimation. I have gathered data on GDP, consumption expenditures, investment expenditures, CPI, real wages, government debt and unemployment for both a northern and a southern block of countries. Moreover, the data on the nominal interest rate set by the ECB is added to the observables. The southern block consists of the so-called PIGS countries, i.e. Portugal, Italy, Greece and Spain. North represents the other Eurozone countries that were early members of the EMU, namely Austria, Belgium, Finland, France, Germany, Ireland, Luxembourg and the Netherlands.[10] The variables are seasonally adjusted and detrended prior to the estimation. The source of the data is mostly the OECD database, except for the interest rate and government debt data which is taken from Eurostat. A more extensive description of the data used is given in the appendix. The estimation period is from the first quarter of 2000 until the third quarter of 2016. Lack of data availability, especially for the fiscal variables for Greece, limits the estimation to a period of 67 quarters.

4.4.1 Calibrated parameters

In the Bayesian estimation of the model, some parameters are calibrated rather than estimated. Due to their relation to the trend of variables, these structural parameters cannot be pinned down in the estimation. For setting the values of these parameters, I follow the existing literature such as Smets and Wouters (2003), Kolasa (2009) and Hollmayr (2012).

[10] One could consider Ireland as a reasonable candidate for the southern block of countries within the EMU as these are also referred to as PIIGS-countries. However, the share of Ireland's GDP in the northern block is 1.1% and if added to the South it would be 2.4%. Therefore, it is not likely that the estimation results would be substantially affected by this.

Table 4.4.1: Calibrated parameters

Parameter	North	South
	Structural parameters	
n	0.66	0.34
β	0.99	0.99
σ	2	2
α	0.04	0.12
ξ	0.025	0.025
ζ	0.33	0.33
ω	0.5	0.5
	Monetary policy parameters	
ρ	0.7	
ψ_Y	0.3	
ψ_π	2.0	
	Steady state values	
$\bar{N}$	0.923	0.881
$\bar{u}$	0.077	0.119
$\frac{\bar{C}}{\bar{Y}}$	0.54	0.58
$\frac{\bar{I}}{\bar{Y}}$	0.24	0.24
$\frac{\bar{G}}{\bar{Y}}$	0.22	0.18
$\frac{\bar{R}}{\bar{D}}$	0.01	0.01
$\frac{T\bar{A}X_C}{\bar{D}}$	0.0462	0.0353
$\frac{T\bar{A}X_K}{\bar{D}}$	0.015	0.015
$\frac{T\bar{A}X_L}{\bar{D}}$	0.0435	0.0338
$\frac{\bar{G}}{\bar{D}}$	0.0404	0.0321
$\frac{\bar{u}\cdot\bar{ub}}{\bar{D}}$	0.0372	0.0214

The relative size of the northern block of countries in the Euro area, leaving aside the late entrants, is 66%. For the discount factor β and the elasticity of intertemporal substitution σ, I follow the parameterization that is commonly used in the DSGE literature. The home bias for the North and the South is calculated based on the estimates of the home bias for each EMU member country as in Hollmayr (2012). The North has a larger home bias than the southern block, which is mainly because of the extensive trade with Germany. The depreciation rate of capital ξ is set at 2.5% which implies a yearly depreciation rate of approximately 10%. The elasticity of output with respect to capital is calibrated at the standard value of 0.33. Furthermore, I set ω, the elasticity of the matches to unemployment, equal to 0.5 as in Gertler et al. (2008).

The monetary policy rule contains commonly used parameter values, in which the weight on the inflation gap is larger than the weight on the output gap. This is also a reasonable assumption for the European Central Bank and in line with the existing literature, for example Smets and Wouters (2003).

There are log-linearized equations that contain the steady state value of the variables due to the existence of additive terms in the original equations. I approximate these steady state values by using long-run averages of these variables, provided by the OECD database. The average unemployment rate is equal to 7.7% in North and 11.9% in South, which also leads to the average value of the employed population of 92.3% and 88.1% respectively. Private consumption expenditures make up for 54% of northern GDP and 58% of southern GDP. Investment expenditures are approximately 24% of GDP in both North and South, whereas government expenditures are slightly larger in North compared to South. The steady state values for the fiscal variables are the long-run averages on government debt, different types of tax revenues and expenditures on unemployment benefits taken from Eurostat.

4.4.2 Prior distribution and parameter estimates

The assumptions on the prior distribution as well as the estimated posterior distribution for the structural parameters of the model are shown in table 4.4.2. The prior means in this table are set close to values used in the existing literature, and I set the priors of the standard errors such that the domain covers reasonable values of the parameters. The last columns show the mean of the posterior distribution, as well as the confidence bounds at the 10% and 90% level.

The inverse elasticity of labor supply ϕ is assumed to have a gamma distribution, such that it cannot become negative. The estimate for the South is significantly larger than that for the North. The prior for ψ, which is the parameter for the hiring cost function, is set equal to one which would imply a constant marginal cost. The estimate for the North is larger than one, meaning that the marginal cost increases with hiring, whereas the marginal cost of hiring is decreasing in South. The separation rate δ is estimated to be larger in the South than in the North, and both estimates are higher than the calibrated job separation rate in the paper by Abbritti and Mueller (2013). The fact that the North is more rigid in this sense has implications for the effectiveness of the EUBS, as we will see in section 5.3. The Calvo parameters for price setting are relatively high in both regions, suggesting a substantial degree of price rigidity.

Table 4.4.2: Estimation results: Structural parameters

	Prior distribution			Posterior distribution		
	Type	Mean	St. Error	Mean	10%	90%
ϕ	gamma	0.7	0.1	0.7201	0.7067	0.7339
ϕ^*	gamma	0.7	0.1	0.5398	0.5130	0.5684
ψ	gamma	1.0	0.2	1.0630	1.0264	1.0952
ψ^*	gamma	1.0	0.2	0.9556	0.9311	0.9721
δ	beta	0.1	0.05	0.2672	0.2551	0.2795
δ^*	beta	0.1	0.05	0.3871	0.3763	0.3972
θ	beta	0.8	0.1	0.9649	0.9610	0.9690
θ^*	beta	0.8	0.1	0.9285	0.9229	0.9340
γ	beta	0.3	0.1	0.2622	0.2325	0.2931
γ^*	beta	0.3	0.1	0.2620	0.2289	0.2982
η	beta	0.5	0.1	0.4755	0.4369	0.5084
η^*	beta	0.5	0.1	0.4581	0.4363	0.4799
χ	gamma	1.0	0.2	1.5034	1.4937	1.5142
χ^*	gamma	1.0	0.2	1.3486	1.3301	1.3672

Table 4.4.3: Estimation results: Regional fiscal policy parameters

	Prior distribution			Posterior distribution		
	Type	Mean	St. Error	Mean	10%	90%
ρ_G	beta	0.7	0.1	0.7997	0.7483	0.8499
ρ_G^*	beta	0.7	0.1	0.9153	0.8830	0.9476
ρ_{τ_C}	beta	0.8	0.1	0.9935	0.9902	0.9984
$\rho_{\tau_C}^*$	beta	0.8	0.1	0.9573	0.9427	0.9735
ρ_{τ_K}	beta	0.8	0.1	0.9897	0.9819	0.9979
$\rho_{\tau_K}^*$	beta	0.8	0.1	0.7221	0.6682	0.7641
ρ_{τ_L}	beta	0.8	0.1	0.9358	0.9201	0.9493
$\rho_{\tau_L}^*$	beta	0.8	0.1	0.9364	0.9077	0.9652
ρ_{UB}	beta	0.7	0.05	0.8105	0.8032	0.8167
ρ_{UB}^*	beta	0.7	0.05	0.7676	0.7554	0.7804
γ_{τ_C}	normal	0.2	0.1	0.0500	0.0426	0.0583
$\gamma_{\tau_C}^*$	normal	0.2	0.1	0.3862	0.3529	0.4197
γ_{τ_K}	normal	0.2	0.1	0.3926	0.3621	0.4184
$\gamma_{\tau_K}^*$	normal	0.2	0.1	0.2028	0.1817	0.2175
γ_{τ_L}	normal	0.2	0.1	0.1381	0.1246	0.1489
$\gamma_{\tau_L}^*$	normal	0.2	0.1	0.1715	0.1517	0.1943

The parameter for wage rigidity is rather similar in the two regions, though lower than the value 0.5 that Abbritti and Mueller (2013) use for the calibration of their model. In terms of the relative bargaining power of workers η there is only a small difference between the North and the South. Southern workers seem to have a slightly smaller weight in the bargaining process. The parameter χ governs the disutility of employment, where it seems that the marginal disutility from working in the North is higher than in the South.

For setting the prior distribution of the regional fiscal policy parameters, the focus is on economic intuition. The persistence parameters for government expenditures and the tax rates are assumed to have a beta distribution, since they are naturally between zero and one. The difference between the northern and southern parameters is not too large, except for the lower persistence in southern capital income taxes and northern government expenditures. Moreover, I estimate the dependence of the unemployment benefits on real wages with ρ_{UB}, where we can observe that the replacement rate in North is higher than that in the South. In order to ensure fiscal solvency, one would expect that the tax rates respond positively to government debt. The coefficients for the tax rates show that the response to government debt is positive, with quite substantial differences between the North and the South for the consumption and capital income tax rate.

The AR(1) processes for productivity and investment efficiency are assumed to have a persistence parameter of 0.7, whereas the process for the preference variable is assumed to be less persistent. The priors of the standard deviations of the shock processes are assumed to follow an inverted gamma distribution. We can observe in table 4.4.4 that the estimates on the volatilities of shocks differ in size. The estimates indicate that shocks to consumer preferences, investment efficiency and capital income taxes have larger standard deviations than the other shocks. There is hardly any evidence that shocks are more volatile in either the South or the North.

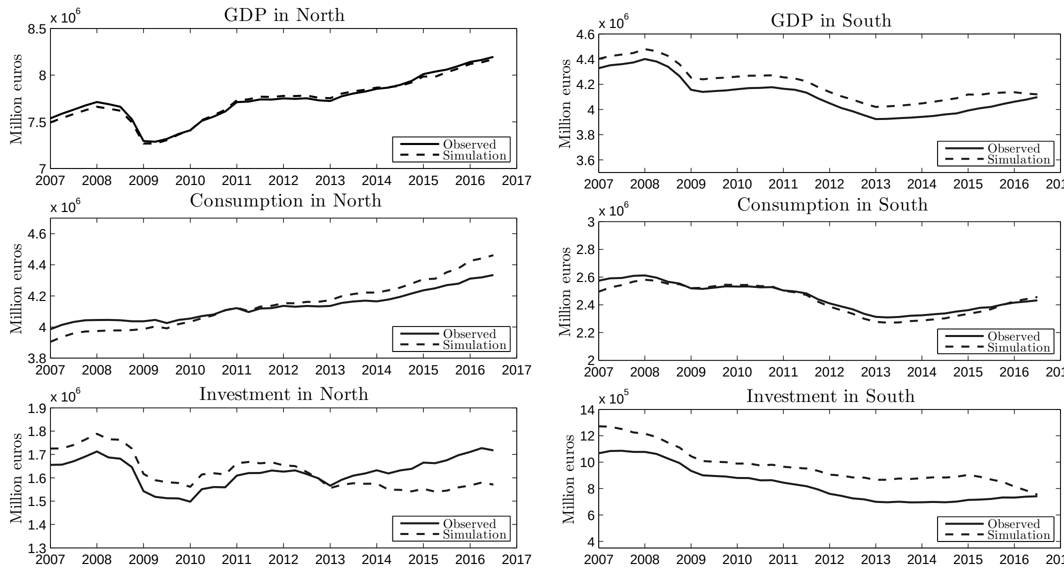
Table 4.4.4: Estimation results: Shock parameters

	Prior distribution			Posterior distribution		
	Type	Mean	St. Error	Mean	10%	90%
ρ_A	beta	0.7	0.1	0.8438	0.8164	0.8667
ρ_A^*	beta	0.7	0.1	0.9253	0.9149	0.9366
ρ_O	beta	0.25	0.1	0.5646	0.5504	0.5782
ρ_O^*	beta	0.25	0.1	0.5775	0.5730	0.5844
ρ_E	beta	0.7	0.1	0.7179	0.6939	0.7423
ρ_E^*	beta	0.7	0.1	0.7830	0.7444	0.8166
σ_A	inv. gamma	2.0	inf	1.0613	0.9054	1.2120
σ_A^*	inv. gamma	5.0	inf	0.8848	0.7477	1.0268
σ_O	inv. gamma	7.0	inf	3.5266	2.8297	4.1563
σ_O^*	inv. gamma	7.0	inf	3.2539	3.0175	3.5196
σ_E	inv. gamma	4.0	inf	2.9042	2.5817	3.2129
σ_E^*	inv. gamma	4.0	inf	2.3091	2.0550	2.5762
σ_R	inv. gamma	2.0	inf	0.9340	0.8152	1.0536
σ_G	inv. gamma	0.2	inf	0.0265	0.0236	0.0296
σ_G^*	inv. gamma	0.2	inf	0.0349	0.0286	0.0396
σ_{TC}	inv. gamma	1.0	inf	0.1674	0.1468	0.1856
σ_{TC}^*	inv. gamma	1.0	inf	0.2661	0.2270	0.2985
σ_{TK}	inv. gamma	7.0	inf	1.7266	1.4475	1.9724
σ_{TK}^*	inv. gamma	7.0	inf	1.6839	1.5196	1.8424
σ_{TL}	inv. gamma	1.0	inf	0.1693	0.1440	0.1905
σ_{TL}^*	inv. gamma	1.0	inf	0.3439	0.2879	0.3893

4.4.3 Fitting the model to the data

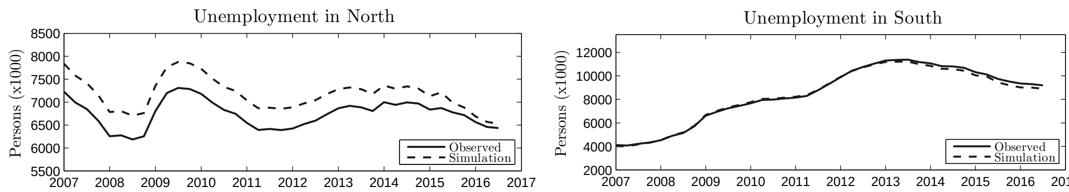
In order to make justified statements on the effectiveness of a European unemployment benefit scheme in the North and the South of the Euro area, the estimated model for those two regions should fit the data reasonably well. Figure 4.1 plots the observed time series against the simulations of the estimated model for real GDP, real consumption and real investment from the first quarter of 2007 until the third quarter of 2016 for both regions. These simulations are based on the policy functions and the exogenous shocks as estimated by the model. The model is quite well able to get close to the observed time series. Except for investment in the North after 2013, the main peaks and drops in these variables are reflected well by the estimated model.

Figure 4.1: Model simulations of GDP, consumption and investment



The simulations of the model for unemployment are depicted in figure 4.2, in which we are particularly interested as the labor market is extensively modeled. The model does really well in reproducing the time series of unemployment, as the simulated series follows the observed time series closely.

Figure 4.2: Model simulations of unemployment



4.5 Policy Experiments

To what extent would the introduction of a European unemployment benefit scheme have been effective in the past? This is the first question that will be addressed in this section by hypothetically introducing an EUBS in the year 2013 and exploring the effect on the main macroeconomic variables and welfare. There are different scenarios for the introduction of an EUBS, of which I will explore two. The main analysis will focus on a European unemployment insurance that replaces the existing regional insurance systems, but I will also top up the existing schemes with a European one. Furthermore, I will answer the second research question of this chapter, that asks whether the EUBS would be ex ante beneficial for both regions. Lastly, I will examine the extent to which labor market harmonization would affect the working of an EUBS.

4.5.1 The effectiveness of an EUBS in the past

In the year 2012, proposals were made by the European Commission to set up a European unemployment benefit scheme. In the Four Presidents' Report of December 5th in that year, a common unemployment insurance was advocated by the presidents of the European Council, European Commission, Eurogroup and ECB (Van Rompuy (2012)). I will use the estimated DSGE model for the Euro area to analyze the effectiveness of a European unemployment benefit scheme in the past. For this objective, I simulate the hypothetical introduction of this unemployment insurance scheme in 2013.

From that moment on, an unemployment benefit, that depends on the weighted average of the real wages in North and South, is paid to all unemployed in the Euro area. The unemployment benefit given to citizens in each region is adjusted by a factor as to make sure that both northern and southern unemployed face similar replacement rates. The unemployment benefit in this experiment is on average equal to 35% of the regional wage. The estimation of the two-region model of the EMU contains the regional unemployment benefit system of the North and the South. The size of the unemployment benefit is assumed to depend on the wage, and the coefficient for this term, comparable to the replacement rate, is estimated for both regions. However, the scenario of an EUBS on top of the existing regional unemployment benefit schemes might not be desirable or attainable. Therefore, I assume the abolishment of all regional systems when a European scheme is introduced.

Both regions finance this system by paying a fixed proportion of the total expenditures based on the relative unemployment level at the introduction of the EUBS in 2013. In this way, the system makes sure that the region hit by high unemployment is temporarily subsidized by the other region. This way of risk sharing might help to cope with asymmetric shocks in the Euro area. In 2013 the unemployment rate for South was increasing, whereas the unemployment rate in North was much lower and stayed rather constant. Because of the increasing unemployment rate of South, a large extent of the cost for the EUBS was paid for by North. Hence, for the first quarters after the introduction of the EUBS, the North was a net contributor whereas the South got paid more in terms of benefits for their unemployed than it was paying for. However, when the unemployment rate in the South starts to decline, the South is starting to pay more and more for its own share of the unemployed within the EMU. Then, the North is becoming the net recipient, whereas the South will be net contributor to the system.

The effect of the EUBS on economic variables goes via two main channels. The first channel, which is especially interesting for the Euro area, is the channel of risk sharing between regions. Due to the setup of the EUBS and especially the way of financing, a region affected by a more severe unemployment dip is offered temporary relief by the other region. The other channel is related to the level of the unemployment benefit and how it relates to the previously existing regional unemployment benefit.

In order to consider only this first risk sharing channel, I simulate the model with a European unemployment benefit scheme in which the level of the benefit is determined as for the regional benefit before. The only difference between the two situations is that the total expenditures on unemployment benefits in both regions are shared by North and South. In table 4.5.1 the average quarterly results over the period 2013 until 2016 are shown. The increase in the debt level in North and the opposing decrease in the southern debt level implies that the North is now taking a relatively larger share of the expenditures on unemployment benefits, hence it is supporting the South. The introduction of an EUBS leads to positive risk sharing effects on consumption for both North and South. Even though the North is a net contributor at the benefit of the South, also the North profits slightly from this type of risk sharing. Both northern and southern unemployment are lower than in the situation without risk sharing. The fact that the North is paying more than it would without the risk sharing comes back in investment, which is decreasing for the North. This is also the reason why northern GDP is lower.

Table 4.5.1: Risk sharing channel: period 2013-2016

	North	South
GDP (in %)	-0.06%	+0.10%
Consumption (in %)	+0.02%	+0.11%
Investment (in %)	-0.34%	+0.20%
Debt (in %)	+0.85%	-0.32%
Unemployment (in %)	-0.08%	-0.01%

Replacing the regional unemployment benefit by a European system also leads to a second effect, as the height of the unemployment benefit in the two regions is different for the situation without and with the EUBS. Given the chosen replacement rate, I actually find that, in the beginning, the unemployment benefit given to northern unemployed under EUBS is smaller than the regional benefit it would have had otherwise. For the South, the European unemployment benefit scheme implies an increase in the unemployment benefit compared to the regional benefit system.

Since the introduction of a European unemployment benefit replacing the existing regional benefit leads to a higher outside option for southern workers, they bargain for a higher wage. Labor demand from the firm's side decreases which leads to an increase in unemployment. Firms place fewer vacancies due to the expected lower surplus from a match on the labor market. Even though there will be more searching workers in the labor market, matching and thus the number of hires is on average lower. This is the case for the South, whereas in the North unemployment first falls with the introduction of an EUBS and only then increases. Southern workers and unemployed obtain a higher income which leads to an increase in consumption, but also consumption in North will be higher due to the lower amount of unemployed. Investment in North is positively affected by the introduction of the EUBS, whereas southern investment will be lower. Production in South cannot be at the same level due to this channel of higher unemployment benefits, because of the smaller labor force and lower capital stock due to smaller investments. Effects on GDP, investment and unemployment via this second channel are therefore different from those identified by the first risk sharing channel.

The question is of course which of the two channels will dominate and thus which would be most reflected in the total effect. The answer can be found in table 4.5.2. In terms of GDP and investment, the second channel seems to dominate the risk sharing channel, as the overall effect for southern GDP and investment is negative. The European unemployment benefit system would have led to an increase in consumption in both North and South by a quarterly average of 0.58% and 0.62% respectively. In South, there is crowding out of investment by consumption, whereas in North both are increasing as a result of the introduction of the EUBS. Both channels would lead to fewer unemployed in the North, but in the South, the positive second effect is dominating the negative, but small, risk sharing effect on unemployment.

Table 4.5.2: Effectiveness of EUBS in period 2013-2016

	North	South
GDP (in %)	+0.25%	-0.02%
Consumption (in %)	+0.58%	+0.62%
Investment (in %)	+0.09%	-1.62%
Debt (in %)	+0.33%	-0.63%
Unemployment (in %)	-0.08%	+0.14%
Welfare	+0.13%	+0.15%

The impact of the European unemployment benefit scheme on both northern and southern consumers is analyzed using the consumption-equivalent welfare measure. The welfare of both regions would have increased when the EUBS would be introduced as table 4.5.2 shows. For the North, the increase in consumption affects utility positively, though the higher employment level would actually lower the welfare measure. Southern consumption increases whereas the employment decreases, which both affects welfare positively. Though the variance of consumption and labor supply also play a role in the welfare function, the impact is limited here which is because of the limited variation and the short timespan of the simulation.

One may argue that the role of a European unemployment benefit scheme in stabilizing the two regions could partially be taken up by migration in response to adverse shocks. The model does not allow for any labor mobility, therefore my analysis does not take migration related to country-specific shocks and unemployment differences into account. However, there has been some empirical research into labor mobility and unemployment in Europe. Arpaia et al. (2015), for example, find that only 25% of asymmetric labor demand shocks is absorbed by labor mobility within one year. This shows that labor mobility is a slow adjustment mechanism to labor demand shocks whereas the mechanism that I propose here is meant for quicker responses. In the paper by Beyer and Smets (2015), the authors show that only 18 percent of the workers migrate in the first year following a country-specific shock. Furthermore, it is important to take into account that migration flows between the North and the South are even more limited than the results described above. Migration between the Netherlands and Germany is considered intraregional migration and will not lead to any adjustment to region-specific shocks in this model. According to Eurostat data for 2015, immigration into Belgium from southern economies is only 11.3% of total immigration, which implies that the migration flow from South to Belgium would be 0.15% of total Belgian population. Immigration into the Netherlands and Austria, for example, is respectively only 8.6% and 3.9% of total immigration. Migration from North to South is also not very common, as only 4.3% of total immigration into Italy comes from the North. Therefore, it seems right to conclude that labor mobility will not pick up a large role in the adjustment to region-specific shocks.

European benefit on top of regional benefit

If a European unemployment benefit scheme would be introduced on top of the existing regional unemployment insurance, then the effects would naturally be larger in size. In this simulation, the size of the unemployment benefit relative to the wage is the same as in section 5.1, but since this tops up the regional benefit, table 4.5.3 shows that there would be substantial differences in the macroeconomic outcomes.

Table 4.5.3: Effectiveness of EUBS on top of regional benefit

	North	South
GDP (in %)	+1.23%	+1.57%
Consumption (in %)	+5.41%	+5.37%
Investment (in %)	-3.17%	-1.46%
Debt (in %)	+0.16%	-0.46%
Unemployment (in %)	+6.05%	+4.91%
Welfare	+1.19%	+1.28%

The impact of the introduction of an EUBS on consumption would be larger for both regions in absolute terms. However, this comes at the cost of investment, which are affected by the higher tax rates on capital income. Furthermore, unemployment will be higher in both regions as the risk sharing channel is firmly exceeded by the second channel related to the height of the benefit. Since consumption and unemployment both rise substantially, the welfare benefit of the introduction of an EUBS is higher for northern and southern consumers.

4.5.2 Would an EUBS be beneficial for the future?

For the implementation of a European unemployment benefit scheme, it is relevant to find out whether the scheme would be beneficial for both regions in the future. Therefore, it is important to gain knowledge about the ex ante implications of an EUBS. The likelihood that an EUBS would actually be implemented of course increases with the ex ante benefits for both regions. The goal of this common unemployment benefit system is to introduce an automatic stabilizer that mainly focuses on decreasing fluctuations in employment and/or unemployment and on increasing welfare. Therefore, I consider an EUBS beneficial if it would lead to lower volatility of employment, and even more if it also leads to higher welfare.

For this policy experiment, the model has been simulated 200 periods ahead, which resembles 50 years in the future. Random shocks to investment efficiency and productivity can occur in the North and the South in every period.[11] The distribution of the shocks is given by the mean and variance of the estimated shocks in the period 2000-2016, except for one outlier in the shock to investment efficiency in Q2-2015. There is also a random chance for each type of shock that it does not occur in a certain period. The European unemployment benefit scheme is introduced with the financing scheme based on the unemployment levels in the third quarter of 2016, which is the last period in the estimation sample. Moreover, I will simulate the hypothetical introduction of the EUBS on top of the existing regional unemployment benefit, in order to make sure that the total unemployment benefit does not become too small. Given that the shock processes could take the economy quite far from the steady state, an EUBS on

[11] Here I only consider the main shocks of the model, namely shocks to productivity and investment efficiency in both economies. Shocks to household preferences directly affect labor input, and hence these are not the type of shocks an EUBS should respond to. Fiscal and monetary policy shocks are ignored as these shocks would interfere with the working of the unemployment benefit scheme which would impede the identification of the effect of the EUBS. Moreover, I want to consider the effect of the EUBS assuming all other policy measures stay the same.

top of the regional system will make sure that the results from the simulations will be reasonable in terms of replacement rate.[12] The average results over 3500 simulations show us what countries could expect from a European unemployment benefit scheme in the future.

Table 4.5.4: Effectiveness of EUBS in the future

	North	South
Variance of employment	-30.9%	-16.1%
Welfare	+0.41%	+0.27%
Periods in which net contributor	61.3%	38.7%

Table 4.5.4 depicts the change in the variance of employment that would result from the introduction of an EUBS in the future. There are substantial gains for both regions, as the variance of employment is expected to decrease by 30.9% in the North and 16.1% in the South. Because of the reduced volatility of employment and therefore unemployment[13], both regions expect to benefit in the future if a European unemployment benefit scheme would be introduced. Moreover, welfare is expected to increase in both economies, where the expected gain for North is higher than for South. This could be related to the higher rigidities in the northern labor market, such that the North has more to gain from a European unemployment benefit scheme.

The EUBS is meant for temporary subsidization of one region by the other, and not for permanent redistribution. Therefore, I will look at whether both regions are carrying the burden of the system somewhat equally. On average over the simulations, the North is a net contributor in 61.3% of the periods, whereas the South is contributing in 38.7% of the periods. The direction of the transfer does not say anything yet about the size of the net transfers, which could be even more equalized. Moreover, it does happen only once in all 3500 simulations that one region is the net contributor for the course of 50 years. This

[12]The size of the EUBS will be approximately half of the size in the case for a hypothetical introduction in 2013, such that the total benefit does not reach unrealistic levels.

[13]The size of the labor force is fixed in this model, so employment and unemployment move together. Therefore, the effects on the variance of employment and the variance of unemployment are similar.

result is a step in the right direction for the attainability of such a scheme, as it means that, ex ante, there are no clear winners or losers.

4.5.3 Labor market harmonization and an EUBS

Looking at the main differences in the estimated labor market parameters for the North and the South, the first impression would be that the labor market seems more rigid in the North. The separation rate δ is smaller in the northern block, and northern workers have slightly more bargaining power relative to their southern colleagues. Though there are small differences in the estimates for the coefficient on labor disutility ϕ and the elasticity of the hiring cost function ψ, I will focus on the more interesting asymmetries of the northern and southern labor market institutions. In this section, I will discuss the consequences of more harmonized labor markets as well as the potential changes in the effectiveness of the EUBS when labor markets are harmonized. It is important to realize that these labor market parameters, such as the separation rate and the bargaining power of workers, can be influenced only to a limited extent by governments. However, it is still interesting to look at the situation in which governments would be able to close the large gap between the labor market institutions in the North and the South.

I start with the separation rate, for which it holds that a lower separation rate implies a larger rigidity. The separation rate is set equal to $\delta = 0.33$ for both regions, which is the average of the two estimates. In North, the separation rate has thus increased, while the southern separation rate has become smaller in order to achieve a similar parameter value. A lower separation rate means that it becomes more costly to hire workers, and hence adjustment to shocks in terms of quantity is constrained, so firms will adjust their prices. In good times, this results into higher inflation whereas inflation will be lower after negative shocks. Therefore, real wages will be lower in normal times, in contrast to real wages in crisis times. The rigidity also flattens out the cycle of GDP and consumption, as consumption and GDP will be smaller in normal times but higher in crisis times, compared to an economy with a smaller rigidity (and higher separation rate). For the North, rigidities have become smaller which results into higher real wages and higher consumption and GDP during normal times, but worse values during crisis times.

Setting the parameter for relative bargaining power of the worker equal to $\eta = 0.4668$ for both regions implies that the bargaining power of northern workers slightly decreases, whereas the southern workers gain some power. If bargaining power decreases, as in the North, then the share of surplus that workers get from the Nash bargaining is smaller. Therefore, firms expect larger profits and start to post more vacancies. Employment will therefore be higher in the North, though this effect is reversed in crisis times. GDP and consumption will thus be higher in normal times, but lower in periods with adverse shocks. The opposite holds for the southern economy where bargaining power of the workers increases. Hence, compared to a country with low labor market rigidities, a country with a rigidity caused by a low separation rate actually fares well in a recession, and also a higher bargaining power for workers is a worthwhile rigidity in crisis times.

An interesting question is then whether labor market harmonization would affect the working of the European unemployment benefit scheme. Equalizing the parameters for the separation rate, the relative bargaining power of the workers and the elasticity of the hiring cost function, I simulate the introduction of an EUBS replacing the existing regional schemes in the year 2013. Table 4.5.5 shows the effect on the main economic variables. If we compare these to the results in table 4.5.2, we find that labor market harmonization leads to a more equalized effect of the EUBS on GDP, though in this case the effect of the EUBS on consumption is slightly larger. With the less rigid labor market in North, unemployment falls even more in response to the EUBS, whereas the opposite happens in South. This leads to the South benefiting from the labor market harmonization in terms of welfare, whereas northern welfare does not increase due to the opposite effect of harmonization on consumption and unemployment.

Table 4.5.5: EUBS with harmonized labor markets

	North	South
GDP (in %)	+0.19%	+0.19%
Consumption (in %)	+0.65%	+0.73%
Investment (in %)	-0.84%	-0.52%
Debt (in %)	+0.00%	-0.33%
Unemployment (in %)	-0.78%	+0.71%
Welfare	+0.13%	+0.19%

One might also be interested in whether labor market harmonization would affect the working of an EUBS in the future. For that reason, I also simulate the model 200 periods ahead with random shocks to productivity and investment efficiency, with equalized parameters for the separation rate, relative bargaining power and elasticity of the hiring cost function.[14] The average results over 3500 simulations are reported in table 4.5.6.

Table 4.5.6: EUBS with harmonized labor markets in the future

	North	South
Variance of employment	-26.7%	-16.8%
Welfare	+0.49%	+0.22%

With harmonized labor markets, the decrease in the variance of employment is more equal for the North and the South. The volatility of employment will on average decrease by 26.7% in the North and 16.8% in the South. Since the effectiveness of the EUBS is represented by the ability to decrease this volatility and to increase welfare, both regions would profit even more from an EUBS if labor markets would be more harmonized.

4.6 Conclusion

In this chapter, a DSGE model for the Euro area is presented to analyze the implications of a European unemployment benefit scheme in the EMU. Bayesian methods are used to estimate the model for a northern and southern block of countries within the Euro area. Two main research questions are answered using the estimated model. The first question is whether an EUBS would have been effective in the past in terms of increasing GDP, consumption and employment. The second question is whether an EUBS would, ex ante, be beneficial for both regions in the EMU. The differences in labor market institutions in the two regions have been taken into account while answering these questions.

The analysis in this chapter suggests that a European unemployment insurance, that replaces the existing regional unemployment benefit, would have been effective in raising consumption, GDP, investment and employment in the North. The risk sharing mechanism behind the EUBS is beneficial for both regions, but the negative effect of the level of the benefit on employment and GDP dominates in the South. The EUBS would be beneficial for both regions in terms

[14] For the sake of completeness, I also set the elasticity of the hiring cost function equal to $\psi = 1.01$. Since the difference between these parameters for the North and the South are not that large, equalizing these does not affect the results for the introduction in 2013. However, since the simulations for the future cover a longer period, the results are affected here.

of welfare. In the hypothetical case of an EUBS on top of the existing regional systems, the effects would have been much larger and unemployment in North and South would have been higher than with only the regional benefits. The estimated model displays a more rigid labor market in the North compared to the southern labor market. Labor market harmonization would therefore imply fewer rigidities in the North and more in the South. When an EUBS would be introduced under these conditions, the impact of the EUBS on GDP would actually be more equal, whereas the impact on unemployment would be further apart for the two regions.

The decision on whether to implement a European unemployment benefit scheme will to a large extent depend on the expectations of policymakers for the future. If the EUBS is expected to have benefits for both regions in terms of a decreased volatility in employment, then EMU members will be more inclined to agree upon the introduction of the EUBS. The simulations for the future using random shocks show us that the variance of employment would be reduced substantially, and that welfare would be higher. Moreover, the objective of the EUBS is to provide temporary subsidization without permanent redistribution. In the simulations, the chance of being a contributor to the EMU-wide system is not that different for both regions, such that there are no systematic net contributors or net recipients. Labor market harmonization would actually make the European unemployment benefit scheme even more effective in decreasing volatility of employment in South, and more welfare improving in North.

There are several directions in which future research could extend this work. A relevant question is whether the introduction of the European unemployment insurance would reduce the need for labor market reforms in the EMU member states. It is a concern of the policymakers that once an EUBS is introduced, several countries would not feel the need to restructure their labor market or pension system. Moreover, it would be interesting to study the interaction between a European unemployment benefit scheme and fiscal policy. In this model, regions are free to set their own fiscal policy and it is assumed that governments do not change their policy once an EUBS is introduced. However, it might be realistic to study whether regions would have an incentive to change their fiscal policy setting in response to the introduction of EMU-wide unemployment insurance. Furthermore, one may wonder whether the introduction of an EUBS should be accompanied with fiscal rules or a common fiscal authority for the Euro area. Finally, it would also be interesting to look at how optimal monetary policy is affected when a European unemployment benefit scheme is implemented.

4.A Appendix

4.A.1 Log-linearized model

This section contains the log-linearized equations of the model. The variables in small letters with a hat denote the log deviations from the steady state. The constant terms with bar and without time subscript are the steady state values of the corresponding variables.

Market-clearing conditions

$$\begin{aligned}\hat{y}_t - \frac{\bar{A}^H Z^H (\bar{x}^H)^\psi \bar{h}^H}{\bar{Y}} \left(\psi \cdot \hat{x}_t^H + \hat{h}_t^H\right) = \\ = \frac{(1-\alpha)\bar{S}^\alpha \bar{C}}{\bar{Y}} \left(\alpha \cdot \hat{s}_t + \hat{c}_t\right) + \frac{1-n}{n} \frac{\alpha \bar{S}^{1-\alpha} \bar{C}^*}{\bar{Y}} \left((1-\alpha) \cdot \hat{s}_t + \hat{c}_t^*\right) \\ \frac{(1-\alpha)\bar{S}^\alpha \bar{I}}{\bar{Y}} \left(\alpha \cdot \hat{s}_t + \hat{i}_t\right) + \frac{1-n}{n} \frac{\alpha \bar{S}^{1-\alpha} \bar{I}^*}{\bar{Y}} \left((1-\alpha) \cdot \hat{s}_t + \hat{i}_t^*\right)\end{aligned} \tag{4.A.1}$$

$$\begin{aligned}\hat{y}_t^* - \frac{\bar{A}^F Z^F (\bar{x}^F)^\psi \bar{h}^F}{\bar{Y}^*} \left(\psi \cdot \hat{x}_t^F + \hat{h}_t^F\right) = \\ = \frac{(1-\alpha)\bar{S}^{-\alpha} \bar{C}^*}{\bar{Y}^*} \left(-\alpha \cdot \hat{s}_t + \hat{c}_t^*\right) + \frac{n}{1-n} \frac{\alpha \bar{S}^{\alpha-1} \bar{C}}{\bar{Y}^*} \left((\alpha-1) \cdot \hat{s}_t + \hat{c}_t\right) \\ \frac{(1-\alpha)\bar{S}^{-\alpha} \bar{I}^*}{\bar{Y}^*} \left(-\alpha \cdot \hat{s}_t + \hat{i}_t^*\right) + \frac{n}{1-n} \frac{\alpha \bar{S}^{\alpha-1} \bar{I}}{\bar{Y}^*} \left((\alpha-1) \cdot \hat{s}_t + \hat{i}_t\right)\end{aligned} \tag{4.A.2}$$

Consumption (Euler) equations

$$\hat{c}_{t+1} - \hat{c}_t = \frac{1}{\sigma} \left(\hat{\Omega}_{t+1} - \hat{\Omega}_t\right) + \frac{1}{\sigma} \left(\hat{r}_t - \hat{\pi}_{t+1}\right) + \frac{\bar{\tau}_C}{\sigma(1+\bar{\tau}_C)} \left(\hat{\tau}_{C,t} - \hat{\tau}_{C,t+1}\right) \tag{4.A.3}$$

$$\hat{c}_{t+1}^* - \hat{c}_t^* = \frac{1}{\sigma} \left(\hat{\Omega}_{t+1}^* - \hat{\Omega}_t^*\right) + \frac{1}{\sigma} \left(\hat{r}_t^* - \hat{\pi}_{t+1}^*\right) + \frac{\bar{\tau}_C^*}{\sigma^*(1+\bar{\tau}_C^*)} \left(\hat{\tau}_{C,t}^* - \hat{\tau}_{C,t+1}^*\right) \tag{4.A.4}$$

Labor supply

$$\hat{n}_t^H = \frac{1}{\phi} \hat{w}_t^H - \frac{\sigma}{\phi} \hat{c}_t - \frac{\bar{\tau}_L}{\phi(1-\bar{\tau}_L)} \hat{\tau}_{L,t} - \frac{\bar{\tau}_C}{\phi(1+\bar{\tau}_C)} \hat{\tau}_{C,t} \tag{4.A.5}$$

$$\hat{n}_t^F = \frac{1}{\phi} \hat{w}_t^F - \frac{\sigma}{\phi} \hat{c}_t^* - \frac{\bar{\tau}_L^*}{\phi^*(1-\bar{\tau}_L^*)} \hat{\tau}_{L,t}^* - \frac{\bar{\tau}_C^*}{\phi(1+\bar{\tau}_C^*)} \hat{\tau}_{C,t}^* \tag{4.A.6}$$

International risk sharing

$$\hat{q}_t = \hat{\Omega}_t^* - \hat{\Omega}_t - \sigma(\hat{c}_t^* - \hat{c}_t) \tag{4.A.7}$$

Real exchange rate

$$\hat{q}_t = (1 - 2\alpha) \cdot \hat{s}_t \tag{4.A.8}$$

Labor market tightness

$$\hat{x}_t^H = \hat{v}_t^H - \hat{U}_t^H \tag{4.A.9}$$

$$\hat{x}_t^F = \hat{v}_t^F - \hat{U}_t^F \tag{4.A.10}$$

Evolution of employment

$$\hat{n}_t^H = (1 - \delta^H) \cdot \hat{n}_{t-1}^H + \delta^H \cdot \hat{h}_t^H \tag{4.A.11}$$

$$\hat{n}_t^F = (1 - \delta^F) \cdot \hat{n}_{t-1}^F + \delta^H \cdot \hat{h}_t^F \tag{4.A.12}$$

Job seekers

$$\hat{U}_t^H = -\frac{(1 - \delta^H)\bar{N}^H}{1 - (1 - \delta^H)\bar{N}^H} \cdot \hat{n}_{t-1}^H \tag{4.A.13}$$

$$\hat{U}_t^F = -\frac{(1 - \delta^F)\bar{N}^F}{1 - (1 - \delta^F)\bar{N}^F} \cdot \hat{n}_{t-1}^F \tag{4.A.14}$$

Unemployment

$$\hat{u}_t^H = -\frac{\bar{N}^H}{\bar{u}^H} \cdot \hat{n}_t^H \tag{4.A.15}$$

$$\hat{u}_t^F = -\frac{\bar{N}^F}{\bar{u}^F} \cdot \hat{n}_t^F \tag{4.A.16}$$

Matching

$$\hat{m}_t^H = \omega \cdot \hat{U}_t^H + (1 - \omega) \cdot \hat{v}_t^H \tag{4.A.17}$$

$$\hat{m}_t^F = \omega \cdot \hat{U}_t^F + (1 - \omega) \cdot \hat{v}_t^F \tag{4.A.18}$$

Probability of finding a job

$$\hat{s}_t^H = \hat{m}_t^H - \hat{U}_t^H \tag{4.A.19}$$

$$\hat{s}_t^F = \hat{m}_t^F - \hat{U}_t^F \tag{4.A.20}$$

Probability of filling a vacancy

$$\hat{q}_t^H = \hat{m}_t^H - \hat{v}_t^H \tag{4.A.21}$$

$$\hat{q}_t^F = \hat{m}_t^F - \hat{v}_t^F \tag{4.A.22}$$

Aggregate hiring

$$\hat{h}_t^H = \hat{q}_t^H + \hat{v}_t^H \tag{4.A.23}$$

$$\hat{h}_t^F = \hat{q}_t^F + \hat{v}_t^F \tag{4.A.24}$$

Nash bargained wage

$$\begin{aligned}
&\frac{(1-\bar{\tau}_L)\bar{w}^{H,N}}{\bar{A}^H}\bar{S}^{\alpha}\cdot\left(\hat{w}_t^{H,N} - \frac{\bar{\tau}_L}{1-\bar{\tau}_L}\hat{\tau}_{L,t} - \hat{a}_t^H + \alpha\hat{s}_t\right) = \\
&\frac{\chi\bar{C}^{\sigma}(\bar{N}^H)^{\phi}\bar{S}^{\alpha}}{\bar{A}^H}\cdot\left(\sigma\hat{c}_t + \phi\hat{n}_t^H + \alpha\hat{s}_t - \hat{a}_t^H\right) + \frac{\bar{ub}^H\bar{S}^{\alpha}}{\bar{A}^H}\cdot\left(\hat{ub}_t^H + \alpha\hat{s}_t - \hat{a}_t^H\right) \\
&+ \eta Z^H(\bar{x}^H)^{\psi}\cdot\left(\psi\hat{x}_t^H\right) - (1-\delta^H)\beta\eta Z^H(\bar{x}^H)^{\psi}\cdot\left(\left(\hat{\Omega}_{t+1} - \hat{\Omega}_t\right)\right. \\
&-\sigma\left(\hat{c}_{t+1} - \hat{c}_t\right) + \alpha\left(\hat{s}_t - \hat{s}_{t+1}\right) + \left(\hat{a}_{t+1}^H - \hat{a}_t^H\right) + \left.\psi\hat{x}_{t+1}^H\right) \\
&+ (1-\delta^H)\beta\eta Z^H(x^H)^{1+\psi}\cdot\left(\left(\hat{\Omega}_{t+1} - \hat{\Omega}_t\right) - \sigma\left(\hat{c}_{t+1} - \hat{c}_t\right)\right. \\
&+\alpha\left(\hat{s}_t - \hat{s}_{t+1}\right) + \left(\hat{a}_{t+1}^H - \hat{a}_t^H\right) + \left.(1+\psi)\hat{x}_{t+1}^H\right)
\end{aligned} \tag{4.A.25}$$

$$\begin{aligned}
&\frac{(1-\bar{\tau}_L^*)\bar{w}^{F,N}}{\bar{A}^F}\bar{S}^{-\alpha}\cdot\left(\hat{w}_t^{F,N} - \frac{\bar{\tau}_L^*}{1-\bar{\tau}_L^*}\hat{\tau}_{L,t}^* - \hat{a}_t^F - \alpha\hat{s}_t\right) = \\
&\frac{\chi(\bar{C}^*)^{\sigma}(\bar{N}^F)^{\phi}\bar{S}^{-\alpha}}{\bar{A}^F}\cdot\left(\sigma\hat{c}_t^* + \phi\hat{n}_t^F - \alpha\hat{s}_t - \hat{a}_t^F\right) + \frac{\bar{ub}^F\bar{S}^{-\alpha}}{\bar{A}^F}\cdot\left(\hat{ub}_t^F - \alpha\hat{s}_t - \hat{a}_t^F\right) \\
&+ \eta Z^F(\bar{x}^F)^{\psi}\cdot\left(\psi\hat{x}_t^F\right) - (1-\delta^F)\beta\eta Z^F(\bar{x}^F)^{\psi}\cdot\left(\left(\hat{\Omega}_{t+1}^* - \hat{\Omega}_t^*\right)\right. \\
&-\sigma\left(\hat{c}_{t+1}^* - \hat{c}_t^*\right) - \alpha\left(\hat{s}_t - \hat{s}_{t+1}\right) + \left(\hat{a}_{t+1}^F - \hat{a}_t^F\right) + \left.\psi\hat{x}_{t+1}^F\right) \\
&+ (1-\delta^F)\beta\eta Z^F(\bar{x}^F)^{1+\psi}\cdot\left(\left(\hat{\Omega}_{t+1}^* - \hat{\Omega}_t^*\right) - \sigma\left(\hat{c}_{t+1}^* - \hat{c}_t^*\right)\right. \\
&-\alpha\left(\hat{s}_t - \hat{s}_{t+1}\right) + \left(\hat{a}_{t+1}^F - \hat{a}_t^F\right) + \left.(1+\psi)\hat{x}_{t+1}^F\right)
\end{aligned} \tag{4.A.26}$$

Marginal cost intermediate goods producers

$$\begin{aligned}&\bar{\mu}^H\bar{A}^H(1-\zeta)\frac{(\bar{K}^H)^\zeta}{(\bar{N}^H)^\zeta}\cdot\left(\hat{mc}_t^H+\hat{a}_t^H+\zeta\hat{k}_t^H-\zeta\cdot\hat{n}_t^H\right)=\bar{W}^H\cdot\hat{w}_t^H\\&+\bar{A}^HZ^H(\bar{x}^H)^\psi\cdot\left(\hat{a}_t^H+\psi\cdot\hat{x}_t^H\right)-(1-\delta^H)\beta\bar{A}^HZ^H(\bar{x}^H)^\psi\cdot\left(\left(\hat{\Omega}_{t+1}-\hat{\Omega}_t\right)\right.\\&\left.-\sigma\left(\hat{c}_{t+1}-\hat{c}_t\right)+\alpha\left(\hat{s}_t-\hat{s}_{t+1}\right)+\hat{a}_{t+1}^H+\psi\cdot\hat{x}_{t+1}^H\right)\end{aligned}\tag{4.A.27}$$

$$\begin{aligned}&\bar{\mu}^F\bar{A}^F(1-\zeta)\frac{(\bar{K}^F)^\zeta}{(\bar{N}^F)^\zeta}\cdot\left(\hat{mc}_t^F+\hat{a}_t^F+\zeta\hat{k}_t^F-\zeta\cdot\hat{n}_t^F\right)=\bar{W}^F\cdot\hat{w}_t^F\\&+\bar{A}^FZ^F(\bar{x}^F)^\psi\cdot\left(\hat{a}_t^F+\psi\cdot\hat{x}_t^F\right)-(1-\delta^F)\beta\bar{A}^FZ^F(\bar{x}^F)^\psi\cdot\left(\left(\hat{\Omega}^*_{t+1}-\hat{\Omega}^*_t\right)\right.\\&\left.-\sigma\left(\hat{c}^*_{t+1}-\hat{c}^*_t\right)-\alpha\left(\hat{s}_t-\hat{s}_{t+1}\right)+\hat{a}_{t+1}^F+\psi\cdot\hat{x}_{t+1}^F\right)\end{aligned}\tag{4.A.28}$$

Phillips curves

$$\hat{\pi}_t^H=\beta\mathrm{E}_t\hat{\pi}_{t+1}^H+\frac{(1-\beta\theta)(1-\theta)}{\theta}\hat{mc}_t^H\tag{4.A.29}$$

$$\hat{\pi}_t^F=\beta\mathrm{E}_t\hat{\pi}_{t+1}^F+\frac{(1-\beta\theta)(1-\theta)}{\theta}\hat{mc}_t^F\tag{4.A.30}$$

Real wage rate

$$\hat{w}_t^H=(1-\gamma)\cdot\hat{w}_t^{H,N}\tag{4.A.31}$$

$$\hat{w}_t^F=(1-\gamma)\cdot\hat{w}_t^{F,N}\tag{4.A.32}$$

Capital accumulation

$$\hat{k}_{t+1}^H=(1-\xi)\cdot\hat{k}_t^H+\xi\cdot\left(\hat{\varepsilon}_{I,t}+\hat{i}_t\right)\tag{4.A.33}$$

$$\hat{k}_{t+1}^F=(1-\xi)\cdot\hat{k}_t^F+\xi\cdot\left(\hat{\varepsilon}^*_{I,t}+\hat{i}^*_t\right)\tag{4.A.34}$$

Investment demand

$$\hat{i}_t-\hat{i}_{t-1}=\beta\cdot\left(\hat{i}_{t+1}-\hat{i}_t\right)+\frac{1}{\bar{\varepsilon}_I}\cdot\left(\hat{q}_{T,t}+\hat{\varepsilon}_{I,t}\right)\tag{4.A.35}$$

$$\hat{i}^*_t-\hat{i}^*_{t-1}=\beta\cdot\left(\hat{i}^*_{t+1}-\hat{i}^*_t\right)+\frac{1}{\bar{\varepsilon}^*_I}\cdot\left(\hat{q}^*_{T,t}+\hat{\varepsilon}^*_{I,t}\right)\tag{4.A.36}$$

Price of installed capital

$$\hat{q}_{T,t} = \beta(1-\xi)\cdot\hat{q}_{T,t+1} - (\hat{r}_t - \hat{\pi}_{t+1}) + (1-\beta(1-\xi))\cdot\left(\hat{r}_{K,t+1} - \frac{\bar{\tau}_K}{1-\bar{\tau}_K}\hat{\tau_{K,t+1}}\right) \tag{4.A.37}$$

$$\hat{q}^*_{T,t} = \beta(1-\xi)\cdot\hat{q}^*_{T,t+1} - (\hat{r}^*_t - \hat{\pi}^*_{t+1}) + (1-\beta(1-\xi))\cdot\left(\hat{r}^*_{K,t+1} - \frac{\bar{\tau}^*_K}{1-\bar{\tau}^*_K}\hat{\tau^*_{K,t+1}}\right) \tag{4.A.38}$$

Real cost of capital

$$\hat{r}_{K,t} = \hat{\mu}_t + \hat{a}^H_t + (1-\zeta)\cdot\hat{n}^H_t + (\zeta-1)\cdot\hat{k}^H_t \tag{4.A.39}$$

$$\hat{r}^*_{K,t} = \hat{\mu}^*_t + \hat{a}^F_t + (1-\zeta)\cdot\hat{n}^F_t + (\zeta-1)\cdot\hat{k}^F_t \tag{4.A.40}$$

Monetary policy rule

$$\hat{i}_t = \rho\cdot\hat{i}_{t-1} + (1-\rho)\cdot\left[\rho_\pi\hat{\pi}^{EMU}_t + \rho_y\hat{y}^{EMU}_t\right] + u_{R,t} \tag{4.A.41}$$

Union-wide inflation and output

$$\hat{\pi}^{EMU}_t = n\cdot\hat{\pi}_t + (1-n)\cdot\hat{\pi}^*_t \tag{4.A.42}$$

$$\hat{y}^{EMU}_t = n\cdot\hat{y}_t + (1-n)\cdot\hat{y}^*_t \tag{4.A.43}$$

Real interest rate

$$\hat{r}_t = \hat{i}_t - \hat{\pi}_{t+1} \tag{4.A.44}$$

$$\hat{r}^*_t = \hat{i}_t - \hat{\pi}^*_{t+1} \tag{4.A.45}$$

Government debt

$$\begin{aligned}\hat{b}_t = {} & \frac{\bar{R}}{\bar{B}}\hat{r}_t + (1+\bar{R})\hat{b}_{t-1} + \frac{\bar{UB}}{\bar{B}}\hat{ub}_t + \frac{\bar{G}}{\bar{B}}\hat{g}_t \\ & - \frac{\bar{tax}_C}{\bar{D}}\hat{tax}_{C,t} - \frac{\bar{tax}_K}{\bar{D}}\hat{tax}_{K,t} - \frac{\bar{tax}_L}{\bar{D}}\hat{tax}_{L,t}\end{aligned} \tag{4.A.46}$$

$$\begin{aligned}\hat{b}^*_t = {} & \frac{\bar{R}^*}{\bar{B}^*}\hat{r}^*_t + (1+\bar{R}^*)\hat{b}^*_{t-1} + \frac{\bar{UB}^*}{\bar{B}^*}\hat{ub}^*_t + \frac{\bar{G}^*}{\bar{B}^*}\hat{g}^*_t \\ & - \frac{\bar{tax}^*_C}{\bar{D}^*}\hat{tax}^*_{C,t} - \frac{\bar{tax}^*_K}{\bar{D}^*}\hat{tax}^*_{K,t} - \frac{\bar{tax}^*_L}{\bar{D}^*}\hat{tax}^*_{L,t}\end{aligned} \tag{4.A.47}$$

Unemployment benefits

$$\hat{ub}_t = \rho_{ub} \cdot \hat{ub}_{t-1} + u_{ub,t} \tag{4.A.48}$$

$$\hat{ub}^*_t = \rho_{ub} \cdot \hat{ub}^*_{t-1} + u^*_{ub,t} \tag{4.A.49}$$

Government expenditures

$$\hat{g}_t = \rho_g \cdot \hat{g}_{t-1} + u_{g,t} \tag{4.A.50}$$

$$\hat{g}^*_t = \rho_g \cdot \hat{g}^*_{t-1} + u^*_{g,t} \tag{4.A.51}$$

Consumption tax revenues

$$t\hat{a}x_{C,t} = \hat{\tau}_{C,t} + \hat{c}_t \tag{4.A.52}$$

$$t\hat{a}x^*_{C,t} = \hat{\tau}^*_{C,t} + \hat{c}^*_t \tag{4.A.53}$$

Capital income tax revenues

$$t\hat{a}x_{K,t} = \hat{\tau}_{K,t} + \hat{r}^H_{K,t} + \hat{k}^H_t \tag{4.A.54}$$

$$t\hat{a}x^*_{K,t} = \hat{\tau}^*_{K,t} + \hat{r}^F_{K,t} + \hat{k}^F_t \tag{4.A.55}$$

Labor income tax revenues

$$t\hat{a}x_{L,t} = \hat{\tau}_{L,t} + \hat{w}^H_t + \hat{n}^H_t \tag{4.A.56}$$

$$t\hat{a}x^*_{L,t} = \hat{\tau}^*_{L,t} + \hat{w}^F_t + \hat{n}^F_t \tag{4.A.57}$$

Consumption tax rate

$$\hat{\tau}_{C,t} = \rho_{\tau_C} \cdot \hat{\tau}_{C,t-1} + \gamma_{\tau_C} \cdot \hat{b}_{t-1} + u_{\tau_C,t} \tag{4.A.58}$$

$$\hat{\tau}^*_{C,t} = \rho_{\tau_C} \cdot \hat{\tau}^*_{C,t-1} + \gamma^*_{\tau_C} \cdot \hat{b}^*_{t-1} + u^*_{\tau_C,t} \tag{4.A.59}$$

Capital income tax rate

$$\hat{\tau}_{K,t} = \rho_{\tau_K} \cdot \hat{\tau}_{K,t-1} + \gamma_{\tau_K} \cdot \hat{b}_{t-1} + u_{\tau_K,t} \tag{4.A.60}$$

$$\hat{\tau}^*_{K,t} = \rho_{\tau_K} \cdot \hat{\tau}^*_{K,t-1} + \gamma^*_{\tau_K} \cdot \hat{b}^*_{t-1} + u^*_{\tau_K,t} \tag{4.A.61}$$

Labor income tax rate

$$\hat{\tau}_{L,t} = \rho_{\tau_L} \cdot \hat{\tau}_{L,t-1} + \gamma_{\tau_L} \cdot \hat{b}_{t-1} + u_{\tau_L,t} \tag{4.A.62}$$

$$\hat{\tau}^*_{L,t} = \rho_{\tau_L} \cdot \hat{\tau}^*_{L,t-1} + \gamma^*_{\tau_L} \cdot \hat{b}^*_{t-1} + u^*_{\tau_L,t} \tag{4.A.63}$$

Productivity shocks

$$\hat{a}_t = \rho_a \cdot \hat{a}_{t-1} + u_{a,t} \tag{4.A.64}$$

$$\hat{a}^*_t = \rho_a \cdot \hat{a}^*_{t-1} + u^*_{a,t} \tag{4.A.65}$$

Preference shocks

$$\hat{\Omega}_t = \rho_\Omega \cdot \hat{\Omega}_{t-1} + u_{\Omega,t} \tag{4.A.66}$$

$$\hat{\Omega}^*_t = \rho_\Omega \cdot \hat{\Omega}^*_{t-1} + u^*_{\Omega,t} \tag{4.A.67}$$

Investment efficiency shocks

$$\hat{\varepsilon}_t = \rho_e \cdot \hat{\varepsilon}_{t-1} + u_{e,t} \tag{4.A.68}$$

$$\hat{\varepsilon}^*_t = \rho_e \cdot \hat{\varepsilon}^*_{t-1} + u^*_{e,t} \tag{4.A.69}$$

Monetary shock

$$u_{R,t} \tag{4.A.70}$$

4.A.2 Model derivations

Household optimization

The optimization problem of the household involves the maximization of its lifetime utility function subject to the sequence of budget constraints and the law of motion for capital. The Lagrangian of this problem is as follows:

$$\begin{aligned}\mathcal{L} =& \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\Omega_t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\phi}}{1+\phi} \right] + \lambda^1_t \left[V^H_t + (1-\tau_{L,t}) W^H_t N^H_t \right.\right. \\ & + (1-\tau_{K,t}) R^H_{K,t} K^H_t + U B^H_t u^H_t + \Pi^H_t - T^H_t - (1+\tau_{C,t}) P_t C_t - P_t I_t \\ & \left.\left. - \frac{V^H_{t+1}}{R_t} \right] + \lambda^2_t \left[-K^H_{t+1} + (1-\xi) K^H_t + \varepsilon_{I,t} \left(1 - S\left(\frac{I_t}{I_{t-1}} \right) \right) I_t \right] \right]\end{aligned} \tag{4.A.71}$$

where λ^1_t is the Lagrangian multiplier on the household budget constraint and λ^2_t the multiplier on the law of motion for capital. The utility function is maximized with respect to consumption, labor input, investment and the portfolio and capital stock in the next period. The first-order conditions are therefore given by:

$$\frac{\partial \mathcal{L}}{\partial C_t} = \Omega_t C_t^{-\sigma} - \lambda_t^1 (1 + \tau_{C,t}) P_t = 0 \tag{4.A.72}$$

$$\frac{\partial \mathcal{L}}{\partial N_t^H} = -\Omega_t \chi (N_t^H)^{\phi} + \lambda_t^1 (1 - \tau_{L,t}) W_t^H = 0 \tag{4.A.73}$$

$$\frac{\partial \mathcal{L}}{\partial V_{t+1}^H} = \beta \mathrm{E}_t \lambda_{t+1}^1 - \lambda_t^1 \frac{1}{R_t} = 0 \tag{4.A.74}$$

$$\frac{\partial \mathcal{L}}{\partial I_t} = -\lambda_t^1 P_t + \lambda_t^2 \varepsilon_{I,t} \left[1 - S(\cdot) - S'(\cdot)\right] - \beta \mathrm{E}_t \lambda_{t+1}^2 \varepsilon_{I,t+1} S'(\cdot) \left(-\frac{I_{t+1}}{I_t I_t}\right) = 0 \tag{4.A.75}$$

$$\frac{\partial \mathcal{L}}{\partial K_{t+1}^H} = -\lambda_t^2 + \beta \mathrm{E}_t \lambda_{t+1}^1 (1 - \tau_{K,t+1}) R_{K,t+1}^H + \beta \mathrm{E}_t \lambda_{t+1}^2 (1 - \xi) = 0 \tag{4.A.76}$$

The first-order conditions (4.A.72) and (4.A.74) together give the well-known Euler equation:

$$\frac{1}{R_t} = \beta \mathrm{E}_t \left[\frac{\Omega_{t+1}}{\Omega_t} \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \frac{P_t}{P_{t+1}} \frac{1 + \tau_{C,t}}{1 + \tau_{C,t+1}}\right] \tag{4.A.77}$$

The combination of equation (4.A.72) and (4.A.73) gives the following condition for labor supply:

$$\frac{\chi (N_t^H)^{\phi}}{C_t^{-\sigma}} = \frac{(1 - \tau_{L,t}) W_t^H}{(1 + \tau_{C,t}) P_t} \tag{4.A.78}$$

The relative price of installed capital is defined as $Q_{T,t}^H \equiv \frac{\lambda_t^2}{\lambda_t^1 P_t}$. Using the first-order condition with respect to investment, equation (4.A.75), I can derive investment demand:

$$\begin{aligned} 1 = {} & Q_{T,t}^H \varepsilon_{I,t} \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}}\right] \\ & + \mathrm{E}_t \left[\frac{Q_{T,t+1}^H}{R_t} \frac{P_{t+1}}{P_t} \varepsilon_{I,t+1} S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_{t+1}}{I_t}\right] \end{aligned} \tag{4.A.79}$$

Using equation (4.A.74) and the definition of the relative price of capital, I find the following first-order condition for the price of installed capital:

$$Q^H_{T,t} = \mathrm{E}_t \left[\frac{(1-\tau_{K,t+1}) R^H_{K,t+1}}{P_t R_t} + (1-\xi) \frac{Q^H_{T,t+1}}{R_t} \frac{P_{t+1}}{P_t} \right] \tag{4.A.80}$$

Intermediate goods producer optimization

The intermediate good producers maximize their discounted expected future profits subject to the evolution of employment and the production function of the firm. The Lagrangian of this optimization problem is given by:

$$\begin{aligned} \mathcal{L} = \mathrm{E}_0 \sum_{s=0}^{\infty} \Big[\Lambda_{t,t+s} \Big[& P^H_{I,t+s} X^H_{t+s}(z) - P^H_{t+s} G^H_{t+s} h^H_{t+s}(z) - W^H_{t+s} N^H_{t+s}(z) \\ & - R^H_{K,t+s} K^H_{t+s}(z) \Big] + \lambda^1_t \Big[(1-\delta^H) N^H_{t+s-1}(z) + h^H_{t+s}(z) - N^H_{t+s}(z) \Big] \\ & + \lambda^2_t \Big[A^H_{t+s} N^H_{t+s}(z)^{1-\zeta} K^H_{t+s}(z)^{\zeta} - X^H_{t+s}(z) \Big] \Big] \end{aligned} \tag{4.A.81}$$

The intermediate goods producer maximizes its profits with respect to hiring, production, labor input and capital input. The first-order conditions are given by:

$$\frac{\partial \mathcal{L}}{\partial h^H_t(z)} = -\Lambda_{t,t} P^H_t G^H_t + \lambda^1_t = 0 \tag{4.A.82}$$

$$\frac{\partial \mathcal{L}}{\partial X^H_t(z)} = \Lambda_{t,t} P^H_{I,t} - \lambda^2_t = 0 \tag{4.A.83}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial N^H_t(z)} = & -\Lambda_{t,t} W^H_t - \lambda^1_t + \lambda^2_t (1-\zeta) A^H_t N^H_t(z)^{-\zeta} K^H_t(z)^{\zeta} \\ & + \mathrm{E}_t \lambda^1_{t+1} \Lambda_{t,t+1} (1-\delta^H) = 0 \end{aligned} \tag{4.A.84}$$

$$\frac{\partial \mathcal{L}}{\partial K^H_t(z)} = -\Lambda_{t,t} R^H_{K,t} + \lambda^2_t \zeta A^H_t N^H_t(z)^{1-\zeta} K^H_t(z)^{\zeta-1} \tag{4.A.85}$$

Combining the first-order conditions (4.A.82), (4.A.83) and (4.A.84) leads to the following equation:

$$\begin{aligned} \mu^H_t (1-\zeta) A^H_t N^H_t(z)^{-\zeta} K^H_t(z)^{\zeta} = & \frac{W^H_t}{P_t} (S_t)^{\alpha} + G^H_t - \\ & (1-\delta^H) \mathrm{E}_t \left[\beta \frac{\Omega_{t+1}}{\Omega_t} \frac{C^{-\sigma}_{t+1}}{C^{-\sigma}_t} \frac{S^{\alpha}_t}{S^{\alpha}_{t+1}} G^H_{t+1} \right] \end{aligned} \tag{4.A.86}$$

Moreover, equation (4.A.83) and (4.A.85) together give a relationship between the real cost of capital, the marginal cost and the use of the input factors:

$$\frac{R_{K,t}^H}{P_t^H} = \mu_t^H \zeta A_t^H N_t^H(z)^{1-\zeta} K_t^H(z)^{\zeta-1} \tag{4.A.87}$$

4.A.3 Welfare measure

Welfare measure

The welfare measure in this model is based on a second-order Taylor series expansion of the utility function around the steady state. The expected discounted value of the sum of utilities of the representative household is given by

$$U_0 = \sum_{t=0}^{\infty} \beta^t \mathrm{E}_0 U(C_t, N_t, \Omega_t)$$

for both regions.[15] The period utility function is given by

$$U(C_t, N_t, \Omega_t) = \Omega_t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\phi}}{1+\phi} \right]$$

The second-order Taylor expansion of this period utility function around the steady state is given by[16]

$$\begin{aligned} U(C_t, N_t) \approx\; & \bar{U} + \bar{U}_C \tilde{C}_t + \bar{U}_N \tilde{N}_t + \frac{1}{2}\bar{U}_{CC}\tilde{C}_t^2 + \frac{1}{2}\bar{U}_{NN}\tilde{N}_t^2 \\ & + \bar{U}_{CN}\tilde{C}_t\tilde{N}_t + \mathcal{O}(||\zeta||^3) \end{aligned}$$

where a tilde denotes the deviation of the variable from the steady state (i.e. $\tilde{C}_t = C_t - \bar{C}$). The last term refers to higher order exogenous disturbances. Filling in the first- and second-order partial derivatives in the steady states leads to

$$\begin{aligned} U(C_t, N_t) \approx\; & \bar{U} + (\bar{C})^{-\sigma}\tilde{C}_t - \chi(\bar{N})^{\phi}\tilde{N}_t - \frac{\sigma}{2}(\bar{C})^{-\sigma-1}\tilde{C}_t^2 \\ & - \frac{\phi}{2}\chi(\bar{N})^{\phi-1}\tilde{N}_t^2 + \mathcal{O}(||\zeta||^3) \end{aligned}$$

[15] The region index is suppressed here since the welfare measure is the same for the two regions, except for the estimates of the parameters and the steady state values. Union-wide welfare is given by the weighted average of welfare in the two regions such that $U^{EMU} = n \cdot U^i + (1-n) \cdot U^{i*}$.

[16] Since the preference variable Ω_t is a shock process that is not affected by the policy experiments I introduce, I neglect this variable in the derivation of the welfare measure.

Since this model used log deviations of variables from their steady state value, I use the following Taylor expansion:

$$\frac{C_t}{\bar{C}} = 1 + \hat{c}_t + \frac{1}{2}\hat{c}_t^2 + \mathcal{O}(||\zeta||^3)$$

such that

$$\tilde{C}_t = C_t - \bar{C} = \bar{C}\left(\hat{c}_t + \frac{1}{2}\hat{c}_t^2\right) + +\mathcal{O}(||\zeta||^3)$$

The approximation of utility around the steady state then becomes:

$$\begin{aligned} U(C_t, N_t) \approx \bar{U} + (\bar{C})^{-\sigma}\bar{C}\left(\hat{c}_t + \frac{1}{2}\hat{c}_t^2\right) - \chi(\bar{N})^{\phi}\bar{N}\left(\hat{n}_t + \frac{1}{2}\hat{n}_t^2\right) \\ - \frac{\sigma}{2}(\bar{C})^{-\sigma-1}\bar{C}^2\hat{c}_t^2 - \frac{\phi}{2}\chi(\bar{N})^{\phi-1}\bar{N}^2\hat{n}_t^2 + \mathcal{O}(||\zeta||^3) \end{aligned}$$

which simplifies into

$$\begin{aligned} U(C_t, N_t) \approx \bar{U} + (\bar{C})^{1-\sigma}\left(\hat{c}_t + \frac{1}{2}\hat{c}_t^2\right) - \chi(\bar{N})^{1+\phi}\left(\hat{n}_t + \frac{1}{2}\hat{n}_t^2\right) \\ - \frac{\sigma}{2}(\bar{C})^{1-\sigma}\hat{c}_t^2 - \frac{\phi}{2}\chi(\bar{N})^{1+\phi}\hat{n}_t^2 + \mathcal{O}(||\zeta||^3) \end{aligned}$$

$$\begin{aligned} U(C_t, N_t) \approx \bar{U} + (\bar{C})^{1-\sigma}\left(\hat{c}_t + \frac{1-\sigma}{2}\hat{c}_t^2\right) \\ - \chi(\bar{N})^{1+\phi}\left(\hat{n}_t + \frac{1+\phi}{2}\hat{n}_t^2\right) + \mathcal{O}(||\zeta||^3) \end{aligned}$$

Expected lifetime utility is thus given by

$$\begin{aligned} U_0 = \sum_{t=0}^{\infty}\beta^t \mathrm{E}_0 \Big[\bar{U} + (\bar{C})^{1-\sigma}\left(\hat{c}_t + \frac{1-\sigma}{2}\hat{c}_t^2\right) \\ -\chi(\bar{N})^{1+\phi}\left(\hat{n}_t + \frac{1+\phi}{2}\hat{n}_t^2\right) + \mathcal{O}(||\zeta||^3)\Big] \end{aligned}$$

$$\begin{aligned} U_0 = \sum_{t=0}^{\infty}\beta^t \Big[\bar{U} + (\bar{C})^{1-\sigma}\left(\mathrm{E}_0(\hat{c}_t) + \frac{1-\sigma}{2}\mathrm{E}_0(\hat{c}_t^2)\right) \\ -\chi(\bar{N})^{1+\phi}\left(\mathrm{E}_0(\hat{n}_t) + \frac{1+\phi}{2}\mathrm{E}_0(\hat{n}_t^2)\right) + \mathcal{O}(||\zeta||^3)\Big] \end{aligned}$$

We use the consumption equivalent welfare measure, as in Lucas (2003), to evaluate the welfare effect of the policy experiments. The welfare gain is defined as the permanent percentage change in steady state consumption that will make the representative household indifferent between a specific situation, called situation

A, and the steady state:

$$\begin{aligned} U^A &= \sum_{t=0}^{\infty} \beta^t \mathrm{E}_0 U(C_t^A, N_t^A) \\ &= \sum_{t=0}^{\infty} \beta^t U((1+\lambda)\bar{C}, \bar{N}) \\ &= \sum_{t=0}^{\infty} \beta^t \left[\frac{((1+\lambda)\bar{C})^{1-\sigma}}{1-\sigma} - \chi \frac{\bar{N}^{1+\phi}}{1+\phi} \right] \end{aligned}$$

The last term can be derived using a first-order Taylor approximation in consumption equivalence measure λ:

$$\begin{aligned} \left[\frac{((1+\lambda)\bar{C})^{1-\sigma}}{1-\sigma} - \chi \frac{\bar{N}^{1+\phi}}{1+\phi} \right] &\approx \left[\frac{(\bar{C})^{1-\sigma}}{1-\sigma} - \chi \frac{\bar{N}^{1+\phi}}{1+\phi} \right] + (\bar{C})^{1-\sigma} \cdot \lambda \\ &= \bar{U} + (\bar{C})^{1-\sigma} \cdot \lambda \end{aligned}$$

Then the solution for λ is obtained:

$$\sum_{t=0}^{\infty} \beta^t U((1+\lambda)\bar{C}, \bar{N}) = \sum_{t=0}^{\infty} \beta^t \mathrm{E}_0 U(C_t, N_t)$$

such that

$$\begin{aligned} \bar{U} + (\bar{C})^{1-\sigma} \cdot \lambda = \bar{U} &+ (\bar{C})^{1-\sigma} \left(\mathrm{E}_0(\hat{c}_t) + \frac{1-\sigma}{2} \mathrm{E}_0(\hat{c}_t^2) \right) \\ &- \chi(\bar{N})^{1+\phi} \left(\mathrm{E}_0(\hat{n}_t) + \frac{1+\phi}{2} \mathrm{E}_0(\hat{n}_t^2) \right) \end{aligned}$$

which leads to the consumption equivalent welfare measure:

$$\lambda = \left(\mathrm{E}_0(\hat{c}_t) + \frac{1-\sigma}{2} \mathrm{E}_0(\hat{c}_t^2) \right) - \chi(\bar{N})^{1+\phi}(\bar{C})^{\sigma-1} \left(\mathrm{E}_0(\hat{n}_t) + \frac{1+\phi}{2} \mathrm{E}_0(\hat{n}_t^2) \right)$$

Steady state values

The relative weight of each component in the consumption equivalent welfare measure depends on the steady state values of the variables in the utility function. The steady state values of consumption are approximated by solving numerically for the steady state equations of the model[17], given the estimated parameters of the model. Steady state consumption is given by $\bar{C} = 0.6352$ and $\bar{C}^* = 0.7131$. The steady state values of employment are derived from the steady state

[17]The steady state equations of the model can be found in the appendix.

equations and the steady state values of unemployment. The parameters in the welfare measure are the region-specific parameters as estimated using Bayesian methods.

4.A.4 Data description

The DSGE model for two regions of a monetary union is estimated for the North and the South of the Euro area using Bayesian methods. I have gathered data on 15 key macroeconomic variables for the two blocks of countries. Because of data availability, only first generation members of the EMU are included in the data collection. The South consists of Portugal, Italy, Greece and Spain. The countries in the Northern block are Austria, Belgium, Finland, France, Germany, Ireland, Luxembourg and the Netherlands. The estimation is done at a quarterly frequency, so I have collected quarterly data from the period between 2000:Q1 and 2016:Q3. The key variables in the estimation are real GDP, real consumption, real investment, CPI, real wages, unemployment, government debt and the nominal interest rate set by the ECB. The source of the time series is explained in more detail below:

- **Real GDP**: Data on GDP (following the expenditure approach) is taken from the OECD statistical database. The series is expressed in volume estimates with reference year 2010 that is seasonally adjusted.

- **Real consumption**: Data on 'Private final consumption expenditure' is taken from the OECD database. The series is expressed in volume estimates with reference year 2010 that is seasonally adjusted.

- **Real investment**: Investment is approximated by 'Gross fixed capital formation', taken from the OECD statistics database. The series is expressed in volume estimates with reference year 2010 that is seasonally adjusted.

- **Consumer price index**: Inflation is approximated by the data on 'Consumer prices - all items' from the OECD database. The reference year is 2010.

- **Real wages**: The nominal wage is given by 'Labour compensation per employed person' which is seasonally adjusted data and has 2010 as the reference year. The data is from the OECD statistical database. The real wage is obtained by dividing the index for labor compensation by the consumer price index.

- **Nominal interest rate**: The nominal interest rate in this model is given by 3-month money market rate from the Eurostat database. The nominal interest rate is the same for both regions, as they were member of the monetary union during the whole estimation period.

- **Government debt**: Government debt is given by 'Gross consolidated government debt', spent by the general government. The data is available in the Eurostat database and the series is expressed in millions of euros.

- **Unemployment**: Unemployment is measured as 'Unemployed population' in thousands of persons. The data is obtained from the 'Short-Term Labour Market Statistics' dataset in the OECD database.

A summation of the data yields most of the series for North and South. For inflation and the real wage rate, however, I calculate the weighted average using the share of GDP as the weight. The series are seasonally adjusted using the TramoSeats method[18] in Demetra+. The chosen specification RSA3 tests for the log/level specification, it automatically detects outliers and identifies and estimates the best ARIMA model for the seasonal adjustment.[19] After detrending the data, the variables are expressed in log deviations from the steady state to match with the measurement equations of the model.

The observables are mapped onto the model via the observation equations. The measurement equation for GDP looks as follows:

$$y_t^{obs} = \hat{y}_t^i \tag{4.A.88}$$

where y_t^{obs} is the observable time series for GDP. The model gives a simulation of $\hat{y}_t^i$, based on the estimated parameters, which is the log deviation of output from the steady state. The measurement equations for c_t^{obs}, i_t^{obs}, w_t^{obs}, d_t^{obs}, u_t^{obs}, π_t^{obs} and r_t^{obs} are of the same type, and these are similar for both regions.

[18] The TramoSeats method is also used by the OECD to seasonally adjust the data series.

[19] More information can be found in the Demetra+ User Manual (Grudkowska (2011)).

Bibliography

Abadie, A., Diamond, A., and Hainmueller, J. (2010). Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program. *Journal of the American Statistical Association*, 105(490):493–505.

Abadie, A., Diamond, A., and Hainmueller, J. (2015). Comparative Politics and the Synthetic Control Method. *American Journal of Political Science*, 59(2):495–510.

Abadie, A. and Gardeazabal, J. (2003). The Economic Costs of Conflict: A Case Study of the Basque Country. *The American Economic Review*, 93(1):113–132.

Abbas, S. A., Belhocine, N., Elganainy, A., and Horton, M. (2011). A Historical Public Debt Database. *IMF Economic Review*, 59(4):717–742.

Abbritti, M. and Fahr, S. (2013). Downward wage rigidity and business cycle asymmetries. *Journal of Monetary Economics*, 60(7):871–886.

Abbritti, M. and Mueller, A. I. (2013). Asymmetric Labor Market Institutions in the EMU and the Volatility of Inflation and Unemployment Diffferentials. *Journal of Money, Credit and Banking*, 45(6):1165–1186.

Allard, C., Brooks, P. K., Bluedorn, J. C., Bornhorst, F., Christopherson, K., Ohnsorge, F., and Poghosyan, T. (2013). Toward a Fiscal Union for the Euro Area. *IMF Staff Discussion Note 13/9, International Monetary Fund.*

Antia, Z., Djoudad, R., and St-Amant, P. (1999). Canada's Exchange Rate

Regime and North American Economic Integration: The Role of Risk-Sharing Mechanisms. *Working Papers 99-17, Bank of Canada.*

Arpaia, A., Kiss, A., Palvolgyi, B., and Turrini, A. (2015). Labour Mobility and Labour Market Adjustment in the EU. *IZA Policy Papers 106, Institute for the Study of Labor (IZA).*

Asdrubali, P., Sorensen, B. E., and Yosha, O. (1996). Channels of Interstate Risk Sharing: United States 1963-1990. *The Quarterly Journal of Economics*, 111(4):1081–1110.

Baldwin, R., DiNino, V., Fontagné, L., De Santis, R. A., and Taglioni, D. (2008). Study of the Impact of the Euro on Trade and Foreign Direct Investment. *European Economy - Economic Papers 321, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.*

Bargain, O., Dolls, M., Fuest, C., Neumann, D., Peichl, A., Siegloch, S., and Pestel, N. (2013). Fiscal Union in Europe? Redistributive and Stabilising Effects of a European Tax-Benefit System and Fiscal Equalisation Mechanism Fiscal Union in Europe? *Economic Policy*, 28(75):375–422.

Barr, D., Breedon, F., and Miles, D. (2003). Life on the outside: economic conditions and prospects outside euroland. *Economic Policy*, 18(37):573–613.

Beblavý, M., Marconi, G., and Maselli, I. (2015). A European Unemployment Benefits Scheme: The rationale and the challenges ahead. *CEPS Papers 10952, Centre for European Policy Studies.*

Beblavý, M. and Maselli, I. (2014). An Unemployment Insurance Scheme for the Euro Area: A simulation exercise of two options. *CEPS Papers 9889, Centre for European Policy Studies.*

Benigno, P. and Woodford, M. (2005). Inflation Stabilization and Welfare: The Case of a Distorted Steady State. *Journal of the European Economic Association*, 3(6):1185–1236.

Berger, H. and Nitsch, V. (2008). Zooming out: The trade effect of the euro in historical perspective. *Journal of International Money and Finance*, 27(8):1244–1260.

Bertola, G. (2013). Policy Coordination, Convergence, and the Rise and Crisis of EMU Imbalances. *CEPR Discussion Papers 9471.*

Beyer, R. C. M. and Smets, F. (2015). Labour market adjustments in Europe and the US: How different? *Working Paper Series 1767, European Central Bank.*

Blanchard, O. and Gali, J. (2008). Labour Markets and Monetary Policy: A New Keynesian Model with Unemployment. *CEPR Discussion Papers 6765.*

Campos, N. F., Coricelli, F., and Moretti, L. (2014). Economic Growth and Political Integration: Estimating the Benefits from Membership in the European Union Using the Synthetic Counterfactuals Method. *CEPR Discussion Paper 9968.*

Chari, V. V., Kehoe, P. J., and Grattan, E. R. M. C. (2002). Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates? *Review of Economic Studies*, 69(3):533–563.

Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy*, 113(1):1–45.

Christoffel, K. and Linzert, T. (2005). The Role of Real Wage Rigidity and Labor Market Frictions for Unemployment and Inflation Dynamics. *IZA Discussion Papers 1896, Institute for the Study of Labor (IZA).*

Commission of the European Communities (1990). One market, one money: an evaluation of the potential benefits and costs of forming an economic and monetary union. *European Economy 44.*

Delors, J. (1989). Report on economic and monetary union in the European Community. *By Commitee for the Study of Economic and Monetary Union.*

Dolls, M., Fuest, C., Neumann, D., and Peichl, A. (2015). An Unemployment Insurance for the Euro Area? A Comparison of Different Alternatives Using Micro Data. *CESifo Working Paper 5581, CESifo Group Munich.*

Drake, L. and Mills, T. C. (2010). Trends and cycles in Euro area real GDP. *Applied Economics*, 42(11):1397–1401.

Dullien, S. and Fichtner, F. (2013). A Common Unemployment Insurance System for the Euro Area. *DIW Economic Bulletin*, 3(1):9–14.

Evers, M. P. (2012). Federal fiscal transfer rules in monetary unions. *European Economic Review*, 56(3):507–525.

Evers, M. P. (2015). Fiscal Federalism and Monetary Unions: A Quantitative Assessment. *Journal of International Economics*, 97(1):59–75.

Farhi, E. and Werning, I. (2012). Fiscal Unions. *NBER Working Papers 18280, National Bureau of Economic Research.*

Fernández, C. and García-Perea, P. (2015). The impact of the euro on euro area GDP per capita. *Documentos de Trabajo 1530, Banco de Espana.*

Flam, H. and Nordström, H. (2006). Trade volume effects of the euro: aggregate and sector estimates. *Seminar Papers 746, Stockholm University, Institute for International Economic Studies.*

Frankel, J. and Rose, A. (2002). An Estimate of the Effect of Common Currencies on Trade and Income. *The Quarterly Journal of Economics*, 117(2):437–466.

Furceri, D. and Zdzienicka, A. (2013). The Euro Area Crisis: Need for a Supranational Fiscal Risk Sharing Mechanism? *IMF Working Papers 13/198, International Monetary Fund.*

Galí, J. and Monacelli, T. (2008). Optimal monetary and fiscal policy in a currency union. *Journal of International Economics*, 76(1):116–132.

Gertler, M., Sala, L., and Trigari, A. (2008). An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining. *Journal of Money, Credit and Banking*, 40(8):1713–1764.

Giannone, D., Lenza, M., and Reichlin, L. (2010). Business Cycles in the Euro Area. *CEPR Discussion Papers 7124.*

Gomis-Porqueras, P. and Puzzello, L. (2015). Winners and Losers from the euro. *Economic Series 2015_2, Deakin University, Faculty of Business and Law, School of Accounting, Economics and Finance.*

Grudkowska, S. (2011). Demetra+ User Manual. *National Bank of Poland.*

Hall, R. E. (2005). Employment Fluctuations with Equilibrium Wage Stickiness. *American Economic Review*, 95(1):50–65.

Hepp, R. and von Hagen, J. (2013). Interstate risk sharing in Germany: 1970-2006. *Oxford Economic Papers*, 65(1):1–24.

Hollmayr, J. (2012). Fiscal Spillovers and Monetary Policy Transmission in the Euro Area. *Working Paper, Goethe University, Frankfurt an Main.*

Jara, H. X. and Sutherland, H. (2014). The implications of an EMU unemployment insurance scheme for supporting incomes. *EUROMOD Working Papers EM5/14, EUROMOD at the Institute for Social and Economic Research.*

Jondeau, E. and Sahuc, J.-G. (2008). Optimal Monetary Policy in an Estimated DSGE Model of the Euro Area with. *International Journal of Central Banking*, 4(2):23–72.

Kaufmann, D., Kraay, A., and Mastruzzi, M. (2010). The Worldwide Governance Indicators Methodology and Analytical Issues. *Policy Research Working Paper Series 5430, The World Bank.*

Kenen, P. B. (1969). The Theory of Optimum Currency Areas: An Eclectic View. In Mundell, R. and Swoboda, A., editors, *Monetary Problems of the International Economy*, pages 41–60. The University of Chicago Press.

Kolasa, M. (2009). Structural heterogeneity or asymmetric shocks? Poland and the euro area through the lens of a two-country DSGE model. *Economic Modelling*, 26(6):1245–1269.

Lucas, R. E. (2003). Macroeconomic Priorities. *American Economic Review*, 93(1):1–14.

MacDougall, D. and Commission of the European Communities (1977). Report of the Study Group on the Role of Public Finance in European Integration.

Mancini-Griffoli, T. and Pauwels, L. L. (2006). Is There a Euro Effect on Trade? An Application of End-of-Sample Structural Break Tests for Panel Data. *IHEID Working Papers 04-2006, Economics Section, The Graudate Institute of International Studies.*

Martin, P. and Philippon, T. (2014). Inspecting the Mechanism: Leverage and the Great Recession in the Eurozone. *NBER Working Papers 20572, National Bureau of Economic Research.*

Masson, P. R. and Taylor, M. P. (1993). Fiscal Policy within Common Currency Areas. *Journal of Common Market Studies*, 31(1):29–44.

McKinnon, R. I. (1963). Optimum currency areas. *The American Economic Review*, 53(4):717–725.

Melitz, J. and Zumer, F. (1999). Interregional and international risk-sharing and lessons for EMU. *Carnegie-Rochester Conference Series on Public Policy*, 51(1):149–188.

Micco, A., Stein, E., and Ordoñez, G. (2003). The Currency Union Effect on Trade: Early Evidence from EMU. *Economic Policy*, 18(37):315–356.

Moyen, S., Stähler, N., and Winkler, F. (2016). Optimal Unemployment Insurance and International Risk Sharing. *Finance and Economics Discussion Series 2016-054, Board of Governors of the Federal Reserve System (U.S.).*

Mundell, R. A. (1961). A Theory of Optimum Currency Areas. *The American Economic Review*, 51(4):657–665.

Obstfeld, M. and Rogoff, K. (1995). Exchange Rate Dynamics Redux. *The Journal of Political Economy*, 103(3):624–660.

Organization for Economic Co-Operation and Development. OECD.Stat. *Retrieved from: http://stats.oecd.org/.*

Pisani-Ferry, J., Vihriälä, E., and Wolff, G. (2013). Options for a Euro-area fiscal capacity. *Policy Contributions 765, Bruegel.*

Poilly, C. and Sahuc, J.-G. (2008). Welfare Implications of Heterogeneous Labor Markets in a Currency Area. *Macroeconomic Dynamics*, 17(02):294–325.

Pytlarczyk, E. (2005). An estimated DSGE model for the German economy within the euro area. *Discussion Paper Series 1: Economic Studies 2005, 33, Deutsche Bundesbank, Research Centre.*

Saia, A. (2017). Choosing the open sea: The cost to the UK of staying out of the euro. *Journal of International Economics*, 108:82–98.

Sala-i Martin, X. and Sachs, J. (1992). Fiscal Federalism and Optimum Currency Areas: Evidence for Europe from the United States. *CEPR Discussion Papers 632.*

Santos Silva, J. M. C. and Tenreyro, S. (2010). Currency Unions in Prospect and Retrospect. *Annual Review of Economics*, 2(1):51–74.

Smets, F. and Wouters, R. (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association*, 1(5):1123–1175.

Sorensen, B. E. and Yosha, O. (1998). International risk sharing and European monetary unification. *Journal of International Economics*, 45(2):211–238.

Van Rompuy, H. (2012). Towards a Genuine Economic and Monetary Union. *Report of the President of the European Council. Brussels, 5 December.*