Essays on Monetary Policy in the Euro Area

by
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ABSTRACT

TATEVIK SEKHPOSYAN: Essays on Monetary Policy in the Euro Area.
(Under the direction of Neville Francis.)

The sequence of the essays in this thesis studies the differentials in inflation and output growth across the Euro Area countries and addresses the role of monetary policy in explaining these differentials. First I study the extent to which inflation and output growth differentials are explained by the propagation of common monetary policy interventions. Next, I evaluate the performance of the monetary authority in fulfilling the stabilization needs of the member countries when it aims to stabilize the aggregate economy. Lastly, I empirically evaluate a policy interest rule to determine the implicit weight the policymaker puts on the country-specific inflation and output growth differentials in addition to the aggregate.

The results show that monetary policy interventions do not generate significant differences in the inflation behavior across the countries, while they create significant differences in the output dynamics. Moreover, monetary policy innovations do account for a large portion of country-specific output fluctuations. This is in contrast to the business cycle literature where only a small fraction of output variance is attributed to the monetary policy shocks. In addition, it appears that while targeting the aggregate inflation and output dynamics, monetary authority stabilizes cross-country inflation in the face of idiosyncratic shocks fairly well, though there are considerable differences in the welfare losses associated with the cross-country output variability. Furthermore, country-specific inflation deviations are statistically significant in a Taylor type policy feedback rule, while the aggregate output gap and country-specific output gap differentials appear to be statistically insignificant.

To my sister Ani, for inspiration.

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LIST OF ABBREVIATIONS

2SLS	Two-stage least squares
AT	Austria
BE	Belgium
BIC	Bayesian Information Criteria
DE	Germany
DSGE	Dynamic stochastic general equilibrium
EA	Euro Area
ECB	European Central Bank
EMU	European Economic and Monetary Union
ES	Spain
FI	Finland
FR	France
HICP	Harmonized Index of Consumer Prices
IE	Ireland
IPI	Industrial Production Index
IT	Italy
LU	Luxembourg
MCMC	Markov Chain Monte Carlo
MFI	Monetary financial institutions
MSFE	Mean Squared Forecast Error
NL	Netherlands
OLS	Ordinary Least Squares
PT	Portugal
RLS	Recursive Least Squares
VAR	Vector Autoregression

Chapter 1

Foreword

In 1989 the Delors Report proposed three stages for European Economic and Monetary Union (EMU) that intended to create a single market in Europe. Stage 1 started on July 1, 1990 and aimed at completing internal markets and removing all obstacles to financial integration. The second stage initiated the creation of the EMU on January 1994, according to which countries move from co-ordination of national policies to a common monetary policy. In addition, countries are required to adhere to convergence criteria otherwise known as Maastricht Criteria, which aimed for gradual convergence of inflation, interest rates, and exchange rates, as well as threshold values for the government debt and deficit to GDP values among the future members of the monetary union. On June 1998 the European Central Bank (ECB) and the Eurosystem are set up, and by January of 1999 Stage 3 of the EMU begins. The exchange rates of the 11 participating nations in terms of Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Ireland (IE), Italy (IT), Luxembourg (LU), Netherlands (NL), and Portugal (PT) are fixed. Euro begins to trade on financial markets, and the ECB takes the responsibility of the common monetary policy.

The initiation of the Euro Area (EA) started an intense debate in academic and policy circles. Jonung and Drea (2010) summarize the literature in academia and central banks in regards to the anticipated success of the Euro Area before its inception and in the first few years of its operation. Figure C.1 captures the intensity of the literature, while Table B.1 summarizes the academic literature about EMU over the period of 1989-2002. As the table suggests, the topical coverage for the academic papers varies: it extends from the design of institutional structure, implementation of optimal fiscal policy, evaluation of the union as an optimal currency area to its effects on international markets.

The conclusion of the literature has been skeptical. Given the asymmetry of the shocks, structural differences across the countries in term of relative price responses and labor mobility, as well as the non-existence of a central fiscal authority to implement an interregional transfer program as a way of insuring against asymmetric shocks, the literature suggested that the Eurozone does not qualify for an optimal currency area and would be unable to smooth out the differences in the regional adjustment mechanism. The sequence of essays presented in this thesis reevaluate the notion of optimal currency area in the Eurozone based on the decade long economic performance of the Euro Area (EA).[1]

Having a monetary union presents a trade-off. On one hand there are efficiency gains on the micro level from trade, since single currency reduces transaction costs. On the other hand this gain in efficiency is contrasted with a loss of a country to conduct its independent monetary policy. The presentation of this trade-off is clearly depicted in a John B. Taylor interview with Milton Friedman as in Friedman (2001):

> **Taylor:** Let me ask a question about monetary issues that relates to the global economy. You have Europe's new single currency, and you have Bob Mundell arguing that we should have one world currency. You also have talk about dollarization in Argentina and a greater commitment to floating in Brazil. Where is this all going?
>
> **Friedman:** From the scientific point of view, the Euro is the most interesting thing. I think it will be a miracle–well, a miracle is a little strong. I think it's highly unlikely that it's going to be a great success. It would be very desirable and I would like to see it a success from a policy point of view, but as an economist, I think there are real problems, arising in a small way now when you see the difference between Ireland and Italy. You need different monetary policies for those two countries, but

[1] A thorough discussion and comparative studies for various aspects of regional adjustments in U.S., Euro Area, and Canada can be found in Obstfeld and Peri (2000).

> you can't have it with a single currency. Yet they are independent countries; you are not going to have many Italians moving to Ireland or vice versa. So I do not share Bob Mundell's unlimited enthusiasm for the Euro. But it's going to be very interesting to see how it works. For example, I saw a study in which somebody tried to ask the question, "What is the effect of having a common currency on the volume of intercountry trade?" And the result was surprising. It was that having a common currency had a surprisingly large effect, about four times the effect of geographical proximity or of flexible exchange rates. Now that was just a small sample.

In the thesis I concentrate only on the cost aspect of the currency union, i.e. what are the losses associated with having a common monetary policy. More specifically, I evaluate the country-level performance of the Eurozone economies under the euro regime. I think of a loss in terms of cross country inflation and output growth differentials associated with monetary policy innovations and the capacity of monetary policy to offset the idiosyncratic country-specific disturbances. I then examine whether the cross country inflation and output growth differentials are included in the information set of the ECB when setting monetary policy. In other words, I consider a scenario where the countries matter to the policy interest rate decision with different weights than their size suggests. The details of the thesis are presented below.

In Chapter 2 I look at the differential adjustment mechanisms of the union-member countries upon a common monetary policy innovation. Looking at the monetary policy responses is important from two respects. First and foremost, monetary policy innovations are important since they imply a policy action. On the other hand, by looking at the responses to a common shock enables us to quantify the structural differences across the countries and enables us to look at the flexibility of the member economies to absorb various shocks. In addition, I look at the systematic component of monetary policy and its ability to stabilize the union-member economies in the face of idiosyncratic shocks when it in fact targets the aggregate economy.

In Chapter 3 I estimate a Taylor rule for the Euro Area, first under the assumption that

ECB targets the EA aggregate output gap and inflation, where the aggregates are constructed by weighting the country-specific output and prices proportional to the country size. I then estimate a Taylor rule, where I allow ECB to target the country-specific differentials in addition to the aggregate variables. The relevance of this exercise is to find out whether the central bank is aiming at stabilizing all member economies equally.

The chapters in this thesis have two important features. First, the analysis is conducted based on data that captures the EA dynamics after the ECB took the responsibility of monetary policy. Data coverage is a relevant issue due to the Lucas critique: by considering the time period when currency union has been in place, I reduce the chance of model misspecification. Second, I rely on Bayesian inference, which is appropriate from a methodological point of view due to its small sample properties. In addition, the Bayesian inference provides with an opportunity to incorporate the pre-euro dynamics for the post-euro analysis thus preventing the loss of information. I accomplish the latter by parameterizing the prior consistent with the pre-euro data and using that for inference.

Our findings are as follows.

I show that the monetary policy conducted by the ECB is relatively successful in stabilizing the country-specific measures of consumer prices. The inflation response upon a common monetary policy shock appears to be small and not-significantly different across the countries. On the other hand, the burden of the economic realignment falls on the adjustment of output. There appear to be persistent differences in the output response across the countries. Monetary policy innovations in certain cases capture up to 60% of the business cycle variations.

The systematic component of the policy rule does in fact stabilize the cross-country inflation variability in the presence of idiosyncratic shocks fairly well, though it fails to do so in regards to output variability. In fact, the idiosyncratic shocks are best offset for France, and the worst for Austria.

In regards to the Taylor rule, the European Central Bank responds to the fluctuations in inflation expectations but not to the output gap. The policy feedback rule is well defined (in accord to the Taylor Principle). There appears to be evidence that deviations of inflation from the aggregate matter as well. The deviations of inflation for Spain and France mitigate the policy response, while the deviations of Belgium, Germany, and the Netherlands accentuate the policy response suggesting a weighting matrix for the country-specific variables different from the size of the economy.

Chapter 2

Monetary Policy in a Currency Union: is the Euro Good for All?

2.1 Introduction

Macroeconomists frequently treat the aggregate economy as a homogenous entity. Accordingly, they analyze business cycle dynamics and evaluate macroeconomic policy outcomes on an aggregate level with little or no emphasis on regional variations. This way of thinking builds on the assumption that price and wage adjustment mechanisms within a country are flexible and factors of production reasonably mobile.[1] Therefore, misalignments in regional adjustment are expected to be somewhat short-lived, and the economic consequences arising from such disparities are thought to be negligible.

The welfare effects of unsynchronized regional adjustments have become a topic of heated debate since 1999 when the European Central Bank (ECB) assumed responsibility of a common monetary policy for the Euro Area. On one hand, variations in inflation and output across member countries are considered to be necessary for economic adjustment (Lane (2006)). On the other hand, persistent inflation and output growth differentials are thought to lead to systematic resource misallocations, thus tempering long-run growth and exacerbating cross

[1] In other words, the asymmetries in regional realignment are often overlooked because the economy is presumed to qualify for an optimal currency area, as highlighted in the seminal works of Mundell (1961) and McKinnon (1963).

country differences (Blanchard and Summers (1987), Aghion and Howitt (2006)).

The intensification of the debate is partially due to the fact that there is a clearly defined benchmark for a welfare comparison. The Euro Area members had independent central banks with monetary policies that had the economic welfare of their sovereign countries as a main objective. By entering the currency union, these countries agreed to the ECB objective of union-wide price stability, which was defined as "a year-on-year increase in the Harmonized Index of Consumer Prices (HICP) for the Euro Area below 2%" as opposed to their own inflation and/or output (gap) stabilization policies.[2]

If the sources and magnitudes of the stochastic disturbances the member economies face are not the same, a common monetary policy would be unable to stabilize the economies at a national level. Moreover, if the structure of the member economies differ considerably, monetary policy interventions can contribute to the business cycle differentials as well. This in itself is not a concern if the economies of the member countries are flexible enough for readjustment to occur quickly. However, various surveys of the current economic conditions in the Euro Area provide evidence to the contrary.[3]

In this paper, I establish an empirical benchmark to address the extent to which the propagation of common monetary policy can create differences in the dynamics of the output and inflation across the countries. In addition, I assess the degree to which a common monetary policy aimed at the stabilization of the union can stabilize the economies of individual members in the face of idiosyncratic country-specific stochastic disturbances. I do so by postulating a simple theoretical model, which in fact describes the most desirable situation, that is when the union member countries are perfectly aligned. The theoretical model puts a structure on the transmission channels by which an individual country relates to the union. I then take the theoretical model to motivate the empirical specification and evaluate the country-specific differences created by the union-wide monetary policy.

I find that the cross sectional variability of the inflation response upon a common monetary

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[2] See October 13, 1998 ECB Press Release.

[3] See Economic Survey of the Euro Area, OECD Policy Brief, January 2007 and Report on the European Economy, EEAG European Economic Advisory Group Report, February 2007 among others.

policy shock is statistically insignificant. However, there are significant differences in the output responses across the countries. The differences are both in magnitudes and timing of the trough. In addition, there is a considerable variation in the proportion of the business cycle fluctuations explained by a monetary policy shock across the countries. These variations range from 2 percent to 70 percent for a two year period. In addition, a simulation exercise over a twenty year horizon shows that in the face of idiosyncratic shocks ECB is more successful in stabilizing the country-specific inflation variations and less successful in stabilizing output variations.

The remainder of the paper is organized as follows. Section 2.2 discusses the motivation in a greater detail. Section 2.3 relates the research question to the existing literature and data. Section 2.4 postulates the theoretical model. Section 2.5 outlines the empirical specification. Section 2.6 presents the econometric methodology. Sections 2.7 and 2.8 discuss our findings. Subsequently, I conclude with propositions for further research.

2.2 Motivation

Figures 1a and 1b plot the average output growth and inflation differentials for the original members of the Euro Area, that is Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Ireland (IE), Italy (IT), Luxembourg (LU), Netherlands (NL), and Portugal (PT). The range for the average inflation rate is approximately 0.13 percentage points, while the range for the average output growth stands at 0.42 percentage points. In addition, differences in inflation and output growth are fairly persistent. The median country with a level of output growth (inflation) below (above) that of the aggregate reported such performance about 51 percent of the time.

The relative comovements of inflation and output growth are positive for a number of countries indicating a demand-driven business cycle. For Netherlands and Ireland, the relative measures of inflation and output growth are both positive on average, while for France both measures are negative. Inflation and output growth comovements for the remaining eight countries in the union are negative signaling that the country-level differences relative to the aggregate are overall due to either supply-side phenomena or to varying country-specific demand (in)elasticities.

In evaluating the role of monetary policy in the observed differentials of inflation and output growth, there are two important aspects. First, for the unexpected (discretionary) component of monetary policy to have differential effects, there should be evidence of significant structural heterogeneity across the countries. Second, for the systematic component of the union-wide policy rule to have differential effects, in addition to structural heterogeneity, differences in the sources and magnitudes of stochastic disturbances can also be a contributing factor. Further, I consider the degree to which the systematic and discretionary components of monetary policy factor in the union-wide dynamics.

2.3 Relation to the Existing Literature

There exists vast empirical literature that explores the differences in inflation and output dynamics in the Euro Area. Most of this research was conducted prior to the ECB assuming its responsibilities with a primary objective of forecasting the economic dynamics of potential member countries after monetary integration was complete.[4] Peersman (2004) provides a comprehensive literature review and robustness analysis for the empirical literature based on the pre-euro data. Though several studies considered in this paper find significant differences in the magnitude and timing of the output and inflation responses across union member countries, there is no consensus on the actual magnitudes, timing, or ranking of the differentials across studies.

The theoretical literature (e.g., Benigno (2004) and Galí and Monacelli (2008)), has mainly concentrated on the formulation of the optimal monetary (and fiscal) policy in a currency area. As such, it considers the optimal weights one needs to use in constructing the union-wide aggregates in order to minimize the welfare loss associated with the structural heterogeneity. In conducting an optimal monetary policy, the policymakers' objective is to obviate structural rigidities. Thus, this literature focuses on stabilization around a flexible price equilibrium

[4] See Mihov (2001) and Dornbusch et al. (1998) as examples of such works.

and does not necessarily address the reasons of why and to what extent the flexible price equilibrium might differ across countries.

Jondeau and Sahuc (2008) investigate the sources of heterogeneity within the Euro Area. They estimate a multi-country dynamic stochastic general equilibrium (DSGE) model for the Euro Area. Since the estimated model is not very rich in structure, it leans towards accepting the hypothesis of stochastic heterogeneity (i.e., asymmetry in the shocks) as opposed to structural heterogeneity.[5]

Furthermore, there is an extensive discussion about the various aspects of the economic structure in which the Euro Area member countries differ. The labor and product market rigidities in particular have received considerable attention. Alesina et al. (2008) conclude that the pace of structural reforms in the product market has intensified with the adoption of the euro, while that is not the case for the primary labor markets.[6] Dhyne, Álvarez, Bihan, Veronese, Dias, Hoffmann, Jonker, Lünnemann, Rumler, and Vilmunen (Dhyne et al.) calculate the median frequency of price changes from product level data for several Euro Area member countries. Based on their calculations, Italy exhibits a greatest degree of price stickiness, while Portugal exhibits the lowest degree of price stickiness: the implied durational difference between the two is about five months. Waddington and Hoffmann (2003) show that countries vary considerably with trade union membership rates, while the numbers for collective bargaining coverage are less variable. The unionized share of employed is the smallest in France, while it is quite high in Finland. However, even in France, 90 percent of the employed are covered by some version of collective bargaining. A higher degree of labor and product market rigidities imply a more persistent inflation process, putting the pressure on output in the adjustment process.

In its approach to evaluate the effect of monetary policy on inflation and output differentials across the Euro Area countries, the paper most closely associated with our work is Boivin

[5] Their model does not include labor market rigidities, which are very important for the Euro Area.

[6] The findings are consistent with the Economic Survey of the Euro Area in 2007 as the OECD Policy Brief states: "The early years of monetary union have shown that less flexible economies can have a rough ride, missing out on the full benefits of the single currency. Structural rigidities tend to reduce growth, make inflation more persistent and reduce the economys ability to absorb shocks."

et al. (2008). They assess how the introduction of the euro changed the monetary policy transmission mechanism for the Euro Area countries. The results are particularly important given that the inference relies on post-euro data. By estimating a factor-augmented VAR model, Boivin et al. (2008) show that the effects of the monetary policy have become less important and more homogeneous for all real variables except for the real effective exchange rates and trade as the euro was introduced. The convergence of the long-term interest rates as well as the elimination of the intra-union exchange rate risk appear to be the main reasons for the harmonization of the policy effects.

This paper is similar to Boivin et al. (2008) in that it relies on post-euro data for inference. However, it differs from Boivin et al. (2008) in that it takes a more standard structural VAR approach to the estimation. Although factor-augmented VAR models provide fairly accurate forecasts, it is usually difficult to associate a particularly important factor with a variable regularly observed in the economy. In addition, aside from the monetary policy disturbances, I assess the importance of the systematic component of the monetary policy in the observed inflation and output differentials as well. This is important since the contribution of monetary policy disturbances to the business cycle fluctuations is small as documented for example in Sims and Zha (2006).

2.4 A Theoretical Model of a Currency Union

The theoretical setup considers a currency union that consists, without loss of generality, of two open economies and a union-wide monetary policy authority. The countries share a similar structure in that they can be described with the same type of preferences and frictions. First, I postulate a model of an open economy that is a member of the currency union. Then, I look at aggregation and union-wide dynamics.

Each individual economy is modeled in the spirit of small open economies described in Galí and Monacelli (2005) and Erceg et al. (2007). Each country has a monopolistically competitive intermediate goods sector, which implies control over price setting. In addition, there is "home-bias" in the preferences of the households for the domestically produced consumption good.

Our model is different from Erceg et al. (2007) in that there is no staggered wage adjustment.

In these models the world is exogenous and each economy relates to the world under the assumption that it has no effect on it. In our model I relax the small open economy aspect of the dynamics. Instead of the world, I model a union which is not exogenous to countries, but rather the union is comprised of countries. The latter makes it possible for each union-member country to affect the union dynamics. In addition, this is a currency union model, and as such the law of one price and the effects of nominal exchange rate movements are not considered.

2.4.1 Modeling the Individual Economies

Households

The representative household in an open economy chooses a bundle of consumption goods, hours worked, quantity of one-period riskless bond holdings, and money holdings ($\{C_t, L_t, D_t, M_t\}_{t=0}^{\infty}$) to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, \frac{M_t}{P_t}, L_t\right) \tag{2.1}$$

subject to

$$U\left(C_t, \frac{M_t}{P_t}, L_t\right) = \frac{C_t^{1-\sigma}}{1-\sigma} + \frac{(M_t/P_t)^{1-\nu}}{1-\nu} - \frac{L_t^{1+\varphi}}{1+\varphi} \tag{2.2}$$

$$P_t C_t + Q_t D_t + M_t \leq D_{t-1} + M_{t-1} + W_t L_t + \Gamma_t + T_t \tag{2.3}$$

$$\lim_{T\to\infty} E_t\{D_T + M_T\} \geq 0, \tag{2.4}$$

where P_t is the price of consumption goods and W_t is the nominal wage. Each risk-free bond pays one unit of money at maturity, and its price is Q_t. T_t is the value of lump-sum transfers/taxes in nominal terms, and Γ_t is the profit of all the domestic firms. Ponzi-type schemes are outruled by equation (2.4).

The consumption bundle of the representative household consists of domestically produced

$(C_{H,\ t})$ and imported $(C_{F,\ t})$ goods, aggregated by the following preferences

$$C_t = [(1-\alpha)^{\frac{1}{\eta}}(C_{H,\ t})^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}(C_{F,\ t})^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}}, \tag{2.5}$$

where $\eta > 0$ measures the substitutability of domestic and foreign goods and $\alpha \in [0,1]$ measures the households relative preference for foreign (imported) goods.

$$P_t = [(1-\alpha)(P_{H,\ t})^{1-\eta} + \alpha(P_{F,\ t})^{1-\eta}]^{\frac{1}{1-\eta}} \tag{2.6}$$

I define the aggregate price index by (2.6), where $P_{H,\ t}$ and $P_{F,\ t}$ define the prices of domestic and foreign goods (in the same currency), respectively. Consequently, the optimal allocation of consumption expenditures yields the following derived demand schedules for the aggregate domestic and imported goods.

$$C_{H,\ t} = (1-\alpha)\left(\frac{P_{H,\ t}}{P_t}\right)^{-\eta} C_t \qquad C_{F,\ t} = \alpha\left(\frac{P_{F,\ t}}{P_t}\right)^{-\eta} C_t \tag{2.7}$$

The relevant first-order conditions from the household optimization are given by the Euler equation (2.8), labor supply (2.9), and money demand (2.10) schedules. The demand for bond holdings is determined by the budget constraint (2.3). I rewrite the Euler equation in terms of the gross risk-free interest rate R_t, which is the reciprocal of Q_t.

$$\beta E_t R_t \left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+1}}\right] = 1 \tag{2.8}$$

$$C_t^{\sigma} L_t^{\varphi} = \frac{W_t}{P_t} \tag{2.9}$$

$$C_t^{\sigma}\left(\frac{R_t}{R_t-1}\right) = \left(\frac{M_t}{P_t}\right)^{\nu} \tag{2.10}$$

Firms

There are two types of firms in this economy: firms producing domestic intermediate goods and firms producing domestic finished goods. The intermediate goods sector is monopolistically competitive, while the final goods sector is perfectly competitive.

Final Goods Producers

The domestic final goods producing representative firm buys $Y_t(i)$ of each intermediate good $i \in [0, 1]$ for a nominal price $P_{H,\ t}(i)$ in each period t to produce a final good Y_t. It uses constant-return-to-scale technology, such that

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{(\theta_t - 1)}{\theta_t}} di \right]^{\frac{\theta_t}{(\theta_t - 1)}}, \tag{2.11}$$

where θ_t is the time-varying elasticity of demand for each intermediate good. The final good producing sector maximizes its profit yielding in the following first-order condition

$$Y_t(i) = \left(\frac{P_{H,\ t}(i)}{P_{H,\ t}} \right)^{-\theta_t} Y_t, \tag{2.12}$$

where $P_{H,\ t} = \left[\int_0^1 P_{H,\ t}(i)^{1-\theta_t} di \right]^{\frac{1}{(1-\theta_t)}}$.

Intermediate Goods Producers

There is a continuum of intermediate goods $i \in [0, 1]$, each produced by a monopolistically competitive firm. Each firm uses identical technology and produces its differentiated good by the following

$$Y_t(i) = A_t L_t(i). \tag{2.13}$$

Firms maximize their profit by taking the demand schedules expressed in equation (2.12), the domestic aggregate price level ($P_{H,\ t}$), as well as the domestic aggregate output level (Y_t) as given. In addition, prices are sticky. The latter is implemented by the mechanism proposed by Calvo (1983) and Yun (1996): in each period a firm may reset its price with probability $1 - \phi$. Thus, overall in the economy, in each period $1 - \phi$, intermediate good producers change their prices, while ϕ fraction keeps it unchanged.

The input markets that the intermediate goods producers face are competitive, so each firm chooses its labor input $L_t(i)$, taking the aggregate wage index W_t as given. In addition, the labor is completely mobile in each country.

Given the assumptions, the i-th intermediate-good-producing firm's problem at time t (if it can reset its price) is to choose $P^{*}_{H,\ t}(i)$ in order to maximize

$$\sum_{k=0}^{\infty} \phi^k E_t \left[Q_{t,\ t+k}(P^{*}_{H,\ t}(i) Y_{t+k}(i) - \Phi_{t+k}(Y_{t+k}(i))) \right], \tag{2.14}$$

subject to a sequence of demand schedules

$$Y_{t+k}(i) = \left(\frac{P^{*}_{H,\ t}(i)}{P_{H,\ t+k}} \right)^{-\theta_t} Y_{t+k}, \tag{2.15}$$

where $Q_{t,t+k}$ is the stochastic discount factor for nominal payoffs as in equation (2.3) and $\Phi_t(.)$ is the cost function.

The first-order condition yields

$$\sum_{k=0}^{\infty} \phi^k E_t \left[Q_{t,\ t+k} Y_{t+k}(i) \left(P^{*}_{H,\ t}(i) - \frac{\theta_t}{\theta_t - 1} \Phi'_{t+k}(Y_{t+k}(i)) \right) \right] = 0, \tag{2.16}$$

where $\Phi'_{t+k}(.)$ is the marginal cost. When there are no frictions; that is $\phi = 0$, the first-order condition becomes $P^{*}_{H,\ t}(i) = \frac{\theta_t}{\theta_t - 1} \Phi'_{t+k}(Y_{t+k}(i))$, which gives $\frac{\theta_t}{\theta_t - 1} = \nu_t$ an interpretation of desired markup levels.

The cost minimization of the intermediate goods producers yields an identical marginal cost for all firms defined by

$$\Phi'_{t+k}(Y_{t+k}(i)) = \frac{W_{t+k}}{A_{t+k}}. \tag{2.17}$$

Let $MC_{t+k} = \frac{\Phi'_{t+k}(Y_{t+k}(i))}{P_{H,\ t+k}}$ be the real marginal cost in terms of domestic prices. Under the assumption that when firms reoptimize they choose the same price, that is $P^{*}_{H,\ t}(i) = P^{*}_{H,\ t}$, I can rewrite the firm's first-order condition (2.16) as

$$\sum_{k=0}^{\infty} \phi^k E_t \left[Q_{t,\ t+k} Y_{t+k} P_{H,\ t+k} \left(\frac{P^{*}_{H,\ t}}{P_{H,\ t+k}} \right)^{-\theta_t} \left(\frac{P^{*}_{H,\ t}}{P_{H,\ t+k}} - \nu_t MC_{t+k} \right) \right] = 0. \tag{2.18}$$

Let x_t^1 be the discounted present value of the marginal revenue

$$P_t x_t^1 = \sum_{k=0}^{\infty} \phi^k E_t Q_{t,\ t+k} Y_{t+k} P_{H,\ t+k} \left(\frac{P^*_{H,\ t}}{P_{H,\ t+k}} \right)^{-\theta_t} \frac{P^*_{H,\ t}}{P_{H,\ t+k}}, \tag{2.19}$$

and x_t^2 be the discounted present value of the marginal cost

$$P_t x_t^2 = \sum_{k=0}^{\infty} \phi^k E_t Q_{t,\ t+k} Y_{t+k} P_{H,\ t+k} \left(\frac{P^*_{H,\ t}}{P_{H,\ t+k}} \right)^{-\theta_t} \nu_t MC_{t+k}, \tag{2.20}$$

Let $\tilde{P}_{H,\ t} = P^*_{H,\ t}/P_{H,\ t}$ and $\Pi_{H,\ t+1} = P_{H,\ t+1}/P_{H,\ t}$. I can rewrite equations (2.19) and (2.20) recursively as

$$x_t^1 = Y_t(\tilde{P}_{H,\ t})^{1-\theta_t} + \phi E_t Q_{t,\ t+1} \left(\frac{\tilde{P}_{H,\ t}}{\tilde{P}_{H,\ t+1}} \right)^{1-\theta_t} \Pi_{H,\ t+1}^{\theta_t} x_{t+1}^1 \tag{2.21}$$

$$x_t^2 = Y_t(\tilde{P}_{H,\ t})^{-\theta_t} MC_t \nu_t + \phi E_t Q_{t,\ t+1} \left(\frac{\tilde{P}_{H,\ t}}{\tilde{P}_{H,\ t+1}} \right)^{-\theta_t} \Pi_{H,\ t+1}^{\theta_t+1} x_{t+1}^2, \tag{2.22}$$

then restate (2.18) as $x_t^1 = x_t^2$.

Fiscal Policy

The government purchases some of the domestically produced good G_t, and every period balances its budget by lump-sum taxes

$$G_t = T_t. \tag{2.23}$$

Equilibrium

Market clearing the goods market requires

$$Y_t = C_{H,\ t} + G_t + X_t, \tag{2.24}$$

where X_t is the level of exports, that is the domestically produced goods acquired by the foreign consumers.

Labor market clearing implies

$$L_t = \int_0^1 L_t(i)di. \tag{2.25}$$

The money market clearing implies

$$M_t = M_t^s. \tag{2.26}$$

The equilibrium bond holdings in the economy is zero, that is $D_t = 0$.

Aggregation

Given that in each period $1 - \phi$ proportion of the firms change their price and set it equal to $P^*_{H,\ t}$ and ϕ proportion of the firms do not reset their prices and keep it at $P_{H,\ t-1}$, the aggregate inflation will be

$$\Pi_{H,\ t} = \left[\frac{1}{\phi} - \frac{1-\phi}{\phi}(\tilde{P}_{H,\ t})^{1-\theta_t}\right]^{\theta_t - 1}. \tag{2.27}$$

If I let

$$k_t = \int_0^1 \left(\frac{P_{H,\ t}(i)}{P_{H,\ t}}\right)^{\theta_t} di, \tag{2.28}$$

then I can show the following to hold

$$k_t = (1-\alpha)(\tilde{P}_{H,\ t})^{-\eta} - \alpha\Pi^{\eta}_{H,\ t}k_{t-1}. \tag{2.29}$$

By combining equations (2.12), (2.13), and (2.25) and integrating, I get

$$A_t L_t = Y_t k_t. \tag{2.30}$$

Stochastic Processes

The labor productivity in each country follows a random walk defined by

$$A_t = A_{t-1}e^{\epsilon_{at}}, \tag{2.31}$$

where ϵ_{at} is a serially uncorrelated idiosyncratic country-specific productivity shock that has a normal distribution, $\epsilon_{at} \sim N(\mathbf{0}, \sigma_a)$. In addition, $A_t > 1$ for all t.

As revealed by equation (2.15), $-\theta_t$ measures the time-varying elasticity of the demand for the intermediate goods. As shown in Ireland (2007), the shocks to θ_t translate into markup shocks for the intermediate goods producers and have the interpretation of cost push shocks in equilibrium. I assume the time-varying elasticity follows a stationary stochastic process

$$\theta_t = (\theta_{t-1})^{\rho_\theta} e^{\epsilon_{\theta t}}, \tag{2.32}$$

where $\epsilon_{\theta t} \sim N(\mathbf{0}, \sigma_\theta)$ and $\theta_t > 1$ for all t.

In each economy, the government purchases follow a stationary stochastic process

$$G_t = (G_{t-1})^{\rho_g} e^{\epsilon_{gt}}, \tag{2.33}$$

where ϵ_{gt} is a serially uncorrelated country-specific shock to government purchases that follows a normal distribution, $\epsilon_{gt} \sim N(\mathbf{0}, \sigma_g)$.

2.4.2 Modeling the Union-wide Dynamics

I consider a monetary union that consists of two countries with an isomorphic structures, as specified above. The variables pertaining to each country are marked with an appropriate superscript. The union itself is closed to the rest of the world. Labor is immobile across countries. The international risk sharing condition holds. The monetary policy authority aims at the stabilization of the aggregate (union-wide) economy, as opposed to stabilizing the economies of the member countries directly.

International Risk Sharing

I assume that the representative households in each country start with identical initial conditions. By construction, it is true that $P^{(1)}_{F,t} = P^{(2)}_{H,t}$ and $P^{(1)}_{F,t} = P^{(2)}_{H,t}$. There is a complete securities market that implies the same pricing kernel for each country. Accordingly, I can derive the international risk-sharing condition as

$$C_t^{(1)} = C_t^{(2)} h(S_t)^{\frac{1}{\sigma(1-\eta)}}, \tag{2.34}$$

where S_t is the terms of trade, $S_t = \frac{P_{F,\ t}}{P_{H,\ t}}$ and $h(S) = ((1-\alpha)S_t^{1-\eta} + \alpha)/((1-\alpha) + \alpha S_t^{1-\eta})$.

In accord with the definition of the terms of trade, I can rewrite (2.6) as follows

$$\frac{P_t}{P_{H,\ t}} = ((1-\alpha) + \alpha S_t^{1-\eta})^{\frac{1}{1-\eta}}. \tag{2.35}$$

Market Clearing in the Union

In order for the union to be at an equilibrium, the following relations need to hold

$$X^{(1)} = C_{F,\ t}^{(2)} \qquad X^{(2)} = C_{F,\ t}^{(1)}. \tag{2.36}$$

Aggregate Inflation, Output, and Money Supply

The union-wide inflation and output dynamics are aggregated from the country-specific inflation and output dynamics using exogenously defined weights w and $1-w$

$$Y_t^u = Y_t^{(1)\ w} Y_t^{(2)\ (1-w)} \tag{2.37}$$

$$\Pi_t^u = \Pi_t^{(1)\ w} \Pi_t^{(2)\ (1-w)}. \tag{2.38}$$

Money supply in the union adjusts to accommodate the money demand for each individual country. Consistent with the money market clearing condition listed before (equation [2.26]), the money supply for the union will be

$$M_t^u = M_t^{(1)} + M_t^{(2)}. \tag{2.39}$$

Monetary Policy

The monetary policy authority stabilizes the aggregate output and inflation by the following feedback rule

$$R_t = (\Pi_t^u)^{\phi_\pi} (Y_t^u)^{\phi_y} e^{\epsilon_{rt}^u}, \tag{2.40}$$

where ϵ_{rt}^u is the monetary policy disturbance coming from a normal distribution, $\epsilon_{rt}^u \sim N(\mathbf{0}, \sigma_r^u)$.

2.4.3 Equilibrium Dynamics

Member Country Dynamics

With the setup described in section 2.4.1, the equilibrium dynamics of a country that is a member of a currency union can be described by 21 equations that determine the following endogenous variables

$$\{C_t, C_{H,\ t}, C_{F,\ t}, \Pi_t, \Pi_{H,\ t}, S_t, k_t, L_t, Y_t, X_t, M_t, T_t, D_t, \Gamma_t, x_t^1, x_t^2, MC_t, W_t, A_t, \theta_t, G_t\},$$

where all variables are as defined previously, and $\Pi_t = P_t/P_{t-1}$.

I impose a symmetric, non stochastic (perfect foresight) steady state for the member economies, where the preferences for the countries are identical. The steady state is described in section A.1 of the Appendix.

In order to solve and analyze the dynamic stochastic model described above, I use a first-order Taylor approximation to approximate the nonlinear equations describing the equilibrium dynamics of the member economy with log-linear ones. The derivation of the relevant equations, that is equations determining the state variables of the model, are provided in section A.2 of the Appendix.

The following six equations describe the dynamics of a member economy

$$y_t = E_t y_{t+1} - \frac{(1-g_y)}{\sigma}(r_t - E_t \pi_{t+1}) + g_y(g_t - E_t g_{t+1}) + \alpha(1-g_y)\kappa(s_t - E_t s_{t+1}) \quad (2.41)$$

$$s_t = \frac{y_t - g_y g_t - (y_t^* - g_y g_t^*)}{(1-g_y)\sigma_\alpha} \quad (2.42)$$

$$\pi_{H,\ t} = \beta E_t \pi_{H,\ t+1} + \lambda_1 mc_t + \lambda_2 \hat{\theta}_t \quad (2.43)$$

$$mc_t = \frac{\sigma + \varphi(1-g_y)}{1-g_y} y_t - \frac{\sigma}{1-g_y} g_y g_t - \alpha(\sigma\kappa - 1)s_t - (1+\varphi)a_t \quad (2.44)$$

$$\pi_t = \pi_{t,\ H} + \alpha s_t \quad (2.45)$$

$$m_t = \frac{\sigma}{\nu}\frac{(y_t - g_y g_t)}{(1-g_y)} - \frac{\sigma\psi}{\nu} s_t - \eta r_t. \quad (2.46)$$

Equations (2.41) and (2.42) describe the "open-economy" IS curve, equations (2.43) and (2.44) describe the Phillips curve. Equation (2.45) defines the consumer price index, while equation (2.46) describes the dynamics of the real money balances in the economy. The variables with asterisks (*) pertain to the foreign country, which in this case, by construction, is the second country in the union.

The stochastic disturbances (in a log-linear form) are

$$a_t = a_{t-1} + \epsilon_{at} \quad (2.47)$$

$$\hat{\theta}_t = \rho_\theta \hat{\theta}_{t-1} + \epsilon_{\theta t} \quad (2.48)$$

$$g_t = \rho_g g_{t-1} + \epsilon_{gt}. \quad (2.49)$$

Union

The log-linear dynamics of the output, inflation, interest rate, and real money balances in the union evolves according to the following

$$y_t^u = w y_t^{(1)} + (1-w) y_t^{(2)} \quad (2.50)$$

$$\pi_t^u = w \pi_t^{(1)} + (1-w) y_t^{(2)} \quad (2.51)$$

$$r_t = \phi_1 y_t^u + \phi_2 \pi_t^u + e_{rt}^u \quad (2.52)$$

$$m_t^u = 0.5 m_t^{(1)} + 0.5 m_t^{(2)} + (w - 0.5)s_t. \quad (2.53)$$

2.4.4 DSGE versus VAR

VAR Representation

Under a maintained hypothesis that the dynamic stochastic general equilibrium model is correctly parameterized, the linear approximation to the equilibrium dynamics of the model can be described with recursive laws of motion, where the endogenous and endogenous state variables are expressed in terms of the predetermined variables and exogenous stochastic processes. Appendix A.4 describes the solution in terms of the recursive equilibrium laws of motion pertaining to our currency area model.[7]

Let $Z_t = [x_t \; z_t]'$, where $x_t = [y_t^{(1)} \; \pi_t^{(1)} \; y_t^{(2)} \; \pi_t^{(2)}]'$ is the vector of endogenous state variables, and $z_t = [m_t^{(1)} \; m_t^{(2)} \; y_t^u \; \pi_t^u \; m_t^u \; r_t]'$ is the vector of endogenous variables. I can rewrite the recursive equilibrium laws of motion obtained in the appendix in the following state-space form

$$Z_t = AZ_{t-1} + Bv_t \tag{2.54}$$

$$v_t = Nv_{t-1} + \epsilon_t, \tag{2.55}$$

where $A = [0]$ and $B = [Q \; S]'$.

Equation (2.56) describes the dynamic motion of the observables in terms of the seven latent variables evolving by equation (2.57). Our system is singular in the form provided because the union is a weighted average of the member countries. I drop the variables pertaining to one of the countries and proceed with a system describing the dynamics of a member country and the union. In other words, I modify the system to be

$$\tilde{Z}_t = \tilde{A}\tilde{Z}_{t-1} + \tilde{B}v_t \tag{2.56}$$

$$v_t = Nv_{t-1} + \epsilon_t, \tag{2.57}$$

[7] By assumption the requirements of the saddle path hold.

where $\tilde{Z}_t = [\tilde{x}_t \ \tilde{z}_t]'$. Omitting the country-specific superscripts, I can rewrite the observable variables as $\tilde{x}_t = [y_t \ \pi_t]'$ and $\tilde{z}_t = [m_t \ y_t^u \ \pi_t^u \ m_t^u \ r_t]'$. Consequently, $\tilde{A}$ and $\tilde{B}$ would be the appropriate partitions of the original matrices A and B that correspond to the set of observables considered in the new system.[8] Since B^{-1} exists and the number of shocks are equal to the number of observables, the VAR representation exists and is equivalent to $\tilde{Z}_t = (BNB^{-1})\tilde{Z}_{t-1} + B\epsilon_t = \Gamma\tilde{Z}_{t-1} + u_t$. In the last equation, $u_t = B\epsilon_t$ is a rotation of the structural shocks ϵ_t.

Identification

The fact that the DSGE model has a VAR representation essentially implies that the reduced form shocks u_t span the space of structural shocks. However, invertibility of the VAR does not imply identification. In the process of the estimation, inference about B is made through the variance-covariance matrix Σ of the reduced form errors u_t. The latter gives $k(k+1)/2$ (in our case $k = 7$) equations to estimate k^2 parameters. Thus, further restrictions need to be imposed on the matrix B in order to achieve identification.

The literature has approached identification through various routes. Christiano et al. (1999) establish the empirical benchmark for the monetary policy propagation through short-run restrictions. Starting from the seminal work of Blanchard and Quah (1989), there has been an extensive use of the long-run restriction in the VAR literature. Sign restrictions are intended to choose identification consistent with the patterns of the theoretical models as discussed in Uhlig (2005). However, there seems to be no consensus in the appropriate identification of structural disturbances from reduced-form residuals.

Since the main objective of this paper is to analyze the effects of monetary policy, I follow the more traditional choice of the monetary literature and impose short-run restrictions on the VAR motivated by the theoretical model highlighted before. A careful observation of equations (2.41)–(2.46) and (2.50)–(2.51) shows that the innovations to the interest rate are orthogonal

[8] In fact, since A is a matrix of zeros, dropping some of the endogenous state variables does not cause a problem because the necessary and sufficient condition for existence of a finite order VAR representation stated in the corollary 2.2 of Ravenna (2007) is satisfied.

to the rest of the system. In addition, while domestic and foreign demand-side disturbances (g_t and g_t^* respectively) have a contemporaneous impact throughout the whole dynamic system, the impact of the cost push shocks ($\hat{\theta}_t$) is apparent in the dynamics of the inflation measures only. In addition, interest rates only respond to the union-wide variables contemporaneously.[9] I keep this identification scheme in mind when I proceed with the empirical exercise.

2.5 An Empirical Model of a Currency Union

The empirical model of the currency union is postulated in terms of a structural VAR of the following form

$$z_t' A = C' + \sum_{l=1}^{p} z_{t-l}' A_l + \epsilon_t', \quad \forall t = 1, ..., T, \tag{2.58}$$

where A and A_l are $n \times n$ parameter matrices, C is an $n \times 1$ vector of constant parameters, z_t is an $n \times 1$ vector of endogenous variables at t, and ϵ_t is an $n \times 1$ vector of structural shocks at t. T is the sample size, while p denotes the lag length of the endogenous variables in the VAR selected through BIC.[10] The structural errors are independently and identically distributed normal variables with 0 mean and unit variance, $\epsilon_t \sim N(0_{n\times 1}, I_{n\times n})$. A is assumed to be non-singular. The term structural in this context is used to indicate the theoretical restrictions imposed on the contemporaneous and lagged coefficients (A and A_l, respectively), and, as such, the restrictions are motivated by the theoretical model considered previously.

As implied by the theory, the empirical model consists of country-specific and union-wide variables. However, the structural VAR is augmented with worldwide variables to capture the open economy aspects of the currency union and commodity prices to accommodate the forward-looking nature of the policy maker. More specifically, the general structure of the

[9] I interpret the timing restrictions implied by the model loosely. In essence the system is simultaneous at time t, thus all the shocks exhibit their effect in the dynamics of the system contemporaneously. In addition, I concentrate on the cost push shocks because technology shocks have a permanent effect on the system described above, which can not be captured with short-run restrictions.

[10] I conduct the BIC lag length selection by allowing a maximum of six lags in order to have reasonable degrees of freedom. In all instances the lag length chosen is equal to one.

dynamic process expressed in (2.58) is restricted to the following

$$A' = \begin{bmatrix} D_{11} & 0 & 0 & 0 & 0 & 0 \\ A_{21} & A_{22} & 0 & 0 & 0 & 0 \\ A_{31} & A_{32} & A_{33} & 0 & 0 & 0 \\ A_{41} & 0 & A_{43} & A_{44} & 0 & 0 \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{45} & 0 \\ A_{61} & A_{62} & A_{63} & A_{64} & A_{65} & A_{66} \end{bmatrix}, \quad y_t = \begin{bmatrix} w_t \\ cs_t \\ us_t \\ up_t \\ cf_t \\ uf_t \end{bmatrix}.$$

Here, the variables are divided into world variables w_t, country-specific, slow moving variables cs_t, union-specific, slow-moving variables us_t, policy instrument of the union up_t, country-specific fast moving variables cf_t, and union-specific, fast-moving variables uf_t. Moreover, D_{11} is a diagonal matrix, which together with the zero restrictions yields the vector of the world variables to be exogenous to the union and its member contemporaneously.

I consider $w_t = \{\Delta pcom_t,\ ipi_t^w,\ r_t^w\}$, where $pcom_t$ is a world commodity price index. I use seasonally adjusted U.S. industrial production index for the world output expressed by ipi_t^w. The effective federal funds rate r_t^w proxies the world interest rate. The country-specific output (measured with a seasonally adjusted IPI) and inflation (measured with a first difference in a seasonally adjusted harmonized index of consumer prices [HICP]) are treated as country-specific, slow-moving variables, $cs_t = \{ipi_t,\ \Delta cpi_t\}$. The union-specific, slow-moving variables are measured in seasonally adjusted Euro Area wide IPI and HICP, $us_t = \{ipi_t^{ea},\ \Delta cpi_t^{ea}\}$. The policy instrument is r_t^{ea} – interest rate on the main refinancing operations. In the benchmark specification, I set $cf_t = m1 - cpi$ and $uf_t = m1^{ea} - cpi^{ea}$, that is the seasonally adjusted M1 values (adjusted for prices) for the country and the union, though I consider an alternative set of fast moving variables in the robustness section. All the variables, except the interest rates are in logarithms.

The zero restrictions in the contemporaneous matrix A are consistent with our division of the variables into various categories. In addition, in accord with the theoretical model, I impose a lower triangular structure on A_{22}. The resulting system is overidentified. Among the identified shocks, the ones that are of particular interest are the monetary policy and the country-specific demand and cost-push shocks. In addition, I restrict the lag coefficients such that the behavior of the interest rates is determined by the world or union variables, and the country-specific variables have no effect. This restriction is consistent with the theory and can yield an identical policy response for various iterations of the estimation.

Since the main objective of this paper is analyzing the differences in the performance of the Euro Area countries, a benchmark should be defined. In order to compare the country performance to the overall union performance, I run a VAR for the whole union and take the appropriate metrics of this VAR as a benchmark for comparison. The VAR that considers the dynamics of only the union is similar to the one specified above. The variables included in the union VAR are $y_t = [w_t \; us_t \; up_t \; uf_t]'$. The restrictions on the contemporaneous and lagged coefficients continue to hold.

The data cover the 11 original members of the Euro Area, that is Austria, Belgium, Germany, Spain, Finland, France, Ireland, Italy, Luxembourg, Netherlands, and Portugal. The data are in monthly frequencies, and the final sample includes the period 1999:1–2008:12. All variables, except the commodity price index, are taken from Eurostat. Money supply data specific to each country for the period considered are not readily available and are constructed from the central banks' balance sheet activities. Due to comparable data limitations, I use the value of total deposit liabilities of monetary financial institutions (MFIs) as a measure of money supply. In addition, the data for HICP and total deposit liabilities provided by Eurostat are not seasonally adjusted. I seasonally adjust the series by X-11 filtering. Commodity prices are the average valuation of the commodity dollar index in euros obtained from Global Financial Data.

2.6 Estimation Methodology

Since our empirical model captures the dynamics of an individual member country with the union, I need to conduct the exercise separately for each country. I employ Bayesian methodology, where I estimate the system provided in (2.58) by imposing a prior on the VAR coefficients, combine it with a likelihood function to get the posterior distribution, and draw from that posterior. Taking a Bayesian approach in this context has two contributions. The imposition of the prior reduces the mean squared forecast error (MSFE) of the model by decreasing the bias and increasing the efficiency of estimated coefficients.

It is well known that in the presence of unit roots classical methods underestimate the parameters and bias models toward stationarity in small samples. In general, this is true for inferences based on conditional (on initial observations) likelihood where the weight on initial observations, which can be far from model's steady state, is fairly high.[11] One way the literature has approached resolving this issue is by augmenting the econometric models with pseudo observations (usually referred to as "dummy" observations) that incorporate the beliefs about the steady state of the model and put low probability on the initial observations that are further from the model's steady state. This is in general implemented in the spirit of the Theil mixed estimation, which is discussed in more detail in Sims and Zha (1998).

In addition, in a high dimensional space, the prior imposes extra structure on the empirical model, which results in efficiency gains for the estimated coefficients. In other words, the prior shrinks the parameter space such that overfitting is minimized, while the information contained in the sample is preserved. As a result, the MSFE is improved, and models perform better in out-of-sample forecasting exercises. This improved forecasting performance has long been shown by Doan et al. (1984) and Litterman (1986). Further, Banbura et al. (2008) demonstrate that under an adequate rate of shrinkage the improved predictability still holds even when the systems are very large.

I will estimate a structural Bayesian VAR based on an algorithm provided by Waggoner and Zha (2003). The algorithm enables us to estimate a structural VAR directly. This is in contrast to the two-step procedure commonly used in the literature, where in the first stage a reduced form is estimated and then the structural component is uncovered from the reduced form variance-covariance matrix by a second-stage maximum likelihood procedure. The second stage is most frequently performed by a Choleski decomposition and achieves an exact identification of the VAR. Sims and Zha (1998) show that the second-stage procedure

[11] See Sims (2000) and the references therein for a more thorough discussion.

does not uncover the proper distributional properties of the structural relationships unless the system is just identified. In addition, this algorithm enables us to obtain a measure of uncertainty in a more natural way.

2.6.1 Prior

I can rewrite the system in (2.58) as

$$y_t' A = x_t' F + \epsilon_t', \tag{2.59}$$

where the columns of the matrices A and F denoted by a_i and f_i pertain to a separate structural equation in the system and $i = 1, ..., n$.

I impose a prior of the following form

$$a_i \sim N(0, \bar{S}_i) \quad \text{and} \quad f_i | a_i \sim N(\bar{P}_i a_i, \bar{H}_i). \tag{2.60}$$

The structural equations are assumed to be independent. Similar to Waggoner and Zha (2003), I center the multivariate normal random vectors a_i around zero and specify the standard deviation as $\bar{S}_{i_{jj}} = \lambda_0 / \sigma_j$.

The prior that guides the overall dynamics of the system is a Sims and Zha (1998) random walk prior. Essentially, the prior is parameterized such that the conditional mean of the first lag coefficient is equal to a_i and the rest to zero. The standard deviation of each coefficient on lag p in equation i for variable j is determined by $\bar{H}_{i_{jj}} = \frac{\lambda_0 \lambda_1}{\sigma_j p^{\lambda_3}}$, for $j = 1, ..., k-1$. The prior standard deviation for the constant is $\bar{H}_{i_{jj}} = \lambda_0 \lambda_4$, for $j = k$. σ_j is included in order to account for different units of measurement of the variables. The hyperparemeter values and their description is provided in Table B.2.

In addition, I impose what has come to be known in the literature as inexact priors. These priors are usually introduced in terms of initial "dummy" observations in the data matrix.[12]

[12] In essence, the initial dummy observations ensure that the likelihood function used in forming the posterior is an unconditional likelihood as opposed to a likelihood conditioned on the initial observations. This is particularly important because it is well documented that for time-series data the unconditional likelihood puts a lot of weight

The types of the data observations introduced and the weight put on these observations impose different beliefs about the behavior of the system in general. The particular type of the inexact priors I consider are the unit-root and cointegration priors. The details on these priors are provided in Appendix A.4, and the values of the hyperparameters are in Table 1.

A few words about the prior are needed here. The random walk prior is essentially a hierarchical prior, which constrains the coefficients to be drawn from the same distribution. The hyperparemeters are selected in line with the common values used in the literature, for example, as discussed in Robertson and Tallman (1999). However, while conducting inferences in small samples, the role of the prior is not trivial.

The benchmark estimation is conducted based on a prior that is parameterized the same across the countries. This choice is motivated by the fact that all the countries in the Euro Area should satisfy the Maastricht criteria of economic convergence, which implies that the key nominal economic variables for the countries were within a narrow range at the start of the union. However, it is indeed possible that certain countries had to undergo more changes in order to meet the convergence criteria, and the inertia of the reforms would display themselves after the adoption of the euro. Thus, it is essential to test the degree to which the imposed symmetry across the countries through the prior drive our empirical results. I attempt this in the robustness section.

2.6.2 Sampler

I postulate the theoretical restrictions considered previously in a form of linear restrictions on matrices A and F. Consistent with the restrictions, I get orthonormal rotation matrices U_i and V_i such that $a_i = U_i b_i$ and $f_i = V_i g_i$. In essence, the rotation matrices squeeze the parameter space by reducing its dimensionality in accord with the linear restrictions imposed. Combining

on the initial observations, which results in a stationarity bias when the considered sample size is small. For example, if one writes the regular OLS estimation procedure in terms of recursive least squares (RLS), it would be clear that in order to achieve the OLS results one needs to put less and less weight on the new observations as time progresses. The gain from observing an additional data point becomes negligible eventually, which in econometric terms means that I have asymptotic results. Thus, if the sample is small, the weight on the initial observations are relatively large, and they become potent to drive the results and would particularly bias the results towards stability.

the prior in (2.60) with the likelihood, I get marginal posterior pdfs for b_i and g_i defined by

$$p(b_1, ..., b_m|X, Y) \propto |det[U_1 b_1|...|U_m b_m]|^T exp\left(-\frac{T}{2}\sum_{i=1}^{n} b_i' S_i^{-1} b_i\right) \quad (2.61)$$

$$p(g_i|b_i, X, Y) = \varphi(P_i b_i, H_i), \quad (2.62)$$

where H_i, P_i, and S_i are transformations of the prior mean and variance matrices $\bar{H}_i$, $\bar{P}_i$, and $\bar{S}_i$.

The distribution of the contemporaneous elements is nonstandard. I use the Gibbs sampler to simulate from that distribution. The details of the sampler are discussed in Geweke (1999) and Robert and Casella (1999) among others. The results presented further are based on 10,000 accumulated draws. The initial 5,000 draws are discarded to eliminate the effects of the algorithm initialization. The implied conditional posterior distribution of the lagged coefficients f_i is normal, making it straightforward to draw from its posterior after the contemporaneous matrix is uncovered.

2.7 The Effects of Monetary Policy - Results

I approach analyzing the effects of the common monetary policy from two angles. First I analyze the potency of monetary policy interventions in creating differences in the output and inflation across the Euro Area countries. Second, I evaluate the degree to which the systematic part of the common monetary policy can explain the differences.

Figures C.4 and C.5 look at the impulse response functions of output and inflation for each country upon one standard deviation (15 basis points) contractionary common monetary shock. The figures show the modal (based on the mode of the parameter distributions) impulse responses of output and inflation of each country in the sample and contrast it with the aggregate output and inflation responses of the Euro Area. The differences in the level of the output across member countries are considerably large with a maximum difference of 1.17 percentage points. However, the recovery after a contractionary monetary policy shock occurs about the same time with the range for the start of the recovery times being about six months. For the majority of the countries, the recovery of output is lagging the recovery of the aggregate output. The range of the inflation differentials across the countries reaches 0.04 percentage point at the maximum. There are considerable differences in the timing of the inflation dynamics reversals, which ranges a little above a year. Contrary to the output, inflation dynamics in the majority of the countries recovers earlier compared to the aggregate.

The outputs of Belgium, France, Ireland, and Portugal are less sensitive to the interest rate fluctuations than the aggregate. The response for Portugal is very flat, reaching a 0.2 percentage point contraction at the maximum. The remaining countries in the group contract within the neighborhood of 0.6 percentage points. For these countries, with the exception of Belgium, the trough of monetary induced recession lags that of the aggregate. The impulse response for Luxembourg is closely aligned with that of the Euro Area. The Austrian business cycle, though similar to the aggregate in magnitude and general path, appears to lag the aggregate at any given period.

In the face of a contractionary monetary shock, the outputs for Germany, Spain, Finland, Italy, and the Netherlands contract more than the aggregate Euro Area output does. The level of maximum contraction for this group varies between 1 to 1.8 percentage points. The responses for Spain and Italy overshoot that of the aggregate earlier, and the countries show a greater level of recovery at period 40. For the countries in this group, the timing of the maximum contraction is very close to the timing of the trough of the aggregate recession. Only Germany and the Netherlands start the recovery a couple of months before the aggregate.

With respect to cross-country differences in the behavior of inflation, the countries can be put into two distinct groups. In the first group of countries, inflation is the same or above the aggregate for all periods considered, while in the second group the relative rankings of country-specific and aggregate inflation rates change.[13] Austria, Spain, France, Ireland, and Portugal are members of the first group. The maximum level of inflation for the countries in this group reaches 0.0275 percentage points, and the turning points lag the aggregate recovery

[13] In the analysis above, inflation and deflation rates are used interchangeably, which is justified under the assumption of the symmetry of the business cycles. If the rate of the price change is decreasing upon a contractionary monetary shock, it is thought to increase under an expansionary one.

for about a year.

The second group includes Belgium, Germany, Finland, Italy, Luxembourg, and the Netherlands. For this group of countries, there is a reversal in the relative ranking of country-specific and aggregate inflation rates. Usually country-specific inflation is greater than the aggregate for about 12 to 19 months, thus showing mild evidence of a price puzzle. After that, the aggregate level of price change subsides, while the country-specific inflation continues increasing. The exception in the group is Luxembourg, which recovered much faster. In fact, Luxembourg is the only country where the inflation rate was below the aggregate at 40 months into a recession.

In order to reflect on uncertainty, I plot the density functions for country-specific output and inflation impulse responses. To conserve space, I concentrate on the 24-period ahead impulse response because it more or less corresponds to the timing of the maximum response for the variables of interest. The empirical distribution of country-specific impulse responses are contrasted with that of the aggregate. As Figure C.6 shows, there is far greater uncertainty around the country-specific output responses relative to the aggregate. Moreover, the mode value of the impulse response for countries such as the Netherlands and Portugal correspond to an aggregate value with a very low probability. The distributions of the output responses for Ireland and Luxembourg are very wide. The values of mode responses of Germany, Spain, and Finland are below the mode of the Euro Area. The values of mode responses of Belgium and France are above the mode of the Euro Area. The country with its mode closest to the aggregate is Italy. The case for inflation is different. As Figure C.7 shows, all countries except Spain, Ireland, Italy, and Luxembourg have distributions fairly well aligned with the aggregate.

To summarize, the impulse response functions show that the discretionary component of the monetary policy creates far greater differentials in the magnitudes of cross-country output responses compared to inflation responses. The differentials are also fairly persistent. For 82 percent of the countries, there is no reversal in the ranking of the output response relative to the aggregate in 40 months into a recession. The impulse response function distributions show that in certain cases the difference is also significant. The differentials in inflation responses are small and insignificant. However, the persistence in the relative rankings still exhibits itself.

Once a country is above the aggregate with its output response, the tendency continues for a relatively long time.

Researchers use forecast error variance decomposition to get to the driving forces of the business cycle. Throughout our empirical investigation, the shocks that I are able to identify are the local demand, cost push, and common monetary policy shocks. The contribution of each of these shocks to the total variability of country-specific output and inflation are provided in Table B.3. The variance decomposition exercise shows that monetary policy disturbances have a more predominant role in explaining the business cycle fluctuations in some countries more than in others. In addition, the driving sources of the output fluctuations across the countries are different depending on the countries and the forecast horizon. On the other hand, the inflation variations across the countries and over various horizons are mainly explained by cost push shocks.

The table shows that a greater proportion of the output variation across the countries is driven by the demand side (country-specific aggregate demand and common monetary) disturbances. This is particularly true for countries such as Belgium, Finland, Ireland, Netherlands, and Portugal, where the demand-side explains a larger share of the output variation at least from period 12 and further. The common monetary policy interventions explain a large share of the output variations for Austria, Spain, and Italy for all periods considered. For Germany, the share of the output variation explained by a monetary policy shock increases over time reaching about 70 percent upon a 24 month period. This is in contrast to countries such as Belgium, Ireland, Netherlands, and Portugal where the contribution of monetary policy shocks to the output fluctuation remains small (less than 10%) across all horizons. Nevertheless, the cost-push shocks are also relevant for some countries. They are important for Germany, France, Italy, and Luxembourg at least at a horizon of one year.

In contrast, the sources of inflation variations are more homogenous across the countries. Cost-push shocks explain about 90 percent of the variation across various horizons. The share of monetary shocks in the total variation, on the other hand, is very low. Upon impact, that is by period 3, the range for output variation explained by monetary policy shocks is about 0.46 percentage points, by period 12 it becomes 1.26 percentage points, and by period 24 it is at a level of 4.29 percentage points.

Next, I look at the systematic part of the union-wide monetary policy rule. In order to access how well an aggregate targeting monetary policy manages to stabilize the individual economies, I rely on the monetary literature that evaluates the welfare losses associated with various simple but yet "suboptimal" policy rules. Galí (2003), discusses the literature in a closed economy context, while Galí and Monacelli (2005) conduct such an exercise in an open economy setting. In essence, the evaluation of the various simple policy rules lands itself into simulating the system under various parameterizations for the shock processes and policy rules and then evaluating the welfare loss of the economy compared to a prespecified benchmark.

In our analysis, I think of the steady state of the economies, which are symmetric for the countries in the union as the benchmark. I then simulate the VAR system by drawing from the historical distributions of the country-specific demand and cost-push shocks. I then look at the variability of output and inflation across the countries because their weighted combination in general is associated with a welfare loss function.[14] The simulation results for a time period spanning 20 years are provided in Table B.4. The table lists the contributions of inflation and output variability to country-specific welfare losses. The total welfare loss is calculated by adding the output and inflation variability.[15]

The table shows that the contribution of inflation variability to welfare loss is small across the countries. The country with the highest simulated variation is Austria, while for Germany and France the inflation variation is zero. A considerable part of the variation in the total welfare loss comes from the variability of the output. Belgium follows France with the lowest simulated output variability, while Austria and Ireland record the highest. It appears that the aggregate targeting monetary policy is too "tight" for Austria and Ireland in that the stabilization policy around a symmetric steady state is accomplished with the highest welfare loss equivalent to 3.1137 and 1.1385 points variation. On the other hand, the simulated results show that the systematic component of monetary policy accomplishes the stabilization goal for

[14]See Galí (2008) for details.

[15]The simulation for periods shorter and longer provide qualitatively similar, but quantitatively different results.

countries such Belgium, Finland, France, Italy, and Portugal successfully. Thus, the systematic part of the monetary policy also generates heterogeneity across the union members. Although, it appears that the stabilization of inflation is conducted rather successfully, sometimes it comes at a cost of output variation.

Overall, monetary policy affects some countries more than others. When a contractionary monetary policy hits the economy, it generates differences in magnitude and duration of a recession across the countries. Monetary policy innovations appear to explain small portion of the inflation fluctuations across the countries over business cycle horizons, while they account for a fairly large portion of business cycle fluctuations for the output. The range of output variations attributed to the policy shocks varies across countries. In the face of idiosyncratic country-specific shocks, the systematic component of the monetary policy achieves stabilization for certain countries more successfully than for others. Overall, output variability dominates inflation variability. For some union members, the recession is more severe because monetary policy shocks are a vital part of the business cycle fluctuations. The systematic component is also more successful in obviating the inflation variability across the countries, at times at a cost of output variation. Thus, in general, the inflation and output dynamics highlighted in section 2.2 can be reconciled with the existence of a common monetary policy.

2.8 Robustness to the Prior

It is well known that prior matters in a small sample inference. The results presented above rely on a symmetric hierarchical prior, which imposes a similar structure on the economies at the start. This assumption is not a stretch since the countries need to meet a convergence criteria in order to qualify for entry into a monetary union. However, the concern is that some countries have undergone more changes in order to meet the convergence criteria compared to others. So, one might think that there is some inertia in the reforms that reveals itself even after entry into the union. Alternatively, it is also possible that the observed differences are mere continuations of the differences that occurred prior to the adoption of the euro and are not artifacts of a common monetary policy per se. In order to shed light on this issue, I conduct a robustness exercise for the prior.

I estimate a similar empirical specification using pre-euro data for a number of countries under a flat prior, and then I use the posterior distribution as a prior distribution for the post-euro inference. More specifically, I adhere to the estimation of the system provided in (2.59) with no identification restrictions. In addition, I impose no prior beliefs so that the estimation results are based solely on the likelihood function. In essence, I are conducting an empirical Bayesian exercise where the prior does not come from theoretical "beliefs" about the world. Rather, it summarizes the pattern of the data observable in the Euro Area member countries before the euro was put into circulation. I treat the posterior distributions of the VAR parameters as approximately normal and use sufficient statistics to parameterize multinomial normal priors for the contemporaneous and lagged coefficients.

Admittedly, there is a need to make a choice about the variables to be used since the definitions of the data series for a number of countries has changed after entering the Euro Area. The search of comparable data series pre-1999 narrows the set of countries down to five, namely Belgium, Spain, Finland, France, and Italy. Our sample of pre-Euro data is in a monthly frequency and starts in 1992 to accommodate for the potential changes introduced by the German unification. The data series are the same as listed below, with a few exceptions. I use a measure of a harmonized index of consumer prices excluding energy prices provided by the ECB.[16] Since historical measures of M2 are readily available for the member countries in Eurostat, I use them directly in our estimation. The target interest rate of the German central bank is used as a pre-Euro policy measure. The pre-1999 values of the union-wide prices, industrial production, and money supply (M2) are backcasted by the Eurostat, and I use them as such.

The results of the robustness exercise in terms of the effects of the discretionary monetary interventions are provided in Figures C.8 and C.9. In comparison, Figure C.8 is qualitatively similar to Figures C.4. The Euro Area output response is about the same with a mild change in the timing of the trough. The recovery starts about three months earlier. The responses

[16] The similar series in Eurostat goes back only to 1996.

of the country-specific outputs are less in magnitude when compared to the results under the hierarchical prior. For example, in the case of Belgium, the contraction is 0.1 percentage points less, while in the case of Italy it is about 0.3 percentage points less. In addition, the recovery at a country level also starts earlier compared to the previous discussion. Nevertheless, the relative rankings for the considered countries in terms of the output response and the timing of recovery do not change. The notable exception is Italy, for which the two parameterizations of the prior yield different results. When the prior is parameterized consistent with the empirical regularities of the pre-Euro area, Italy experiences a less severe monetary induced recession compared to the Euro Area.

The juxtaposition of Figures C.9 and C.5 show that the changes in the prior mainly result in a magnitude difference for the inflation response across the countries and the union. For all the countries besides Italy, the inflation response is at most about 0.05 percentage points less than that under the hierarchical prior. This pattern is true for the aggregate response as well. For Italy, inflation contracts twice as much compared to the rest of the considered countries upon a contractionary monetary policy shock. In the case of inflation, the relative rankings of the countries are robust to the change in the prior. In addition, the prior plays no role in the mitigation of the price puzzle.

Thus, I conclude that our results are overall robust to changes in the prior. If anything, the alternative specification of the prior decreases the differences across the Euro Area countries in output, having no effect on the differences in inflation.

2.9 Conclusion

This paper studies the degree to which the business cycle heterogeneity in a currency union can be explained by a common monetary policy. Though the main implications of the paper come from the empirical application, it adds to the literature by postulating an empirical specification consistent with a well-defined theory. The estimation results for the Euro Area show that monetary policy is relatively successful in stabilizing the country-specific measures of consumer price inflation at a symmetric level. However, both the systematic and discretionary components of monetary policy have the potency of creating asymmetric output responses. Which particular transmission channel or structural asymmetry is responsible for the observed variability in the adjustment mechanism of the output remains to be tested more directly. The theoretical model postulated in this paper assumes a symmetric benchmark; thus, it can not address the more explicit reasons for heterogeneity. These questions remain to be addressed with future research.

Chapter 3

Taylor Rule and the Stance of the Monetary Policy

3.1 Introduction

The primary objective of the European Central Bank (ECB) is price stability. Based on its mandate the central bank can pursue the objectives of the European Union (EU) stated as "economic and social progress and a high level of employment and to achieve balanced and sustainable development." Nevertheless, if a conflicting situation is to arise, ECB is committed to give priority to price stability.[1]

Price stability is measured in terms of "a year-on-year increase in the Harmonized Index of Consumer Prices (HICP) for the Euro Area below 2%." It is worth noting that the 2% inflation target is a medium-term target and as such it implies a forward looking policymaking. In addition, the HICP for the Euro Area is calculated as a weighted average of the country-specific HICP-s proportional to their economic size. More specifically, the weights are calculated as shares of country-specific household consumption expenditures in the total for the Euro Area (EA) and are updated annually.

The goal of price stability is achieved based on "two-pilar" strategy, which states that the ECB uses the monitoring of economic data, as well as monetary aggregates simultaneously

[1] Detailed discussion of the European Central Bank, its mandate and policy objectives is provided in The European Central Bank (2009).

as a cross-check for policymaking. In a way, given the setting one could think about the ECB maintaining a longer-term money supply growth target as it responds to the economic fundamentals.

The theoretical literature, on the contrary, suggests a different weighting for the aggregate inflation than it is practically implemented in the EA. Benigno (2004) considers a currency area model where the member economies exhibit various degrees of price rigidities. Given the environment, the optimal monetary policy should weight the country-specific inflations proportional to the degree of nominal rigidity observed in each individual economy. In this specific setup, weighting according to the economic size is optimal only when the degree of nominal rigidities are equal. In a similar exercise, when fiscal policy is introduced to the mix, Galí and Monacelli (2008) show that it is optimal for the monetary authority to stabilize the aggregate inflation, and for the fiscal authority to stabilize the asymmetries associated with the heterogeneity observed in the nominal rigidities across the countries.

The purpose of this paper is to evaluate a simple monetary policy rule for the EA in an effort to conjecture about the weighting matrix associated with the country-specific variables in the monetary policy rule ex-post. The rules considered are from a family of Taylor rules in accord to Taylor (1993). The objectives of the paper are two. First, it gives new evidence about the stance of the monetary policy in the EA relying on the post-Euro data. As such, it contributes to the vast literature on the evaluation of monetary policy rules in practice as in Clarida et al. (1998) and Orphanides (2002). Second, by contrasting a disaggregated monetary policy rule to an aggregate one, I can conjecture about the implicit weights used in the policymaking and contrast it with the findings of the theoretical literature.

The remainder of the paper proceeds as follows. Section 3.2 describes the Taylor rule models considered. Section 3.3 introduces the methodology used. Section 3.4 discusses the data and 3.5 considers the results. Section 3.6 demonstrates a robustness study, while section 3.7 concludes.

3.2 Taylor Rule Specifications

As suggested previously, I consider two types of Taylor rule. The first one is stated as a monetary reaction function that stabilizes the aggregate economy, where the economic fundamentals monetary policy reacts to are weighted averages of country-specific fundamentals. Second, I consider a disaggregated monetary reaction function, where I postulate a monetary policy rule that explicitly targets the country-specific deviations in addition to the aggregates, thus uncovering the weighting implicitly used in policymaking.

3.2.1 Aggregate Taylor Rules

I follow Clarida et al. (1998) in postulating the aggregate monetary reaction function in the following form

$$r_t^* = \bar{r} + \beta(E[\pi_{t+n}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t] - y_t^*), \tag{3.1}$$

where r_t^*, π^*, and y_t^* are the nominal interest rate, inflation, and output gap targets. $\bar{r}$ indicates the long-run equilibrium interest rate, which I elaborate on further, while the central bank reacts to its expectations about n-period ahead inflation and contemporaneous output gap formed based on the information available at time t, Ω_t. In general, to guarantee unique equilibrium one needs to impose the assumption that $\beta > 1$ and $\gamma > 0$.[2]

The Taylor rule of (3.1) is a more general version of the one originally proposed by Taylor (1993). In the original specification of the Taylor rule, the policy authority sets the interest rates in response to the lagged and contemporaneous values of inflation and output respectively as opposed to their expectations. More specifically, it reacts to one percentage point increase in inflation deviations from its target by increasing the nominal interest rate by 1.5 percentage points, while increasing the nominal interest rate by 0.5 percentage points to one percentage point increase in the output deviation. The specification considered in this paper nests the original Taylor rule with unrestricted parameters.

[2]This restriction ensures that the central bank conducts monetary policy based on Taylor Principle, which eliminates the sunspot equilibria in which self-fulfilling expectations drive the explosive dynamics of inflation and output. The relevance of the sunspot equilibria in historic analysis of the monetary policy for the U.S. is provided in Clarida et al. (2000).

In general Taylor rules are important under the assumption that money has real effects, which is in essence possible if the economy can be characterized by nominal rigidities either in product or labor markets or in both. In this case, it is optimal for the monetary policy to make the rigidities non-binding by its interest rate instrument. Suppose, the nominal rigidities are in the product market. By setting the interest rates around a zero inflation target the central bank would make the nominal rigidities irrelevant: when there is no inflation it would not matter for the overall dynamics of the economy that prices are slow to adjust. Consequently, it is optimal for the policy authority to stabilize the economy at the flexible price equilibrium output level and not at any other level. I will denote that point by y_t^*. The interest rate that would prevail at the bliss point for inflation, $\pi_t^* = 0$, and output, y_t^*, would be referred to as long-run interest rate or natural interest rate and is denoted by $\bar{r}$.

It is observed that the central banks move the interest rates in a smooth fashion. Some reasons indicated in the literature as an explanation for this behavior are the unwillingness of the policy authority to disrupt the capital markets or lose credibility from the policy jumps as discussed in Clarida et al. (1998). To account for this dynamics, I follow the literature in assuming that the actual nominal interest rate adjusts to the target in the following way

$$r_t = (1-\rho)r_t^* + \rho r_{t-1} + \nu_t, \tag{3.2}$$

where $\rho \in (0,1)$ and ν_t are i.i.d. policy shocks.

Equations (3.1) and (3.2) give us the first interest rate rule that I consider in the empirical application. Let $x_t = y_t - y_t^*$ and $\alpha = \bar{r} - \beta\pi_t^*$. I will refer to x_t as output gap in the remainder of the paper. By substitution and reparameterization I obtain

$$\begin{aligned} r_t &= (1-\rho)(\bar{r} + \beta(E[\pi_{t+n}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t] - y_t^*)) + \rho r_{t-1} + \nu_t, \\ &= (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)\beta\pi_{t+n} + (1-\rho)\gamma x_t + \epsilon_t, \end{aligned} \tag{3.3}$$

where ϵ_t is a linear combination of inflation and output gap forecast errors and structural disturbances ν_t.

$$\epsilon_t = -(1-\rho)(\beta(\pi_{t+n} - E[\pi_{t+n}|\Omega_t]) + \gamma(x_t - E[x_t|\Omega_t])) + \nu_t$$

To accommodate for the “two-pilar” approach to monetary policy in addition to the benchmark Taylor rule specified in (3.3), I consider a policy rule, which targets money supply growth as well. The rule is specified as follows

$$r_t^* = \bar{r} + \beta(E[\pi_{t+n}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t] - y_t^*) + \kappa(E[m_{t+n}|\Omega_t] - m_{t+n}^*), \tag{3.4}$$

where m is the money supply growth rate and m^* is its target level.

Let $q_{t+n} = m_{t+n} - m_{t+n}^*$. For consistency, I can rewrite equation (3.4) similar to (3.3) as

$$r_t = (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)\beta\pi_{t+n} + (1-\rho)\gamma x_t + (1-\rho)\phi q_{t+n} + u_t, \tag{3.5}$$

where u_t includes ν_t and a weighted forecast error associated with the money growth as well.

3.2.2 Disaggregated Taylor Rules

For disaggregated monetary policy rules I consider the benchmark (equation 3.3) and alternative (equation 3.5) policy rules augmented with country-specific inflation, output gap, and money growth deviations from the aggregate. In particular, I estimate the following two rules for l member countries in the currency union.

1. Benchmark Taylor Rule

$$\begin{aligned} r_t &= (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)(\beta\pi_{t+n} + \sum_{i=1}^{l} \beta_i(\pi_{t+n}^i - \pi_{t+n})) \qquad (3.6) \\ &+ (1-\rho)(\gamma x_t + \sum_{i=1}^{l} \gamma_i(x_t^i - x_t)) + \epsilon_t \end{aligned}$$

2. Alternative Taylor Rule

$$\begin{aligned} r_t &= (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)(\beta\pi_{t+n} + \sum_{i=1}^{l}\beta_i(\pi^i_{t+n} - \pi_{t+n})) \\ &+ (1-\rho)(\gamma x_t + \sum_{i=1}^{l}\gamma_i(x^i_t - x_t)) \\ &+ (1-\rho)(\phi q_{t+n} + \sum_{i=1}^{l}\phi_i(q^i_{t+n} - q_{t+n})) + u_t \end{aligned} \tag{3.7}$$

In essence, the disaggregated Taylor rules in equations (3.6) and (3.7) nest the aggregate Taylor rules in equations (3.3) and (3.5). The maintained null hypothesis is that the country-specific deviations from the aggregate are irrelevant for the policy rule, i.e. $\beta_i = 0$, for $i = 1, ..., l$. Under the null hypothesis, the aggregate and disaggregate models are the same.[3]

3.3 Estimation Methodology

I estimate the Taylor rules specified in (3.3), (3.5), (3.6), (3.7) by instrumental variable approach. Let X_t be a set of variables in the information set of the policy authority at time t (i.e. $X_t \in \Omega_t$), such that $E(\epsilon_t|X_t) = 0$ and $E(u_t|X_t) = 0$. In our case this would include lagged values of inflation, output gap, and growth rate for money supply depending on the Taylor rule specification. In the classical world one would proxy the behavior of the n-step ahead inflation and money growth as well as contemporaneous values of the output gap in the Taylor rule equations with the mentioned instruments to yield unbiased and consistent parameter estimates. Researchers commonly use methods such as two stage least squares, limited information maximum likelihood or generalized method of moments estimation techniques to implement the instrumental variable (IV) estimations and achieve statistical identification.

The Bayesian counterpart that I use for estimating a single equation Taylor rule is similar in spirit to that of two stage least squares in the classical framework. It relies on postulating

[3] Given that l is less than the number of total countries in the Euro Area, I exclude the scenario where the models become identical because the weights put on country-specific deviations in the policy rule are equal to the weights used to construct the corresponding aggregate variables.

a limited information simultaneous equations model, where the dynamics of the endogenous variables are expressed in terms of the instruments. Under particular assumptions which I elaborate on further, one can simulate from exactly specified conditional posterior distributions to identify the structural parameters.

Following Kleibergen and Zivot (2003) I specify a limited information simultaneous equation model in the following structural form

$$\begin{aligned} Y_1 &= Y_2\beta + \epsilon_1 \\ Y_2 &= X\Pi + V_2, \end{aligned} \tag{3.8}$$

where the first equation is the structural equation of ultimate interest and the second presents the dynamics of the endogenous variables in terms of the instruments and other exogenous variables. Accordingly, Y_1 is a $T \times 1$ vector of endogenous variables, Y_2 is a $T \times (m-1)$ matrix of endogenous variables, while X is a $T \times k$ matrix of instruments, i.e. exogenous variables excluded from the single equation regression model. ϵ_1 is a $T \times 1$ vector of structural errors, while V_2 is a $T \times (m-1)$ vector of reduced form errors. X is assumed to be full rank, deterministic, uncorrelated with the error terms, and weakly exogenous for the structural parameter β. Let Σ be the covariance matrix of the error terms, $\Sigma = Cov(\epsilon_1, V_2)$.

I can rewrite the system in (3.8) in the following restricted reduced form

$$\begin{aligned} Y_1 &= X\Pi\beta + \nu_1 \\ Y_2 &= X\Pi + V_2, \end{aligned} \tag{3.9}$$

where $\nu_1 = \epsilon_1 + V_2\beta$ and

$$\Omega = Cov(\nu_1, V_2) = \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \beta & I_{m-1} \end{pmatrix}' \Sigma \begin{pmatrix} 1 & 0 \\ \beta & I_{m-1} \end{pmatrix} \tag{3.10}$$

All endogenous variables can be presented in terms of the exogenous variables in a reduced form

$$
\begin{aligned}
Y_1 &= X\pi + \nu_1 \\
Y_2 &= X\Pi + V_2, \qquad (3.11)
\end{aligned}
$$

I estimate the reduced form specified in (3.11). Identification of structural parameters in β is achieved if and only if $rank(\Pi) = m-1$. In addition, when $k = m-1$, the system is uniquely identified, and, when $k > m-1$, the system is overidentified to $k-m+1$ degree. [4]

In order to outline the estimation methodology, I rewrite the error term ν_1 and accordingly the system in (3.9) in a slightly reparameterized form

$$
\begin{aligned}
Y_1 &= X\Pi\beta + e_1 + V_2\phi \\
Y_2 &= X\Pi + V_2, \qquad (3.12)
\end{aligned}
$$

where $e_1 = \nu_1 - V_2\phi$ and $\phi = \Omega_{22}^{-1}\Omega_{21}$. Accordingly, $Var(e_1) = \omega_{11} = \Omega_{11} - \Omega_{12}\Omega_{22}^{-1}\Omega_{21}$, and e_1 and V_2 are uncorrelated.

Let $Y = (Y_1 \ Y_2)$ and θ be the vector of parameters that are of interest, i.e. $\theta = (\beta, \phi, \Pi, \omega_{11}, \Omega_{22})$. The likelihood function of the model in (3.12) is given by

$$p(Y|X,\theta) = p(Y_1|Y_2,X,\theta)p(Y_2|X,\theta), \qquad (3.13)$$

where

$$
\begin{aligned}
p(Y_1|Y_2,X,\theta) &\propto \omega_{11}^{-0.5T} exp[-0.5\omega_{11}^{-1}(Y_1 - X\Pi\beta - V_2\phi)'(Y_1 - X\Pi\beta - V_2\phi)] \qquad (3.14) \\
p(Y_2|X,\theta) &\propto |\Omega_{22}|^{-0.5T} exp[-0.5\text{tr}(\Omega_{22}^{-1}(Y_2 - X\Pi)'(Y_2 - X\Pi))]. \qquad (3.15)
\end{aligned}
$$

Following Kleibergen and Zivot (2003) I consider a diffuse prior that puts equal probability

[4]The intuition behind the identification restrictions is that you would like the instrumental variables to be able to span the endogenous variable space uniquely.

on the parameter space in the following form

$$p(\theta|X) \propto \omega_{11}^{-m}|\Omega|^{-0.5(m+k-1)}|\Pi' X' X\Pi|^{0.5}. \tag{3.16}$$

This proposition of the prior is motivated by the idea that the set of structural parameters β is not identified if Π has reduced rank, thus the model as such is not informative about β in this case. As discussed in Kleibergen and Zivot (2003), the prior marginally improves the estimation results in the case of weak instruments and behaves similar to the Two-stage least squares (2SLS) in the classical world.

The posterior probability can be expressed as

$$p(\theta|Y,X) \propto p(Y|X,\theta)p(\theta|X) \tag{3.17}$$

Let P_A be the orthogonal projection onto the column space of some nonsingular matrix A, i.e. $P_A = A(A'A)^{-1}A'$, and $M_A = I - P_A$.

Given (3.17), it can be shown that the conditional and marginal probability distributions for the structural parameters are as follows

$$\begin{aligned}
P(\beta|\phi,\Pi,\omega_{11},\Omega_{22},Y,X) &\propto \omega_{11}^{-0.5(m-1)}|\Pi' X' X\Pi|^{0.5} \\
&\quad \times exp[-0.5\omega_{11}^{-1}(\beta-\hat{\beta})'\Pi' X' X\Pi(\beta-\hat{\beta})] && (3.18)\\
P(\phi|\Pi,\omega_{11},\Omega_{22},Y,X) &\propto \omega_{11}^{-0.5(m-1)}|V_2' M_{X\Pi} V_2|^{0.5} \\
&\quad \times exp[-0.5\omega_{11}^{-1}(\phi-\hat{\phi})' V_2' M_{\Pi X} V_2(\phi-\hat{\phi})] && (3.19)\\
P(\omega_{11}|\Pi,\Omega_{22},Y,X) &\propto \omega_{11}^{-0.5(T+2)}|y_1' M_{(X\Pi\ V_2)} y_1|^{0.5T} \\
&\quad \times exp[-0.5\omega_{11}^{-1} y_1' M_{(X\Pi\ V_2)} y_1] && (3.20)\\
P(\Omega_{22}|\Pi,\Omega_{22},Y,X) &\propto |\Omega_{22}|^{-0.5(T+k+m-1)}|V_2' V_2|^{0.5(T+k-1)} \\
&\quad \times exp[-0.5\text{tr}(\Omega_{22}^{-1} V_2' V_2)] && (3.21)
\end{aligned}$$

$$P(\Pi|Y,X) \propto \left[\frac{|\Pi' X' X \Pi|}{|\Pi' X' M_{Y_2} X \Pi|}\right]^{0.5} \left[\frac{|\Pi' X' M_{Y_2} X \Pi|}{|\Pi' X' M_Y X \Pi|}\right]^{0.5T} \times |(\Pi - \hat{\Pi})' X' X (\Pi - \hat{\Pi}) + Y_2' M_X Y_2|^{-0.5(T+k-1)} \tag{3.22}$$

where $\hat{\beta} = (\Pi' X' X \Pi)^{-1} \Pi' X'(Y_1 - V_2 \phi)$, $\hat{\phi} = (V_2' M_{X\Pi} V_2)^{-1} V_2' M_{X\Pi} Y_1$ and $\hat{\Pi} = (X'X)^{-1}(X'Y_2)$.

The distributions in (3.18)-(3.21) are standard. The conditional distributions of β and ϕ expressed in equations (3.18) and (3.19) are multivariate normal. The conditional distribution for ω_{11} (equation 3.20) is Inverse Gamma, while the distribution for Ω_{22} is Inverse Wishart expressed by the density kernel in (3.21). The marginal density function for Π is non-standard and will be simulated based on Markov Chain Monte Carlo (MCMC) methods via a random-walk Metropolis algorithm.

The essence of the Metropolis-Hastings algorithm is to construct a Markov Chain such that its stationary distribution is $P(\Pi|Y,X)$ provided in equation (3.22). For expositional purposes let $P(\Pi|Y,X) = \pi(\Pi)$. First I suggest a proposal density $q(.|\Pi)$ which guides the sampling of the next state of Π_{t+1} given the current state of Π_t. More specifically, I draw a candidate point O from a proposal distribution $q(.|\Pi)$ and accept it as the next state, $\Pi_{t+1} = O$, with an acceptance probability of

$$\alpha(\Pi_t, O) = \min\left(1, \frac{\pi(O) q(\Pi_t|O)}{\pi(\Pi_t) q(O|\Pi_t)}\right) \tag{3.23}$$

As discussed in Gilks et al. (1996), given the algorithm, the stationary distribution will be $P(\Pi|Y,X)$ despite the form of the proposal density $q(.|\Pi)$. In particular, the random walk Metropolis algorithm considers the proposal densities that are symmetric such that $q(O|\Pi_t) = q(\Pi_t|O) = q(|\Pi_t - O|)$. In our particular case, I consider a multivariate normal proposal distribution with a mean $\hat{\Pi}$ and constant covariance matrix $(X'X)^{-1}\sigma^2/l^{0.1}$, where l is the lag of the variable used as an instrument and σ is parameterized such that it generates an acceptance probability between $60\% - 70\%$. In essence, the prior imposes a smaller uncertainty on the lagged values of the instrumental variables compared to the current values. Under the random walk Metropolis algorithm the acceptance probability reduces to

$$\alpha(\Pi_t, O) = \min\left(1, \frac{\pi(O)}{\pi(\Pi_t)}\right) \tag{3.24}$$

I make a Metropolis draw from (3.22), then simulate from the conditional distributions with a Gibbs sampler. I burn-in 20,000 initial simulation values and use the next 80,000 simulated values to calculate the moments of the distributions in concern. I check the convergence of the Metropolis algorithm by Geweke statistics (Geweke (1992)), which tests for the equality of the posterior means of the parameters for different halves of the simulated chain under the maintained hypothesis of equality of the estimated standard deviations over the same halves. If the chain has converged such that the simulated draws come from the same stationary distribution as in (3.22), the Geweke statistic has an asymptotic standard normal distribution. The same applies to the chains that result from a Gibbs sampler. In addition, I truncate the distribution for (3.18) such that the draws for the autoregressive coefficient on the interest rates are below unity.

3.4 Data

Since the policymakers at the ECB target year-to-year inflation rate, I set $n = 12$ to accommodate for one-year ahead inflation forecast given monthly data. The set of instruments considered for the estimation are similar to that in Clarida et al. (1998). For the benchmark rules specified in (3.3) and (3.6) I consider lagged values of output, inflation, interest rates, and commodity prices as a set of instruments. For the alternative rules specified in (3.6) and (3.7) I also consider the lagged values of money supply. In general, when estimating the aggregate Taylor rules, I use 8 lags for each variable as an instrument together with a constant. For all variables other than the interest rates I use lags 1 to 6, as well as 9 and 12 to compile the set of instruments. For the interest rates I use values for lags 2 to 7, together with 9 and 12 as instruments. For the disaggregated Taylor rule in the benchmark specification I use 5 consecutive lags for each variable as an instrument, while for the alternative specification I use 3 lags only. The construction of the lags for the interest rates and the rest of the variables is similar to the construction of the instrument set for the aggregate Taylor rule estimation.

In the disaggregated specification I consider the six largest economies of the Euro zone, i.e. Germany, France, Italy, Spain, the Netherlands, and Belgium. The six countries combined have about 90% of the EA output and population. The data I use is in monthly frequencies and spans the period 1999:1-2008:12. I use the first difference of Harmonized Index of Consumer Prices (HICP) in logs as a measure of union-specific and country-specific inflation rates. I consider the Industrial Production Index (IPI) for the union-specific and country-specific output levels. In order to get a measure for the output gap I detrend the natural logarithm of the IPI using a deterministic trend in a quadratic form. I proxy the money supply data by the value of total deposit liabilities of monetary financial institutions (MFIs) due to unavailability of the comparable readily available data across the EA countries for the period I consider. Commodity price index is taken from the Global Financial Data database and reflects the average valuation of the commodity dollar index in euros. All variables, except the commodity price index, are taken from the Eurostat. The data for HICP and total deposit liabilities have been seasonally adjusted by X-11 filtering.

3.5 Empirical Results

Table B.5 reports the estimation results for the benchmark specification as in equation (3.3).[5] As shown in the table, there is a high weight on the interest rate smoothing for the policy reaction function for the ECB. The median value for the autoregressive term is 0.90, with the 95% coverage area containing values from 0.83 to 0.97. The weight on the output gap is statistically not different from zero. In addition, it appears that the ECB is conducting a very inflation "hawkish" policy, by increasing the interest rate with 3.01 percentage points for every percentage point increase in the anticipated inflation. The 95% coverage area for the reaction function coefficients for the inflation includes values above 1 which is in accord to the Taylor Principle discussed previously.

Once I allow the central bank to target money growth in addition to inflation and output

[5] The constant term in this table and hereafter is reported given the mean of the interest rate. The distribution for the constant is attained from the distribution of the autoregressive component. The data that goes through the estimation algorithm is demeaned.

gap, the latter two lose their significance as suggested by Table B.6. The coefficient on the interest rate smoothing does not change for the alternative specification compared to the benchmark. Since the distribution of α comes from the distribution of the autoregressive coefficient, it does not change as well. It appears that when accounting for one-year ahead money growth in the Taylor rule, the inflation targeting becomes statistically insignificant. As the one-period ahead money growth increases by one percentage point, the median increase in the policy interest rate is 2.27 percentage points.

The results for benchmark specification of the Taylor rule that incorporates country-specific output gap and inflation differentials are depicted in B.7. The coefficient on the aggregate output gap and country specific output gap differentials from the aggregate are not significantly different from zero. Thus, the conclusion that ECB does not respond to the output gap with its policy interest rule continues to hold. The case for inflation is somewhat different. Though ECB reacts to the aggregate inflation in accord to the Taylor rule, it appears that the response to the country-specific inflation deviations from the aggregate are significantly different from zero as well where Italy is the exception. It is interesting to observe that the inflation deviations in Spain and France affect the policy interest rate negatively, while the deviations in Belgium, Germany, and the Netherlands affect the policy response in a direction consistent with the aggregate.

The results for the alternative specification of the Taylor rule are presented in B.8. The dynamics is similar to that in the aggregate Taylor rule specification: once money aggregates are introduced the response of the interest rates to anticipated country-specific inflation differentials becomes largely insignificant. The notable exceptions are Belgium and the Netherlands for which increases in the inflation deviations are accompanied with more than one-to-one increase in the policy interest rate. This is the case even when the response to the aggregate inflation becomes statistically insignificant. Aggregate monetary targeting still appears to be significant, while in general the country-specific deviations from the aggregate do not appear to matter for almost all the countries except Belgium and Germany. The money growth deviations for Germany drive the interest rates higher, while the Belgian deviations have the opposite effect.

3.6 Robustness

As a robustness study, I estimate the Taylor rules treating the time t expectations of inflation and output growth for the next year as exogenous. More specifically, I use the Survey of Professional Forecasters provided by the ECB to get quarterly measure of one-year ahead output growth and inflation expectations for the aggregate economy. Since these forecasts are formed in period t with the information available through period $t-1$, there is no issue of erogeneity and no need to use instrumental variables techniques. I use the data that spans 1999:Q1-2010:Q2. First I consider the data comparable to the period considered in the earlier sections, then I expand the data set to capture the whole sample.

I assume a standard, conjugate Normal-Gamma prior for the regression parameters centered around the values $\rho = 0.9, \beta = 1.5$, and $\gamma = 0.5$. The explicit values are taken from the original suggestions of Taylor (1993) and the baseline estimations of the Budnesbank reaction function as in Clarida et al. (1998). Let δ be a vector of reduced from regression parameters that has a normal prior which assumes

$$\delta|h \propto N(\underline{\delta}, h^{-1}\underline{V}). \tag{3.25}$$

where $\underline{\delta}$ takes the reduced form values corresponding to the values of the structural parameters mentioned earlier. I consider $\underline{V}$ to have fairly large diagonal values such that the prior is non-informative. I impose a prior in a form of a Gamma distribution for h and parameterize it to be non-informative as well.[6]

As shown in Koop (2004) (chapter 3), given the Normal-Gamma conjugate prior, the posterior distribution for the parameter vector of the multivariate linear regression model can be written as

$$\delta|y \propto t(\overline{\delta}, \overline{s}^2\overline{V}, \overline{\nu}), \tag{3.26}$$

[6] I do this by setting the scale parameter to zero.

where

$$\overline{V} = (\underline{V}^{-1} + X'X)^{-1} \tag{3.27}$$

$$\overline{\delta} = \overline{V}(\underline{V}^{-1}\underline{\delta} + X'X\hat{\delta}) \tag{3.28}$$

$$\overline{\nu} = \overline{\nu} + N \tag{3.29}$$

$$\overline{\nu s}^2 = \underline{\nu s}^2 + \nu s^2 + (\hat{\delta} - \underline{\delta})'[\underline{V} + (X'X)^{-1}]^{-1}(\hat{\delta} - \underline{\delta}) \tag{3.30}$$

and ν, s^2, and $\hat{\delta}$ are the OLS quantities.

I report the results from 30,000 Monte Carlo simulations in Table B.9. The simulated chains have converged based on the Geweke statistics discussed previously at 5% significance level. As shown in the table, when using exogenously given expectations data, the weight on the interest rate smoothing goes down such that the upper bound for the 95% confidence interval does not reach 0.90. Despite the sample period considered, the data reveals more weight on the inflation than output growth in the policy reaction function. In addition, the weight on one-year ahead output growth expectations appears to be more precisely estimated such that the 95% confidence interval is narrower compared to that one-year ahead inflation expectations. It appears that the reaction to both inflation and output growth expectations has subdued when I extend the data sample as shown in part (B) of table B.9. However, when I compare the robustness results with the benchmark results presented earlier, I can see that the weight on inflation expectations is not significantly different for the two cases, though the 95% coverage area for the IV case is wider and slightly skewed towards the upper tail. On the contrary, when considering the monetary policy reaction to the one-year ahead output growth, I do get significant response from the policy side. Nevertheless, the response is milder than that for inflation.

3.7 Conclusion

By its mandate the ECB is committed to the objective of price stability for the Euro Area. However, the aggregate variables for the Euro Area are constructed in a particular way such that the economic variables for each country are weighted proportional to their economic size. First, this essay estimated the aggregate Taylor rule, thus contributing to the empirical monetary policy literature using the post-Euro data. I find that the monetary feedback rule is in accord to the Taylor Principle. When I introduce monetary aggregates to the Taylor rule, it appears that the path of the interest rate is significantly explained by monetary targeting. In addition, I estimate a disaggregated Taylor rule where in addition to the aggregate measures I consider country-specific deviations from the aggregate. It appears that certain country-specific deviations in inflation and money growth matter for the policymaking.

Appendix A

Appendix

A.1 Member Country Non-Stochastic Steady State

The first-order conditions of the households utility maximization problem, equations (2.8), (2.9), (2.10), (2.3), together with the market-clearing conditions, equations (2.25), (2.26), ($D_t = 0$), yield the following steady state relationships.

$$\beta R = 1 \tag{A.1}$$

$$C^{\sigma} L^{\varphi} = \frac{W}{P} \tag{A.2}$$

$$C^{\sigma}\left(\frac{R}{R-1}\right) = \left(\frac{M}{P}\right)^{\varphi} \tag{A.3}$$

$$WL + \Gamma + T = PC \tag{A.4}$$

$$D = 0 \tag{A.5}$$

The firms first-order conditions together with the definition of real marginal cost give

$$MC = \frac{W}{AP_H} \tag{A.6}$$

$$x^1 = \frac{Y}{1-\phi\beta} \tag{A.7}$$

$$x^2 = \frac{\nu Y MC}{1-\phi\beta} \tag{A.8}$$

$$x^1 = x^2. \tag{A.9}$$

The goods market clearing in a steady state becomes

$$Y = C_H + G + X, \tag{A.10}$$

and the government budget constraint, equation (2.23), yields $T = G$.

I assume the steady-state values for the variables following the stochastic processes specified by equations (2.31, 2.32, 2.33) are A, θ, G. It follows that the steady-state value of markup is $\nu = \frac{\theta}{\theta - 1}$.

Inflation in steady state is zero, that is $\Pi_H = 1$. From equation (2.30) the steady state value of $k = 1$. The latter, together with (2.29), yields a steady-state value of $Y = AL$.

The international risk-sharing condition (equation 2.34) implies that in a symmetric steady state the value for terms of trade is $S = 1$. The latter, combined with equation (2.35), determines the steady-state value of $\Pi = \Pi_H = 1$.

In the steady state, the consumption bundle and its allocation between domestic and foreign goods is determined by

$$C = Y - G \tag{A.11}$$

$$C_H = (1 - \alpha)C \tag{A.12}$$

$$C_F = \alpha C. \tag{A.13}$$

A.2 Member Country Linear Dynamics

In what follows the lower case variables denote the logarithmic deviation of a variable from a steady state, that is $x_t = lnX_t - lnX$, where X is the steady-state value of the variable X_t. The subscripts for country 1 have been dropped and subscripts for country two have been changed to asterisks (*) for notational simplicity.

The log-linearization of the economy-wide resource constraint (equation 2.37) yields the following

$$y_t = (1 - g_y)(c_t + \alpha(x_t - c_{F,\ t})) + g_y g_t, \tag{A.14}$$

where g_y is the ratio of government expenditures to output in the steady state, that is $g_y = G/Y$.

Terms of trade are determined by $s_t = p_{F,\ t} - p_{H,\ t}$, while the log-linearization of equation (2.38) yields $p_t = p_{H,\ t} + \alpha s_t$. Accordingly, the export and import demand functions are (the following relies on the union-wide market clearing condition, equation (2.36), and that terms of trade for the second country is reciprocal to the first, that is $s_t^* = -s_t$

$$c_{F,\ t} = c_t - \eta(1-\alpha)s_t \tag{A.15}$$

$$x_t = c_t^* + \eta(1-\alpha)s_t, \tag{A.16}$$

$$\tag{A.17}$$

which yields $x_t - c_{F,\ t} = c_t^* - c_t + 2\eta(1-\alpha)s_t = c_t^* - c_t + \kappa_{nx}s_t$, where $\kappa_{nx} = 2\eta(1-\alpha)$.

Log-linearizing the international risk-sharing condition, I get

$$c_t = c_t^* + \frac{1-2\alpha}{\sigma}s_t = c_t^* + \kappa_c s_t, \tag{A.18}$$

where $\kappa_c = (1-2\alpha)/\sigma$.

If I plug in the results into the log-linearized resource constraint, I get

$$y_t = (1-g_y)(c_t + \alpha(\kappa_c + \kappa_{nx})s_t) + g_y g_t. \tag{A.19}$$

The log-linearization of the Euler equation (2.8) gives

$$c_t = c_{t+1} - \frac{1}{\sigma}(r_t - E_t\pi_{t+1}) \tag{A.20}$$

By combining equations (A.19) and (A.20) I get

$$y_t = E_t y_{t+1} - \frac{(1-g_y)}{\sigma}(r_t - E_t\pi_{t+1}) + g_y(g_t - E_t g_{t+1}) + \alpha(1-g_y)\kappa(s_t - E_t s_{t+1}), \tag{A.21}$$

where $\kappa = k_c + k_{nx}$

When I solve for c_t from (A.19) and I plug it into (A.18), I can solve for s_t in terms of output and government expenditures

$$s_t = \frac{y_t - g_y g_t - (y_t^* - g_y g_t^*)}{(1-g_y)\sigma_\alpha} \tag{A.22}$$

where $\sigma_\alpha = ((1+2\alpha)\kappa_c + 2\alpha\kappa_{nx})$.

From log-linearization of equations (2.21), (2.22), and $x_t^1 = x_t^2$ yields

$$\pi_{H,\ t} = \beta\pi_{H,\ t+1} + \lambda_1 mc_t + \lambda_2\hat{\theta}_t, \tag{A.23}$$

where $\lambda_1 = \frac{(1-\phi)(1-\phi\beta)}{\phi}$, $\lambda_2 = \frac{\lambda_1}{(\theta-1)}$, and $\hat{\theta}$ is the log deviation of elasticity of demand for the intermediate good (θ_t) from its steady state.

From equation (2.30) and utilizing the fact that the first-order approximation to k_t around a zero inflation steady state is zero (Galí (2008)), I get $l_t = y_t - a_t$. The definition of marginal cost gives, $mc_t = w_t - a_t - p_{H,\ t}$. The two equations together with the labor supply, equation (2.9), gives $mc_t = \sigma c_t + \alpha s_t + \varphi y_t - (1+\varphi)a_t$. Plugging in for consumption gives

$$mc_t = \frac{\sigma + \varphi(1-g_y)}{1-g_y} y_t - \frac{\sigma}{1-g_y} g_y g_t - \alpha(\sigma\kappa - 1)s_t - (1+\varphi)a_t. \tag{A.24}$$

The log-linearization of equation (2.35) yields the following relationship between the domestic and consumer price inflation

$$\pi_t = \pi_{t,\ H} + \alpha\Delta s_t. \tag{A.25}$$

The log-linearization (up to a constant) of money demand, equation (2.10), with the money market clearing condition, equation (2.26), implies the following

$$m_t = \frac{\sigma}{\nu} c_t - \eta r_t, \tag{A.26}$$

where m_t is the log-deviation of real money demand from its steady state, and $\eta = 1/(\nu(R-1))$.

Plugging in for c_t from (A.19) I get

$$m_t = \frac{\sigma}{\nu}\frac{(y_t - g_y g_t)}{(1-g_y)} - \frac{\sigma\psi}{\nu} s_t - \eta r_t, \tag{A.27}$$

where $\psi = \alpha(\kappa_c + \kappa_{nx})$.

The stochastic processes in a log-linear form are as follows

$$a_t = a_{t-1} + \epsilon_{at} \tag{A.28}$$

$$\hat{\theta}_t = \rho_\theta \hat{\theta}_{t-1} + \epsilon_{\theta t} \tag{A.29}$$

$$g_t = \rho_g g_{t-1} + \epsilon_{gt}. \tag{A.30}$$

A.3 Union Steady State and Linear Dynamics

From equations (2.37) and (2.38) the steady-state output and inflation in the union will be $Y^u = Y^{(1)} = Y^{(2)}$ and $\Pi^u = \Pi^{(1)} = \Pi^{(2)} = 1$. The policy rule expressed by equation (2.40) implies a steady-state value of the interest rate $R = (\Pi^u)^{\phi_\pi}(Y^u)^{\phi_y}$. The steady-state value of money supply is $M^u = 2M$.

The log-linear dynamics of the output, inflation, interest rate, and real money balances in the union are represented by

$$y_t^u = wy_t^{(1)} + (1-w)y_t^{(2)} \tag{A.31}$$

$$\pi_t^u = w\pi_t^{(1)} + (1-w)y_t^{(2)} \tag{A.32}$$

$$r_t = \phi_1 \pi_t^u + \phi_2 \pi_t^u + e_{rt}^u \tag{A.33}$$

$$m_t^u = 0.5m_t^{(1)} + 0.5m_t^{(2)} + (w-0.5)s_t. \tag{A.34}$$

A.4 Solution

Let $x_t = [y_t^{(1)}\ \pi_t^{(1)}\ y_t^{(2)}\ \pi_t^{(2)}]'$ be the vector of endogenous state variables, $z_t = [m_t^{(1)}\ m_t^{(2)}\ y_t^u\ \pi_t^u\ m_t^u\ r_t]'$ be the vector of endogenous variables, and $v_t = [a_t^{(1)}\ \hat{\theta}_t^{(1)}\ g_t^{(1)}\ a_t^{(2)}\ \hat{\theta}_t^{(2)}\ g_t^{(2)}\ \epsilon_{rt}^u]'$ be the vector of exogenous state variables v_t. The stochastic disturbances the economy is prone to are collected in $\epsilon_t = [\epsilon_{at}^{(1)}, \epsilon_{\theta t}^{(1)}, \epsilon_{gt}^{(1)}, \epsilon_{at}^{(2)}, \epsilon_{\theta t}^{(2)}, \epsilon_{gt}^{(2)}, \epsilon_{rt}^u]'$. The equilibrium dynamics of the currency union can be summarized by a system written consistent with the notation in Uhlig (1999).

$$0 = Ax_t + Cz_t + Dv_t \tag{A.35}$$

$$0 = E_t[Fx_{t+1} + Gx_t + Jz_{t+1} + Kz_t + Mv_t] \tag{A.36}$$

$$v_{t+1} = Nv_t + \epsilon_{t+1}, \tag{A.37}$$

The mapping of the matrices to the structural parameters are omitted to conserve space and are available upon request. Since the currency area model highlighted above does not have any pre-determined state variables, the minimum state variable solution (again, consistent with the notation in Uhlig (1999)) is in the form of following stochastic difference equations

$$\begin{bmatrix} x_t \\ z_t \end{bmatrix} = \begin{bmatrix} Q \\ S \end{bmatrix} v_t, \tag{A.38}$$

$$v_t = Nv_{t-1} + \epsilon_t, \tag{A.39}$$

where Q and S are 4×7 and 5×7 matrices respectively with no zero restrictions.[1]

A.5 Inexact Priors

The existence of a unit root in a VAR setting essentially says that the sum of the coefficients on the lags of the dependant variable is one, while the coefficients on the lags of other variables are zero. This prior is imposed by adding n initial observations to the data set, one for each equation in the VAR. The initial observations are added as follows. For $i = 1, ..., n; j = 1, ..., n$, and $s = 1, ..., k$

[1]In fact, the solution has been verified for a currency union, where the economies are parameterized in accord to the values in Galí and Monacelli (2005), $\nu = \sigma$, and the aggregate values of inflation and output are constructed as simple averages of the member economies.

$$y_{ij} = \begin{cases} \mu_5 \bar{y}_{0i} & i = j \\ 0 & \text{otherwise} \end{cases}$$

$$x_{is} = \begin{cases} \mu_5 \bar{y}_{0i} & s = i, i+p, i+2p, ..., s < k \\ 0 & \text{otherwise} \end{cases}$$

where $\bar{y}_{0i}$ is the average of the first p observations for each series i.

The n additional data observations that are being added can be summarized as follows. For some artificial time t^* and series i, I have

$$y_i(t^*) = y_i(t^* - 1) = ... = y_i(t^* - p) = \mu_5 \bar{y}_{0i} \tag{A.40}$$

If I rewrite (2.59) in a reduced form, such that $G = FA^{-1}$, $u_t' = \epsilon_t' A^{-1}$, and the variance-covariance matrix of the reduced form error term u_t is $\Omega = (AA')^{-1}$. The reduced form equation will imply that for $s = i, i+p, i+2p, ..., s < k$

$$\mu_5 \bar{y}_{0i} = \mu_5 \bar{y}_{0i} \sum_s G_{si} + u_{it^*} \tag{A.41}$$

Under the assumption that $(1 - \sum_s G_{si}) \neq 0$,

$$\bar{y}_{0i} = \mu_5^{-1} (1 - \sum_s G_{si})^{-1} u_{it^*}, \tag{A.42}$$

which implies that $\bar{y}_{0i} | G, \Omega \sim N(0, \mu_5^{-2} (1 - \sum_s G_{si})^{-1} \Omega (1 - \sum_s G_{si})'^{-1})$. As $\mu_5 \to \infty$, the parameter space gets increasingly centered around zero, which implies that the model can be expressed exclusively in terms of differenced data.

In order to adjust the prior such that it takes care of stable long-run relations between the series, a new type of initial observation is created. For $j = 1, ..., n,$, and $s = 1, ..., k$, this observation is constructed in such a way that $y_j = \mu_6 \bar{y}_{0j}$, and

$$x_s = \begin{cases} \mu_6 \bar{y}_{0j} & s \leq k-1 \\ \mu_6 & s = k. \end{cases}$$

Analogous to the discussion above, the dummy variable allowing for cointegration can be written

$$\mu_6 \bar{y} = \left(\sum_{s=1}^{k-1} G_s \right) \mu_6 \bar{y} + C + u_{t^*}, \tag{A.43}$$

where C is an $n \times 1$ vector of constants, $C = G'_k$. In this case when $\mu_6 \to \infty$, the parameter space gets centered around $(1 - \left(\sum_{s=1}^{k-1} G_s \right))^{-1} C$. Now if $C \neq 0$, these type of initial observation will impose co-integrating relationship among the variables. $C = 0$ will imply a single unit root, which does not exclude cointegration.

Appendix B

Tables

Table B.1: **Academic Literature on EMU**

1989-1996		1996-2002	
Topics	**Authors**	**Topics**	**Authors**
Maastricht Treaty (including EMS and ESCB)	Wildasin (1990) Giovanni, Cooper and Hall (1990) Dornbusch (1990, 1993) Meltzer (1990) Arndt and Willet (1991) Froot and Rogoff (1991) Frankel (1992, 1993) Branson (1993) Folkerts-Landau and Graber (1992) Letiche (1992) Kenen (1992, 1995) Bayoumi and Eichengreen (1993) Eichengreen and Wyplosz (1993) Eichengreen and Frieden (1994) Eichengreen (1992b, 1993, 1994) Hutchison and Kletzer (1995) Eichengreen and Von Hagen (1996) Wachtel (1996) Salvatore (1996)	Leadership and political issues in the European Union	Feldstein (1997a-b, 1998, 1999, 2000a-b, 2001) Feldstein and Feldstein (1998) Eichengreen (1996a-b) Eichengreen and Ghironi (1996) Eichengreen and Von Hagen (1996) Bayoumi et al. (1997) Makin (1997) Obstfeld (1997, 1998,1999) Kenen (1998a-b) Frieden (1998) Krugman (1998a) Calomiris (1998) Willet (1999, 2000) Schwartz (2001)
Optimum currency area theory	Sala i-Martin and Sachs (1991) Eichengreen (1990a, 1991, 1992b) Bayoumi and Masson (1995) Bayoumi and Eichengreen (1993)	European Union as a suboptimal currency area	Eichengreen (1996a-b, 1997) Frankel and Rose (1996, 1997, 2000) Bayoumi et al. (1997) Bayoumi and Eichengreen (1997) Dornbusch (1997) McKinnon (1997) Salvatore (1997, 1998) Kenen (1998a) Tobin (1998) Eichengreen and Wyplosz (1998) Eichengreen and Frieden (1998) Frieden (1998) Salvatore and Fink (1999)
Fiscal federalism and lessons from the United States	Sala i-Martin and Sachs (1991) Eichengreen (1990b, 1992a) Inman and Rubinfeld (1992) Bayoumi and Masson (1995) Eichengreen and Von Hagen (1996) Frankel (1993) McKinnon (1994) Krugman (1993)		
Political economy of EMU	Feldstein (1992a-b) Schwatz (1993) Gabel (1994) Cohen (1994) Eichengreen and Frieden (1994) McKinnon (1995) Dornbusch (1996a-b)	The euro and the dollar	Eichengreen (1998 a-d, 2000a) Eichengreen and Ghironi (1996) Mundell (1997, 1998,1999) Bergsten (1997a-b, 1999) Prati and Schinasi (1997) Dornbusch et al. (1997) Masson and Turtelboom (1997) Mundell (1997, 1998, 1999) Mussa (1997, 2000) Feldstein (2000a) Scott (1998) Krugman (1998a-b, 1999a-b, 2000) Devereux and Engel (1999) Devereux et al. (1999) Beddoes (1999) Ferson and Harvey (1999) Frankel (2000a-b) Selgin (2000) Salvatore (2000) Cohen (1998, 1999, 2000) Dornbusch (2000, 2001b-c) McKinnon (2001a-b, 2002) Kenen (2002)

Source: Jonung and Drea (2010).

Table B.2: **Sims - Zha Reference Prior**

Hyperparameter	Value	Interpretation
λ_0	0.6	controls the overall tightness of the beliefs
λ_1	0.1	tightens the prior around a random walk
λ_3	0.1	directs the rate of contraction when the lag length increases
λ_4	1	controls the tightness of the constant
μ_5	5	governs the prior on the order of integration
μ_6	5	sets the prior belief on the presence of cointegration
σ_j		is proxied by the sample standard deviation of the residuals that result from a univariate autoregression of order p for series j

Table B.3: **Variance Decomposition**

	Period 3			Period 12			Period 24		
Country	Dnd	Cost Push	Mntry	Dnd	Cost Push	Mntry	Dnd	Cost Push	Mntry
Output									
Austria	0.10	26.68	22.00	1.00	1.83	42.45	1.80	0.43	45.02
Belgium	69.81	13.43	4.14	82.98	2.36	8.43	84.70	0.80	7.15
Germany	1.54	43.54	7.04	4.50	19.96	47.59	9.74	5.63	69.46
Spain	0.42	5.72	36.37	0.34	4.87	63.31	0.48	1.75	59.22
Finland	19.38	2.26	6.44	41.75	0.71	29.04	51.12	0.22	37.41
France	18.08	50.02	4.53	16.78	20.98	23.36	15.54	7.07	34.55
Ireland	80.78	0.87	1.28	92.57	0.41	2.71	93.62	0.42	3.76
Italy	4.94	19.60	15.38	7.36	25.21	47.05	11.88	13.97	54.67
Luxembourg	12.59	30.31	6.04	26.82	12.91	18.02	37.19	6.03	22.18
Netherlands	82.17	6.71	0.45	87.80	0.73	2.32	86.87	0.20	4.47
Portugal	76.17	12.98	0.03	94.76	2.33	0.35	92.77	1.35	1.52
Price									
Austria	1.18	92.17	0.01	1.31	94.49	0.20	1.41	93.42	0.95
Belgium	2.67	86.37	0.00	1.97	91.33	0.08	1.57	92.04	0.24
Germany	0.65	92.90	0.02	0.48	93.40	0.06	0.39	91.95	0.10
Spain	0.17	82.37	0.06	0.05	93.12	0.50	0.03	94.08	1.36
Finland	0.19	92.64	0.04	0.18	94.09	0.08	0.18	92.29	0.67
France	4.29	84.18	0.04	3.70	90.78	0.17	2.92	90.42	0.44
Ireland	1.52	87.03	0.03	2.14	93.68	0.31	2.40	91.91	0.84
Italy	2.60	80.10	0.02	4.76	89.40	0.18	5.85	90.28	0.55
Luxembourg	3.74	83.80	0.16	4.12	91.31	0.23	3.98	92.20	0.20
Netherlands	0.10	91.16	0.03	0.27	91.65	0.04	0.37	90.84	0.41
Portugal	3.99	92.50	0.04	3.02	94.88	0.17	2.26	95.79	0.33

Table B.4: **Contribution to Welfare Loss**

	Var (output)	Var (inflation)	Total
Austria	3.1071	0.0066	3.1137
Belgium	0.0055	0.0004	0.0059
Germany	0.2578	0.0000	0.2578
Spain	0.1433	0.0001	0.1434
Finland	0.0097	0.0006	0.0103
France	0.0008	0.0000	0.0008
Ireland	1.1384	0.0001	1.1385
Italy	0.0480	0.0001	0.0481
Luxembourg	0.4020	0.0002	0.4022
Netherlands	0.1027	0.0004	0.1031
Portugal	0.0346	0.0001	0.0347

Note: The results are reported for a 240 period simulation.

Table B.5: **Aggregate Taylor Rule - Benchmark Specification**

	5th percentile	Median	95th percentile
α	0.17	0.31	1.18
ρ	0.83	0.90	0.97
β	2.02	3.01	8.36
γ	-1.05	0.02	0.25

Note: The table reports the results from 80,000 simulated draws for the aggregate Taylor Rule as in benchmark specification (3.3). More specifically the exact equation corresponds to $r_t = (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)\beta\pi^e_{t+n} + (1-\rho)\gamma y^e_t + \epsilon_t$, where π_{t+n} is the inflation rate between t and $t+n = t+12$ calculated as $(ln(HICP_{t+n}) - ln(HICP_t))/n$. The acceptance probability is 65%, while $\sigma = 5 \times 10^{-7}$.

Table B.6: **Aggregate Taylor Rule - Alternative Specification**

	5th percentile	Median	95th percentile
α	0.17	0.30	0.90
ρ	0.82	0.90	0.97
β	-10.15	-3.69	1.79
γ	-5.59	0.04	2.75
ϕ	1.12	2.08	5.77

Note: The table reports the results from 80,000 simulated draws for the aggregate Taylor Rule as in the alternative specification (3.5). More specifically the exact equation corresponds to $r_t = (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)\beta\pi_{t+n} + (1-\rho)\gamma x_t + (1-\rho)\kappa q_{t+n} + u_t$, where π_{t+n} is the inflation rate between t and $t+n = t+12$ calculated as $(ln(HICP_{t+n}) - ln(HICP_t))/n$, q_{t+n} is calculated similarly. The acceptance probability is 65%, while $\sigma = 3.5 \times 10^{-7}$.

Table B.7: **Disaggregate Taylor Rule - Benchmark Specification**

	5th percentile	Median	95th percentile
α	0.05	0.14	1.38
ρ	0.38	0.78	0.98
β - EA	1.10	3.05	22.74
β - BE	0.51	2.64	26.63
β - DE	1.03	4.69	48.61
β - ES	-34.17	-4.02	-1.34
β - FR	-44.44	-4.30	-1.09
β - IT	-1.38	1.13	9.67
β - NL	0.31	1.52	15.56
γ - EA	-4.67	-0.19	4.75
γ - BE	-1.09	-0.00	0.96
γ - DE	-3.42	-0.29	1.05
γ - ES	-6.75	-0.01	6.67
γ - FR	-6.40	0.59	5.35
γ - IT	-6.24	0.03	6.45
γ - NL	-2.64	0.22	2.54

Note: The table reports the results from 80,000 simulated draws for the aggregate Taylor Rule as in benchmark specification (3.3). More specifically the exact equation corresponds to $r_t = (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)(\beta\pi_{t+n} + \sum_{i=1}^{l} \beta_i(\pi^i_{t+n} - \pi_{t+n})) + (1-\rho)(\gamma x_t + \sum_{i=1}^{l} \gamma_i(x^i_t - x_t)) + \epsilon_t$, where $\pi_{i,t+n}$ is the inflation rate between t and $t+n = t+12$ calculated as $(ln(HICP_{t+n}) - ln(HICP_t))/n$ for each country i. The acceptance probability is 63%, while $\sigma = 7.5 \times 10^{-10}$.

Table B.8: **Disaggregate Taylor Rule - Alternative Specification**

	5th percentile	Median	95th percentile
α	0.06	0.15	1.53
ρ	0.46	0.80	0.98
β - EA	-11.08	1.10	18.83
β - BE	0.14	2.63	31.73
β - DE	-1.55	2.78	38.00
β - ES	-39.37	-4.77	-2.16
β - FR	-30.42	-2.10	1.78
β - IT	-28.40	-2.57	-0.04
β - NL	0.67	1.97	18.37
γ - EA	-5.03	-0.14	5.27
γ - BE	-2.03	-0.02	2.46
γ - DE	-3.83	0.16	3.42
γ - ES	-4.87	0.39	3.24
γ - FR	-7.32	0.55	4.79
γ - IT	-6.45	0.40	7.99
γ - NL	-2.06	-0.13	2.63
ϕ - EA	0.23	0.84	8.39
ϕ - BE	-3.20	-0.33	-0.11
ϕ - DE	0.13	0.47	4.83
ϕ - ES	-0.19	0.06	0.87
ϕ - FR	-0.21	0.07	0.89
ϕ - IT	-0.19	0.01	0.34
ϕ - NL	-0.05	0.01	0.13

Note: The table reports the results from 80,000 simulated draws for the aggregate Taylor Rule as in benchmark specification (3.3). More specifically the exact equation corresponds to $r_t = (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)(\beta\pi_{t+n} + \sum_{i=1}^{l}\beta_i(\pi^i_{t+n} - \pi_{t+n})) + (1-\rho)(\gamma x_t + \sum_{i=1}^{l}\gamma_i(x^i_t - x_t)) + (1-\rho)(\kappa q_{t+n} + \sum_{i=1}^{l}\kappa_i(q^i_{t+n} - q_{t+n})) + u_t$, where $\pi_{i,t+n}$ is the inflation rate between t and $t+n = t+12$ calculated as $(ln(HICP_{t+n}) - ln(HICP_t))/n$ for each country i, $q_{i,t+n}$ is calculated similarly. The acceptance probability is 68%, while $\sigma = 1.6 \times 10^{-9}$.

Table B.9: **Robustness Study - with Survey of Professional Forecasters Data**

A. Sample Size - 1999:Q1 - 2008:Q4

	5th percentile	Median	95th percentile
Aggregate Taylor Rule			
α	10.06	13.51	20.56
ρ	0.69	0.77	0.85
β	2.72	4.20	6.31
γ	1.61	2.25	3.37

B. Sample Size - 1999:Q1 - 2010:Q2

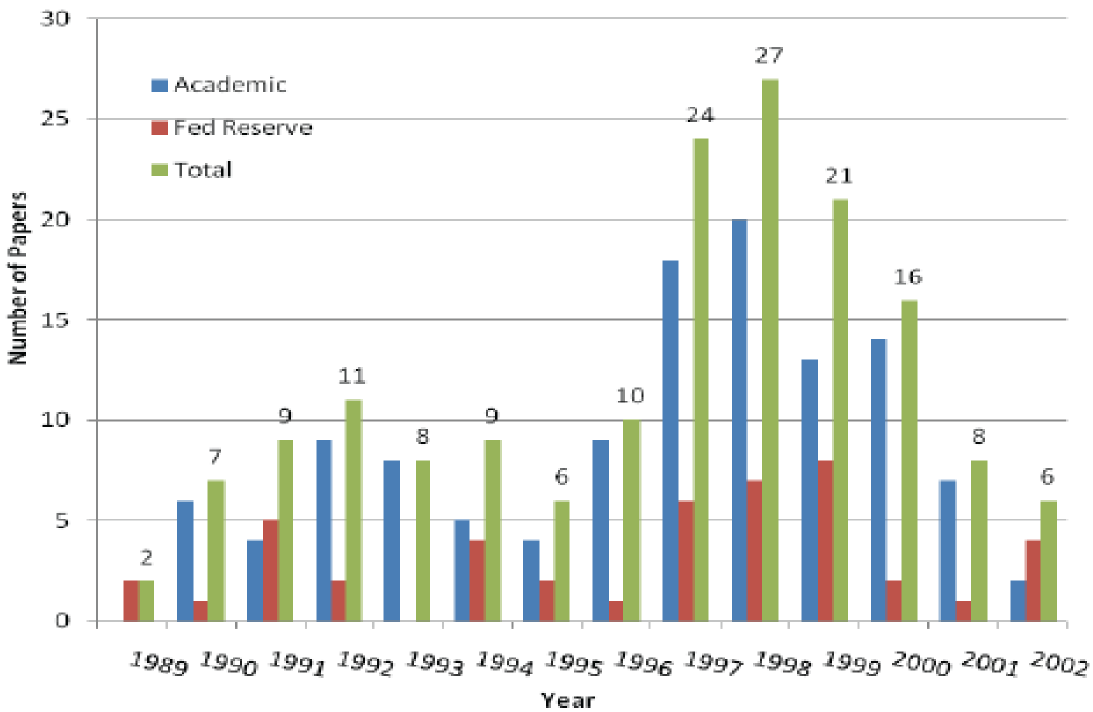
	5th percentile	Median	95th percentile
Aggregate Taylor Rule			
α	9.55	13.60	23.31
ρ	0.70	0.79	0.88
β	0.32	2.02	3.63
γ	0.84	1.30	2.24

Note: The results are for a benchmark specification similar to (3.1), where instead of the contemporaneous output gap value I use one-year ahead expectations for the output growth. More specifically the exact equation corresponds to $r_t = (1-\rho)\alpha + \rho r_{t-1} + (1-\rho)\beta\pi^e_{t+n} + (1-\rho)\gamma y^e_{t+n} + \epsilon_t$, where π^e_{t+n} and y^e_{t+n} are the time t expectations of the $n = 12$ period ahead inflation and output growth formed exogenously.

Appendix C

Figures

Figure C.1: Frequency of Publications on the EMU, 1989-2002



Source: Jonung and Drea (2010).

Figure C.2: Average monthly growth rate of industrial production index (IPI) 1999–2008: deviation from Euro Area IPI growth rate (in percentage points)

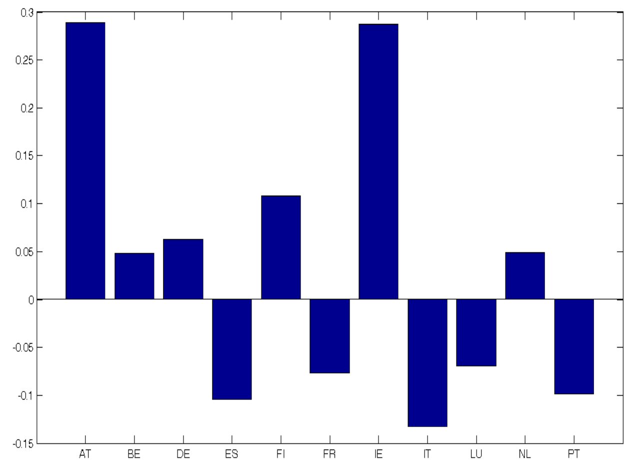
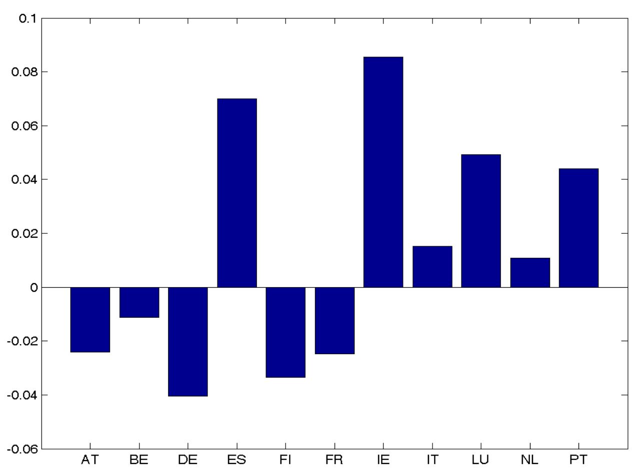
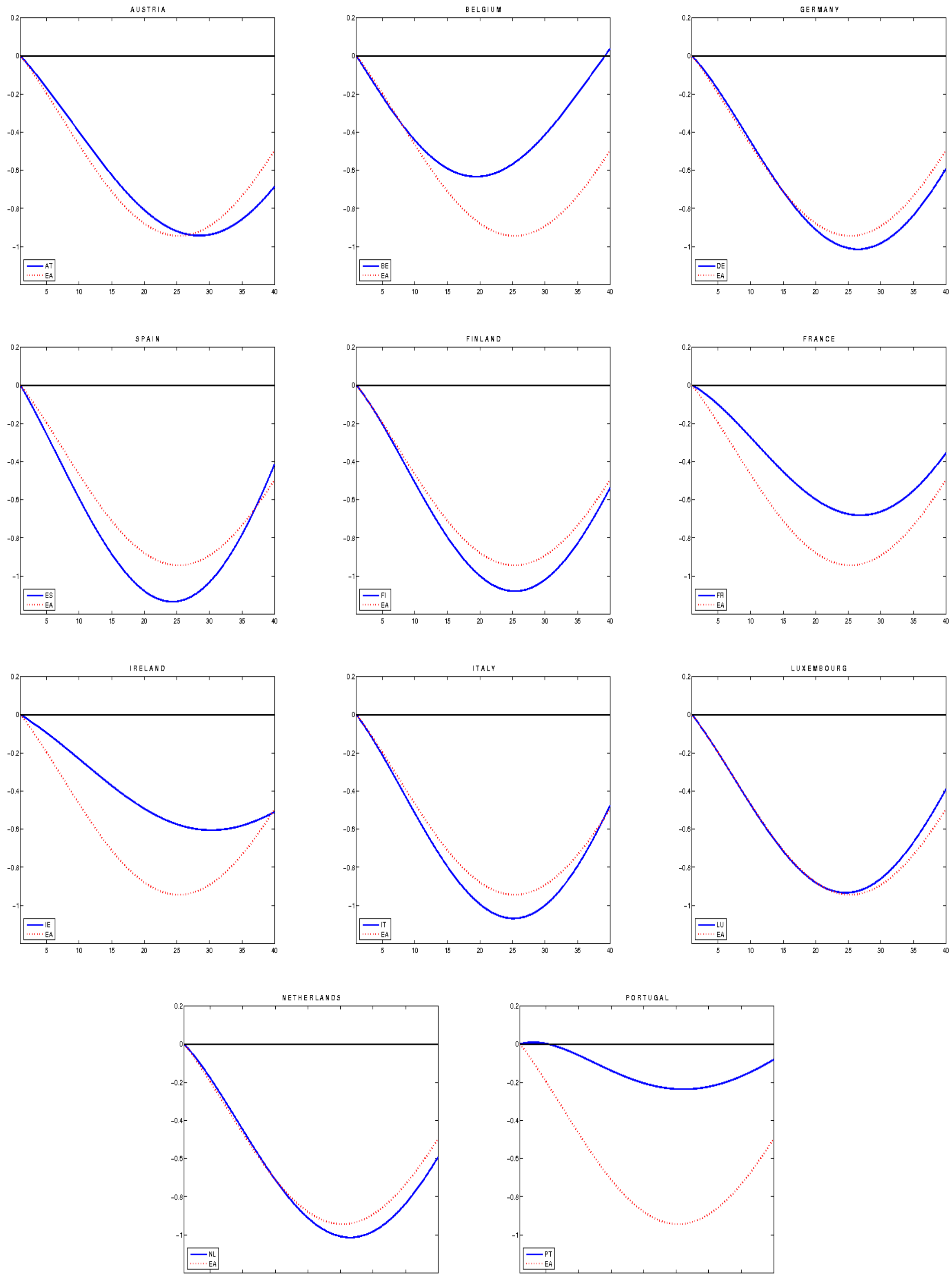


Figure C.3: Average monthly (CPI) inflation 1999–2008: deviation from Euro Area (CPI) inflation (in percentage points)



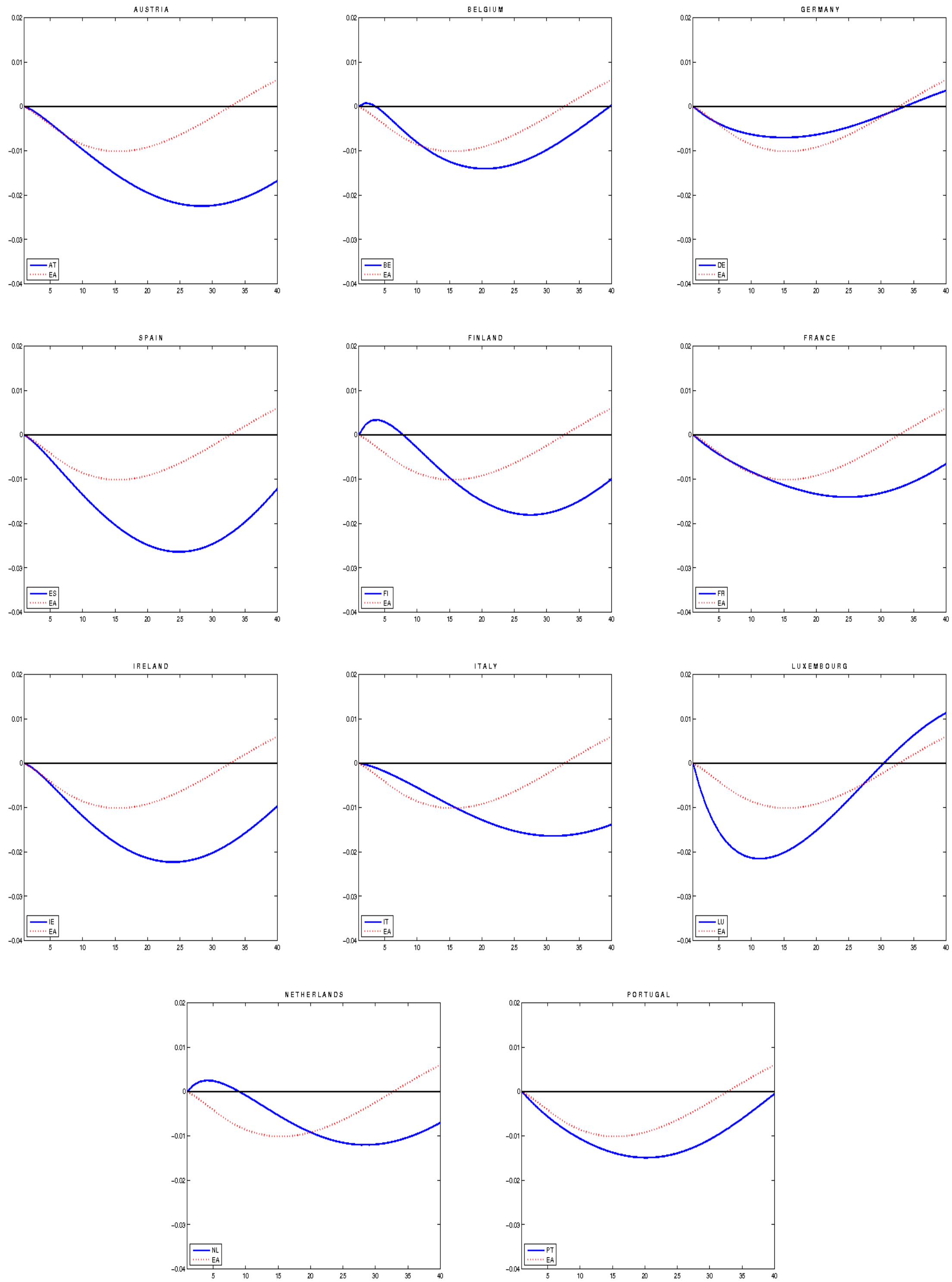
Source: Eurostat. The values for the IPI growth rate are calculated as the differences between seasonally adjusted values of the country-specific and Euro Area (log) IPI growth rates averaged over the period considered. The inflation rate reported is the change in the (log) Harmonized Indices of Consumer Prices. The series have been seasonally adjusted by X-11 filtering prior to calculating the inflation rate. Reported are the differences between country-specific and Euro Area inflation rates averaged over the period considered.

Figure C.4: Modal Impulse Response for Output



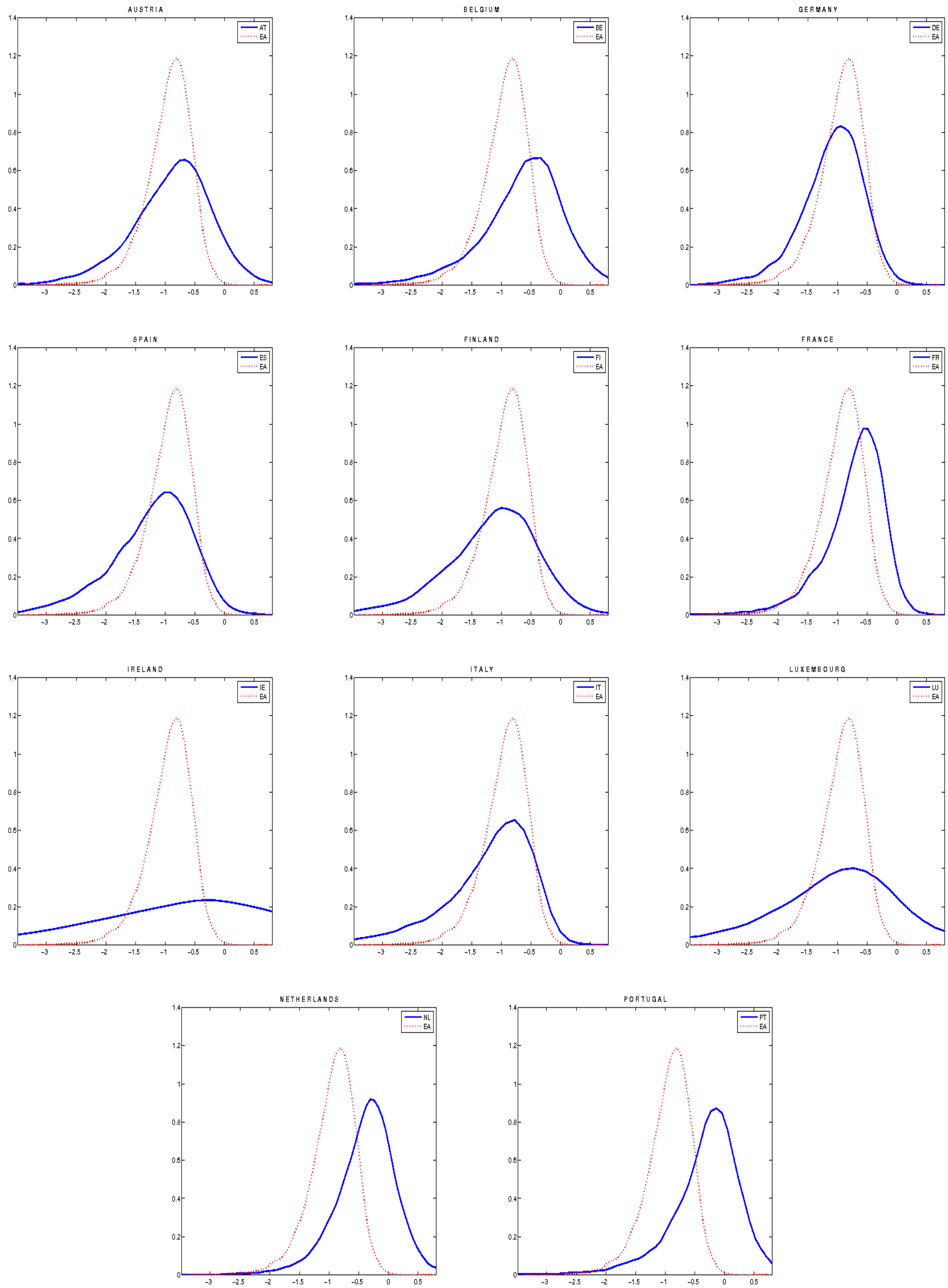
Note: The dashed lines represent the modal impulse response for the Euro Area, while the solid lines represent the modal impulse responses for individual countries.

Figure C.5: Modal Impulse Response for Inflation



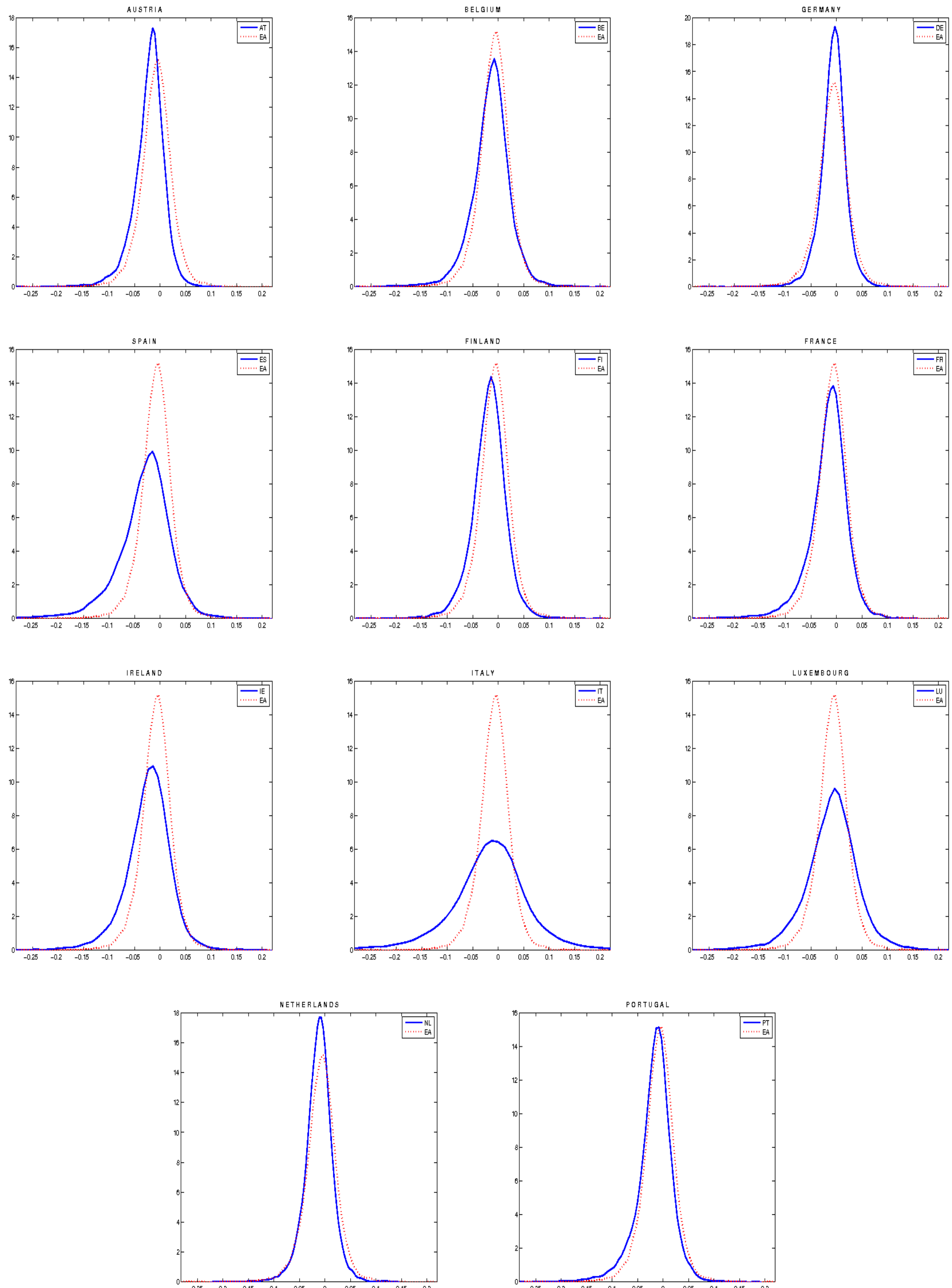
Note: The dashed lines represent the modal impulse response for the Euro Area, while the solid lines represent the modal impulse responses for individual countries.

Figure C.6: Density Functions for Output



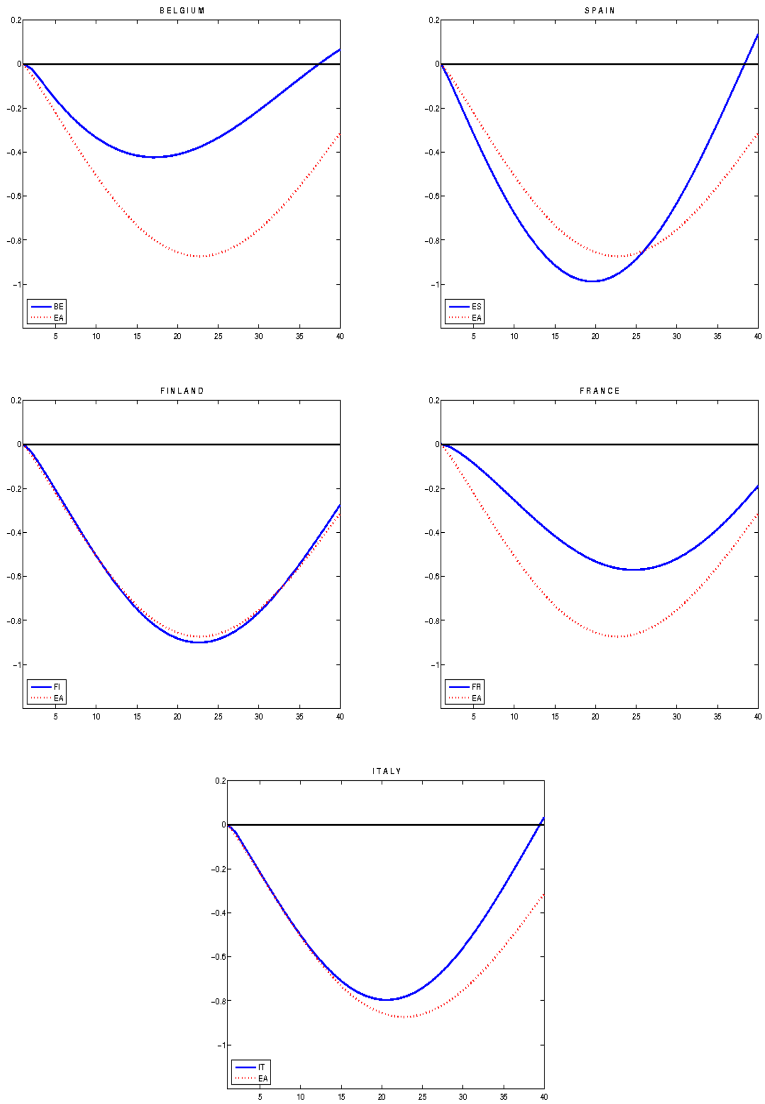
Note: The dashed lines represent the impulse response distribution for the Euro Area, while the solid lines represent the impulse response distributions for individual countries.

Figure C.7: Density Functions for Inflation



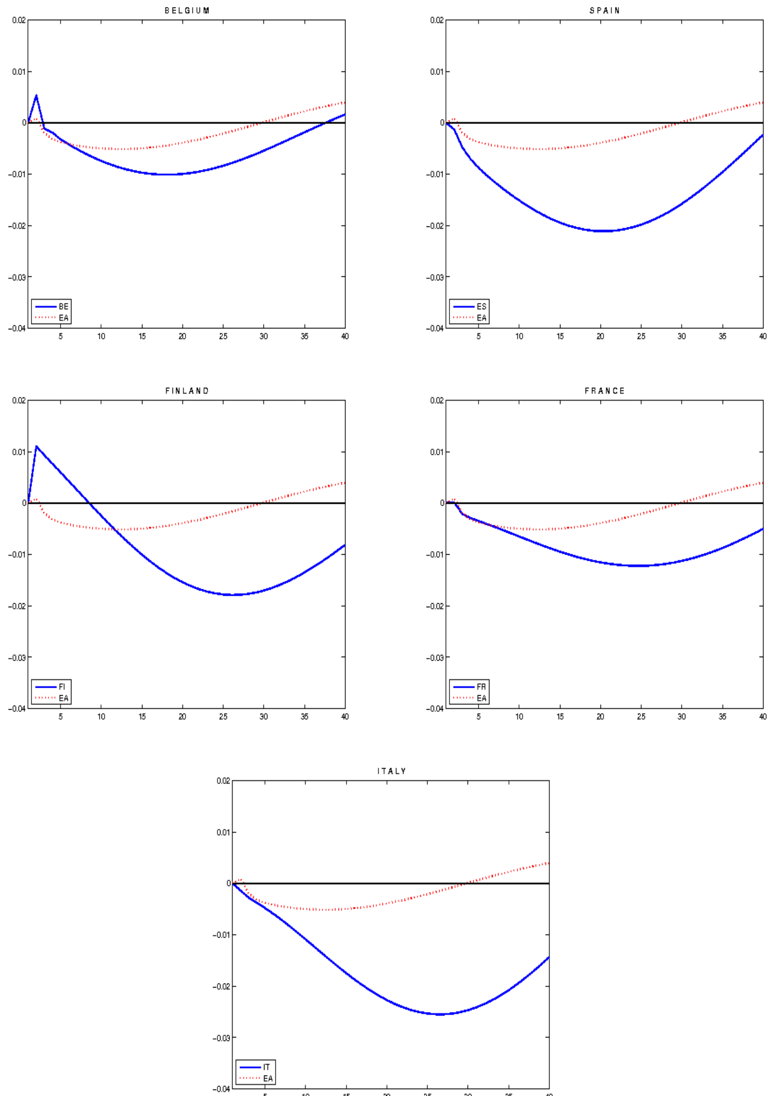
Note: The dashed lines represent the impulse response distribution for the Euro Area, while the solid lines represent the impulse response distributions for individual countries.

Figure C.8: Modal Impulse Response for Output - Empirical Prior



Note: The dashed lines represent the modal impulse response for the Euro Area, while the solid lines represent the modal impulse responses for individual countries.

Figure C.9: Modal Impulse Response for Inflation - Empirical Prior



Note: The dashed lines represent the modal impulse response for the Euro Area, while the solid lines represent the modal impulse responses for individual countries.

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