Extracting Implicit Country Weights in ECB's Monetary Policy*

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Abstract

We propose a new method to estimate implicit country weights in the conduct of monetary policy by the European Central Bank (ECB). We estimate linear and non-linear Taylor rules for 11 countries in the pre-Euro period, and then use the estimated response to produce counterfactual reference interest rates for those same countries in the post-Euro period. The distance between counterfactual interest rates and the ECB's reference rate provides an estimate of a country's implicit weight in Euro area monetary policy, in which the sum of weights adds up to 1. The concept of monetary weight draws on that of monetary stress, initially proposed by Clarida, Galí, and Gertler, 1998, and further developed by Sturm and Wollmershäuser, 2008. Our results show that Germany, Belgium and the Netherlands are persistently assigned the largest weights, whereas Greece and Ireland secure the smallest. This is especially so during the Sovereign Debt Crisis (SDC). The estimated country weights increase with the degree of co-movement between each country's and Germany's business cycle.

JEL classifications: E52, F15, F33, P16.

Keywords: Taylor rule; Counterfactual Interest Rates; Monetary Weights; Aggregate Supply and Demand Shocks.

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1 Introduction

In the second half of the twentieth century Europe experienced increasing economic integration, accompanied by the promise of prosperity and stability. The process of real integration culminated in 1992, with the Maastricht Treaty establishing an institutional framework toward the introduction of a common currency, the Euro. The resulting Economic and Monetary Union (EMU) has gained momentum, but has not gone unchallenged, especially in the wake of the recent financial crisis. Prior to unification, some have suggested that sacrificing monetary autonomy prevents adjustment to country-specific shocks (Bayoumi and Eichengreen, 1992), because a unique monetary policy is unable to address idiosyncratic economic fluctuations. Others have questioned just how independent the ECB would be from political institutions (Alesina and Grilli, 1991). This debate grew deeper after the 2008 financial crisis and the 2010 Sovereign Debt Crisis (SDC), as both crises affected Eurozone member-states differently, highlighting the possible benefit of specific policy responses. Stiglitz, 2016, went as far as arguing that in the presence of an adverse shock, "stronger countries gained at the expense of the weaker". The idea that different member-states were considered differently in the presence of asymmetric economic conditions thus relates to both the size of countries and a possible political prominence of Germany in monetary policy.

In addition to the dispute regarding the optimality of a common currency, a discussion concerning the transparency of the decision-making process within the Eurozone has come to the fore (Caporale and Cipollini, 2002), with the rise of Euroscepticism placing further pressure on European institutions, bringing the possible politics of the Euro to the center of the debate.

The persistence of potential asymmetries in the Eurozone and institutional transparency in the decision-making process of policy enactment gain prominence in light of the recent discussions concerning the need for a centralized fiscal capacity in the EMU. Thus, steps toward assessing just how the differing interests of Eurozone countries are considered, examining further the nature of policy decisions, can promote transparency and institutional development.

We base our assessment on a simple macroeconomic counterfactual, that is, an estimate of how national central banks would have likely responded to both pre- and post-Euro macroeconomic fundamentals, had their behavior mimicked their pre-Euro response functions. We then compute how far the ECB's reference interest rate is from each putative, estimated, national reference interest rate. Our results are remarkably robust to a set of policy rules and do not validate the idea that larger countries are given unwarranted weights. In fact, bigger countries in the

Eurozone such as Germany and France are attributed an estimated implicit weight that is below the weight of their population or GDP size as a share of the Eurozone. Smaller countries, such as Greece, especially in the years following the financial crisis, receive the smallest in the sample. A comparison between the estimated weights and each country's degree of economic integration with Germany shows that the weights obtained are positively correlated with being more integrated with Germany, which is supported by the idea that "the Bundesbank provided the role model for the European Central Bank" (Beyer et al., 2008).

Concluding, neither economic nor population size strongly correlate with the weight attributed to each member-state. Germany, Belgium, and the Netherlands are, across the five different specifications, the countries with greater weights, whereas Greece, Ireland, Portugal, and Italy receive the smallest. Finally, there is a positive relationship between the estimated weights and the degree of economic integration with Germany, herein measured by the correlation of countries' output gaps and supply shocks, i.e. countries that reveal greater symmetry of business cycles and supply shocks with Germany have a greater weight *vis-à-vis* those less correlated or even asymmetric. Our analysis is of utmost importance as it provides unprecedented quantitative evidence to address the debate on the asymmetric consideration of Eurozone member-states by the ECB. We believe this analysis substantiates policy and political discussions that have heretofore not received solid empirical analysis.

2 Related Literature

In order to analyze the ECB's decision-making regarding interest rates, following its mandate to ensure price stability, one needs to understand how monetary policy decisions are *de facto* made. Hence, we first review some of the literature on monetary policy rules and, second, on measures of integration, as our aim is to establish a comparison between country weights and economic convergence over time.

In the decade of 1960s, what is known as the "rational-expectations revolution" contributed to the emergence of a vast range of literature on monetary policy rules (some seminal examples are Friedman, 1960, Kydland and Prescott, 1977, and Barro and Gordon, 1983), most arguing in favor of using policy rules rather than discretion. That influence continues to the present, with most modern central banks deciding on monetary policy "by adjusting the short-term nominal interest rate in response to various disturbances" (Romer, 2012).

Regarding specific policy rules, Taylor, 1993, is one of the most influential references, as the

author presents what is currently known as the Taylor rule, in which the short-term interest rate rises if inflation increases above a given target or if real GDP rises above trend. Given the remarkable fit of the rule to actual policy performance in the United States between 1987 and 1992, it became a benchmark for monetary policy analyses. Another significant contribution is one by Clarida, Galí, and Gertler, 1998, in which monetary policy reaction functions for six countries are estimated, namely Germany, Japan, the US, the UK, France, and Italy. Among different specifications, the authors consider a forward-looking Taylor rule by using expected rather than contemporaneous inflation, and they introduce an interest rate smoothing parameter to represent the notion that central banks tend to smooth changes in interest rates. These two features became standard practice in the estimation of monetary policy rules. Regarding findings, they conclude that while the first three countries had been pursuing an "implicit form of inflation targeting", the remaining "were heavily influenced by German monetary policy".

Several other empirical studies have sought to assess how monetary policy reacted to changes in inflation, the output gap, and other variables using the aforementioned rule, since there may be other policy objectives (Clarida et al., 1998, Taylor, 2001 and Muscatelli et al., 2002, among others). The same authors, Clarida et al., 2000, also estimate monetary policy reaction functions for the US pre- and post-1979, using a simple linear forward-looking smoothed rule. Gerlach and Schnabel, 1999, estimate linear Taylor rules using average interest rates, GDP-weighted average output gaps, and inflation in EMU countries for the period of 1990 to 1998, and conclude that, if there had been an institution such as the ECB which conducted monetary policy using a Taylor rule for that period, the aggregate behavior of interest rates would not have differed significantly from the observed behavior. Eleftheriou, Gerdesmeier, and Roffia, 2006, estimate monetary policy reaction functions for 11 EMU countries in the post-Maastricht period until 1998, using not only inflation and the output gap, but also the exchange rate, money stock, the German interest rate (in the case of Germany, the Federal Funds rate is used), and time dummies to capture "extraordinary events". The authors find that the augmented specification unambiguously improves the rule's fit for all countries, and that rules differ substantially across member-states.

Due to the plausibility of non-linearities in the impact of both inflation and the output gap on nominal interest rates, mostly because of their asymmetric adjustment to the business cycle[1], much of the relevant literature focuses on non-linear approaches. Hamilton, 1989, and Garcia

[1]During upswings, monetary policy tends to be more "hawkish", and during downturns more "dovish", as argued by Hamilton, 1989, Garcia and Perron, 1995, and Castro, 2011.

and Perron, 1995, consider, respectively, a two-state and a three-state Markov-switching model for the US interest rate and find evidence of regime switches in both the mean and variance of the series, thereby providing further support for the use of non-linear approaches. Wesche, 2003, also considers a Markov-switching model for France, Germany, Italy, the UK, and the US, and concludes that the two-states estimated can be classified as either restrictive or accommodative, using data from 1973 until the beginning of the EMU. Castro, 2011, estimates an augmented linear Taylor rule for the Eurozone, the UK, and the US, as well as an augmented smooth transition regression model, with both models including a financial conditions' index. Among other findings, the ECB and the Bank of England's behavior are best described by a non-linear specification, and the ECB reacts actively to expected inflation only when it is above a target of 2.5% and to the output gap when inflation is stabilized below its target. Murray et al., 2015, characterize the Fed's behavior for the period from 1965 to 2007 using a Taylor rule with endogenous Markov-switching coefficients and variance, and conclude that the regime-shift between states in the model occurs when "the Fed does and does not try to stabilize inflation by following the Taylor principle[2]".

Examples are scarce regarding counterfactual interest rate exercises. Wyplosz, 1999, uses the specification proposed by Clarida et al., 1998, to estimate the Taylor rules in several European countries. He then replaces as inputs, in the estimated rule for Germany, the average economic conditions in Europe, in order to obtain a counterfactual of what would have been the ECB's policy prior to the EMU, given that "the Bundesbank is known to have worked as the *de facto* leader in Europe". He concludes that, if the Bundesbank had set interest rates at a wider level, monetary policy would have been looser. Hayo, 2007, estimates linear Taylor rules for 11 EMU countries and then simulates a counterfactual interest rate path until 2004. He concludes that Germany was the only country that realized higher interest rates than warranted by its pre-EMU trajectory.

Concerning measures of integration, the literature is quite extensive. Mundell's, 1961, seminal contribution, later extended by McKinnon, 1963, and others, regarding optimum currency areas, argues that factor mobility and symmetry of shocks are crucial to ensure the proper functioning of common currencies. Thus, assessing labor and capital mobility pose important empirical research avenues, as analyzed by Arpaia et al., 2014, who conclude that, regarding labor, "the response of migration to shocks has been growing over time, becoming almost twice as important

[2]The Taylor Principle is commonly described as a policy rule having a stabilizing inflation coefficient, i.e. greater than 1.

after EMU completion". Another method of evaluating economic integration is assessing the symmetry of country-specific shocks, as performed by Bayoumi and Eichengreen, 1992 and 2018, or, in a similar logic, the symmetry of business cycles (Canova et al., 2007). Others focus on the integration of sovereign debt markets through yield co-movement (Ehrmann et al., 2007) on the real convergence between income levels and productivity (Franks et al., 2018), and on the synchronization of financial cycles, which have received a great deal of attention since the crisis. Given the abundance of contributions regarding integration, we conclude with Gros's, 2018, assertion that since the financial crisis there has been divergence between the Eurozone's northern and southern countries, especially regarding real wages, investment, and consumption, that is deeply connected with the motivation for the present analysis.

3 Empirical Strategy

In this section we describe our empirical strategy, which consists of three steps: the estimation of monetary policy rules, the computing of implicit weights, and the identification of aggregate supply and demand disturbances in order to measure the degree of economic integration between member-states.

3.1 Monetary policy rules

We begin by estimating monetary policy rules for the short-term interest rate in a set of member-states without monetary unification, and use those estimates to infer what the chosen country's reference rate would be after introduction of the Euro, assuming that the policy response function did not change. We produce counterfactual interest rate paths for each member-state using five different methods and two sets of models: (i) a baseline linear rule, (ii) an augmented linear rule, (iii) a baseline non-linear rule, (iv) an augmented non-linear rule, and finally (v) a baseline linear rule, using simulated data for country inflation and the output gap in the post-Euro period. Our aim is to assess the robustness of the estimated implicit weights to different methodologies.

Regarding linear rules, we begin by using the specification proposed by Clarida, Galí, and Gertler, 1998, in which the target interest rate responds to deviations in inflation and output from their targets, as in (1). i_t^* is the target short-term nominal interest rate, $\bar{i}$ is the long-term equilibrium nominal rate, π_{t+n} is the inflation rate between periods t and $t+n$, π^* is the inflation target, y_t is output, and y_t^* is potential output, with the difference between the last two being the output gap.

$$i_t^* = \bar{i} + \beta(\pi_{t+n} - \pi^*) - \gamma(y_t - y_t^*) + \epsilon_t \tag{1}$$

Additionally, as proposed by the authors, we incorporate an interest rate smoothing mechanism, in order to model the partial adjustment undertaken by central banks given the implications of sudden policy changes. Thus, the contemporaneous interest rate is a combination of the target and last period's rate, as presented in (2).

$$i_t = \rho i_{t-1} + (1-\rho) i_t^* + v_t, \rho \in [0,1] \tag{2}$$

Combining equations (1) and (2), along with $\alpha = \overline{r} - \beta\pi^*$ to facilitate estimation, we obtain our final baseline specification as in (3), with x_t being the output gap and $D1$ a dummy variable to account for structural breaks in some countries' series.

$$i_t = \rho i_{t-1} + (1-\rho)(\alpha + \beta\pi_{t+n} + \gamma x_t + \delta_1 D_1) + v_t \tag{3}$$

For the augmented linear specification presented in (4), we include the Federal Funds rate, fed_t , the long-term interest rate on each country's 10-year government bonds, i_t^{lt}, and a national share prices' index, sp_t. The idea is that besides responding to deviations in inflation and the output gap, the linkage posed by financial and trade integration with the United States and market sentiment may affect the decision regarding short-term interest rates, because rules serve as guidelines and some judgement may be recommended (Taylor, 1993). These variables consider a broader set of economic indicators when compared to the baseline specification.

$$i_t = \rho i_{t-1} + (1-\rho)(\alpha + \beta\pi_{t+n} + \gamma x_t + \lambda_1 fed_t + \lambda_2 i_t^{lt} + \lambda_3 sp_t + \delta_1 D_1) + v_t \tag{4}$$

As mentioned in the previous section, the Taylor rule may be subject to parameter instability, especially over the course of the business cycle or according to different policy stances (Ghysels and Marcellino, 2018). Therefore, we estimate non-linear rules using a two-state Markov-switching procedure. As we do not observe the discrete binary state variable, S_t, we will assume that it follows a Markov chain, allowing for probabilistic rather than deterministic regime shifts. We introduce time-varying parameters for inflation and the output gap, and allow for switching in the variance of the error term, thereby deterring the possibility that periods of shifts in volatility are confounded with regime switches (Sims and Zha, 2006). Equation (5) presents the baseline non-linear specification and equation (6) the augmented non-linear version.

$$i_t = \rho i_{t-1} + (1-\rho)(\alpha + \beta_{S_t}\pi_{t+n} + \gamma_{S_t}x_t + \delta_1 D_1) + u_t \tag{5}$$

$$i_t = \rho i_{t-1} + (1-\rho)(\alpha + \beta_{S_t}\pi_{t+n} + \gamma_{S_t}x_t + \lambda_1 fed_t + \lambda_2 i_t^{lt} + \lambda_3 sp_t + \delta_1 D_1) + u_t \tag{6}$$

$$\beta_{S_t} \in \{\beta_1, \beta_2\}, \gamma_{S_t} \in \{\gamma_1, \gamma_2\}$$

$$u_t \sim N(0, \sigma_{S_t}), \;\; \sigma_{S_t} \in \{\sigma_1, \sigma_2\} \tag{7}$$

Finally, the last specification considered uses simulated data based on countries' trajectories prior to unification rather than actual data in the post-Euro period. Our purpose is to estimate the short-term interest rates chosen by national monetary authorities from the inflation rate and output gap series according to their pre-EMU trajectory. We use a Monte Carlo simulation to generate data for the two variables, based on two distinct AR(2) processes, as in (8) and (9).

$$x_t = a_0 + a_1 x_{t-1} + a_2 x_{t-2} + e_{1t} \tag{8}$$

$$\pi_t = b_0 + b_1 \pi_{t-1} + b_2 \pi_{t-2} + e_{2t} \tag{9}$$

The Monte Carlo simulation consists of the following steps: first, equations (8) and (9) are estimated to obtain the coefficients, a_i and b_i, and the standard deviation of the error term; second, data are generated to reproduce a normally distributed random process for the sequences $\{e_{1t}\}$ and $\{e_{2t}\}$, which will then be used in the simulation as the error terms; third, using the estimates from the first step, the randomly-generated errors, and the last two observations of both the inflation and output gap series, we construct the $\{x_t\}$ and $\{\pi_t\}$ sequences. As each generated sequence of the stochastic component can be interpreted as a scenario among several possible outcomes, we generate 10 repetitions for both inflation and the output gap. Thereafter, we estimate the baseline linear rule using the generated sequences for all repetitions, and then compute the implicit weight for each of those series. Finally, we perform a standard geometric average of the weights per country.

3.2 Implicit weights

After estimating the monetary policy rules for each country using the aforementioned methods, we use dynamic forecasting to produce counterfactual interest rates for the EMU period. Using both the actual rate set by the ECB and the country-specific counterfactual rates, we obtain the implicit weight each country has on the ECB's decision-making. Using the inverse of a simple root mean square error (RMSE) as presented in (10), we obtain country-specific weights, w_c. For interpretation purposes, we then consider the relative frequency of implicit weights in order to have each country's weight as a proportion of the total, thus summing up to 1. The concept of monetary weight draws on that of monetary stress, initially proposed by Clarida, Galí, and Gertler, 1998, and further developed by Sturm and Wollmershäuser, 2008.

$$w_c = \frac{1}{\sqrt{\sum_{t=0}^{T}(i_{c,t} - \hat{i}_{c,t})^2}}, \quad c \in [1, 11] \tag{10}$$

3.3 Measuring economic integration

A much-debated feature of monetary unification is the potential feedback loop between the sharing of a common currency and the synchronization of underlying economic shocks. Hence, we examine the extent to which country weights estimated in the previous section result from the degree of synchronisation between each member-state's economic developments and Germany's, the Eurozone's largest economy and certainly one likely focused on for the ECB's decision-making. We consider three measures of economic integration: (i) the correlation of countries' output gaps with those of Germany, (ii) the correlation of countries' aggregate supply shocks with Germany's and (iii) the correlation of countries' aggregate demand shocks with Germany's, with the last two following Bayoumi and Eichengreen, 1992 and 2018. These indicators are assessed over three different periods: (i) before the EMU, (ii) after the EMU and until the SDC, and (iii) after the SDC.

The output gap is obtained using a Hodrick-Prescott filter, as described below in Section 4. The identification of aggregate supply and demand disturbances is achieved using a decomposition proposed by Blanchard and Quah, 1989, which allows for the distinction between permanent and temporary shocks. In this setting, which relies on a standard aggregate demand-aggregate supply (AD-AS) framework, a rise in aggregate supply (i.e. a supply shock) permanently increases output and decreases prices. On the other hand, a positive shock in aggregate demand

has only a temporary effect on output, which rises in the short-run, and a permanent increase in prices. Further details of the procedure can be found in Appendix 1.

4 Data

We examine 11 countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain[3]. The remaining EMU countries were excluded from the analysis given their late entry in the EMU, thus restraining any comparison until their *de facto* adoption of the Euro, and limiting the comparability of results.

For the estimation of monetary policy rules, we use quarterly data from the first quarter of 1980 to the second quarter of 2018 in most specifications. However, the specific time span of available data varies.

Following the literature, we measure the short-term interest rate as the 3-month money market interest rate. This series combines Eurostat and OECD data since the two have earlier starting periods for different countries. The inflation rate corresponds to the OECD's annual growth rate of the Consumer Price Index. The output series corresponds to the OECD's Quarterly National Accounts' GDP using the expenditure approach, in millions of 2010 US dollars, seasonally adjusted. The output gap was obtained using a Hodrick-Prescott filter[4] on the logarithm-transformed output series, multiplied by 100 to obtain more intelligible estimates. The Federal Funds rate was retrieved from the Federal Reserve of St. Louis' database, converted from monthly to quarterly data. The long-term interest rate combines the Eurostat's EMU criterion convergence bond yields and the OECD's long-term interest rate, both for 10-year government bonds. Finally, countries' stock price indices were extracted from the OECD.

For the purpose of estimating the correlation of member-states' aggregate supply and demand shocks with Germany's, we consider the period from 1980 to 2016, for which we collected data on the yearly GDP at current prices and on the GDP deflator, referenced in 2010, both from the OECD, and relying on an output approach. Real GDP was computed for all countries using the aforementioned series.

Before proceeding, we consider the three main variables of our analysis: the short-term interest rate, the inflation rate, and the output gap, presented in Figure 1. The graphical representation of the series highlights significant heterogeneity in the short-term interest rates and inflation prior to the EMU, that countries such as Greece (more saliently than the remaining),

[3]Luxembourg was excluded following the literature and given its size in the context of the Eurozone.
[4]The smoothing parameter considered was $\lambda = 1600$, as is standard practice when using quarterly data.

Ireland, Italy, Portugal, Spain, and, to a certain extent, Finland, experienced greater and faster reductions in interest rates by adopting the Euro.

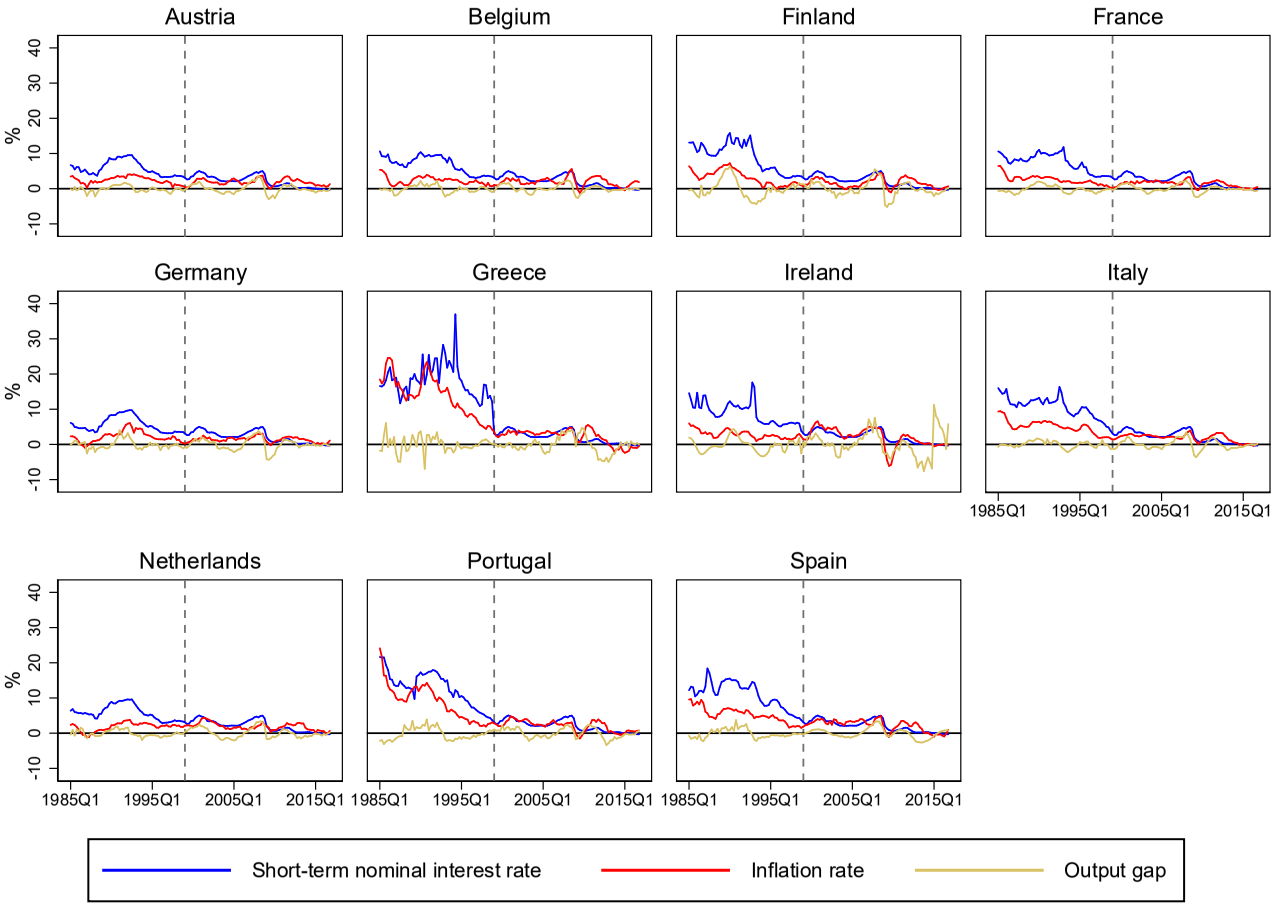
5 Estimation

For each country, both the baseline and the augmented linear rules are estimated using a two-step efficient generalized method of moments (GMM), which derives an optimal weighting matrix with heteroskedastic and autocorrelation consistent (HAC) standard errors, thus providing efficient estimates. The instrument set used includes up to four lags of each of the dependent and independent variables. Since we have more instruments than endogenous regressors, we perform the Sargan test of overidentifying restrictions to assess the validity of the considered instruments. The test considers the joint null hypothesis that the included instruments are uncorrelated with the error term, thus being valid. We fail to reject the null for all of the linear rules. For estimation purposes, several inflation specifications were used, ranging from contemporaneous to six quarters-ahead, and the specification that maximized the adjusted R^2 was selected.

As for the estimation of non-linear rules using a Markov-switching approach, the inflation specification used in each model was chosen according to the minimization of the Akaike Information Criterion (AIC). Regarding the variance-covariance matrix, a White-Huber sandwich estimator is used in order to create estimates that are robust to potential heteroskedasticity.

We use the estimated monetary policy rules to obtain counterfactual monetary policy paths using dynamic forecasting. Lastly, it is important to note that, following the literature, we assume that the variables are stationary across the period considered (Clarida et al., 1998, Eleftheriou et al., 2006).

Figure 1: Short-term nominal interest rate, inflation rate, and output gap between 1985Q1:2016Q4



Source: Eurostat, OECD, and authors' calculations.
Notes: The output gap corresponds to the logarithm-transformed series multiplied by 100. The grey dashed line represents the beginning of the EMU, i.e. 1999Q1.

6 Results

6.1 Parameter estimates

The estimation results of the different policy rules are presented in Appendix 2. For the last specification considered, namely the baseline linear rule using simulated data, we refrain from displaying the parameter estimates obtained given the number of rules estimated for the different values of inflation and the output gap of each repetition of the Monte Carlo simulation.

Regarding the baseline linear rules' estimates using equation (3) presented in Table 2, the interest rate smoothing parameter, ρ, is consistent with the literature, ranging from 0.64 to 0.95. This is entirely intuitive given that countries such as Greece, Italy, and Ireland, which experienced greater changes in interest rates, mostly because of the downward pressure placed by convergence, exhibit less of a preference for interest rate smoothing (i.e. are less influenced by the last period's rate). The magnitude of the coefficient of inflation, β, is also quite informative. A $\beta > 1$ suggests that monetary policy is considered to be inflation-targeting as it is adjusting to stabilize inflation, whereas, if the opposite is observed, monetary policy is said to be accommodative (Clarida, Galí, and Gertler, 1998). As can be observed, Greece, the Netherlands, and Portugal are the only countries that show an inflation coefficient of less than unity, while Belgium is the country that showcases a more aggressive behavior toward inflation through a higher β. Lastly, not all countries are responsive to the output gap, particularly Ireland, although most react in a positive manner, as expected.

When we move to the augmented linear specification in equation (4), the ajusted R^2 increases for all member-states considered, achieving in some cases almost full explanatory power (e.g. 99.18% for the Netherlands and 98.74% for Portugal). By also considering the Federal Funds rate, the long-term interest rate, and share prices, we observe a decrease in most estimates of the interest rate smoothing parameters, as well as in the responses to inflation and the output gap. Austria and Germany are the only countries showing an increase in the impact of inflation, with Germany being the most "hawkish" country of the sample, and with Greece, Ireland, Italy, Portugal and Spain exhibiting an accommodative behavior.

The results from the baseline and the augmented non-linear rules obtained from equations (5) and (6) are presented in Table 3. Here we observe two-states for inflation and the output gap, with the characterization of states being quite heterogeneous among countries. For Germany, for example, we observe a state with accommodative monetary policy and responding positively

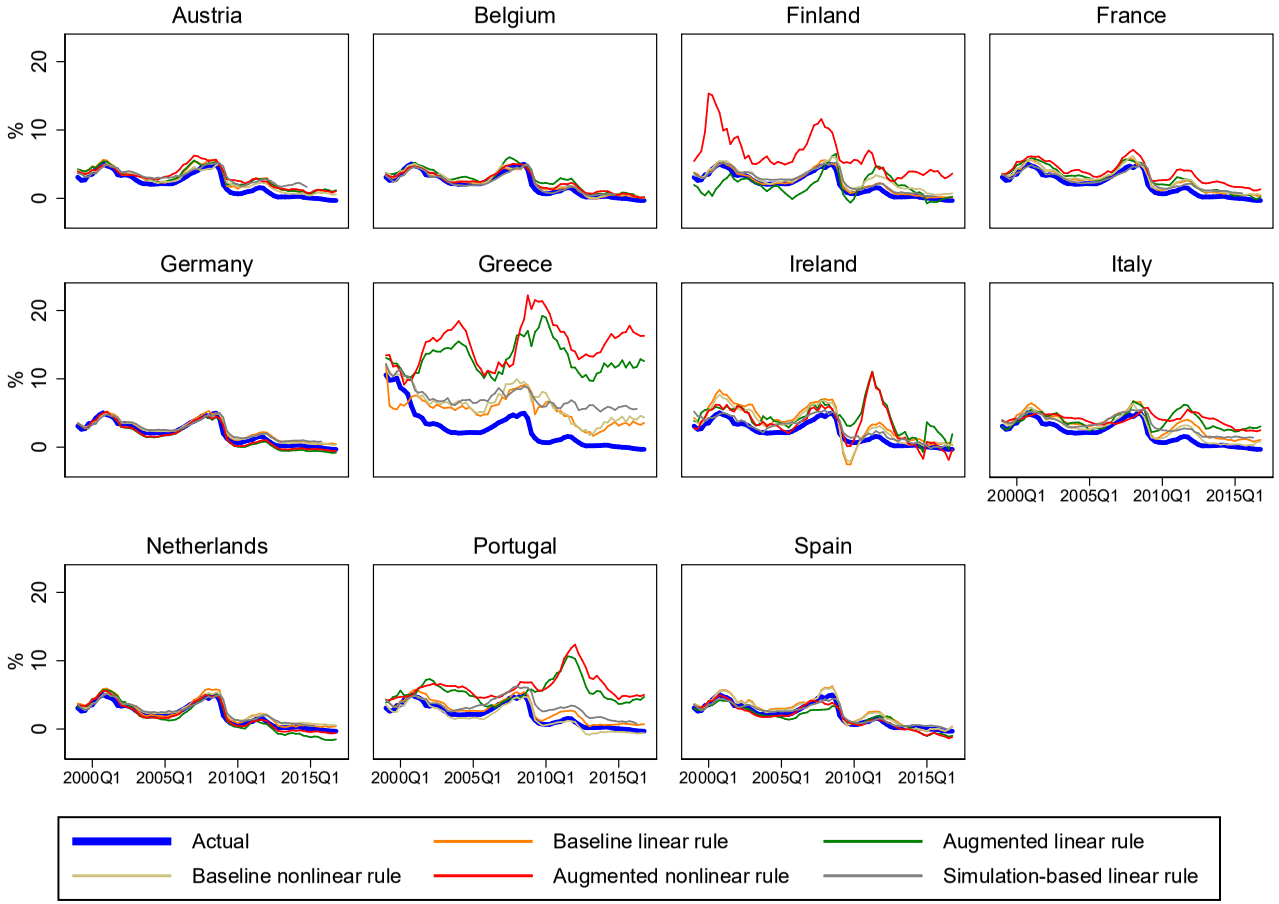
to the output gap, and another in which it is inflation-targeting and responding negatively to the business cycle, thus representing two distinct regimes. In the cases of Ireland, Portugal, and Spain, we do not find evidence of the existence of two-states for these variables' impact on interest rates. In the augmented non-linear rule, as in the case of linear rules, we observe a smaller degree of interest rate smoothing when compared to the baseline. Here, the only countries in which different states characterize different monetary policy regimes are Austria and Germany. For the remaining countries, either both states correspond to the same monetary policy regime or, as previously identified, there is no statistically significant evidence of two distinct states.

6.2 Counterfactual interest rate paths

After the estimation of the five above mentioned rules, which provide an admirable fit of the pre-EMU nominal short-term interest rate series, we forecast the counterfactual interest rate paths. The results are presented in Figure 2, along with the observed interest rate for the period beginning in 1999.

As can be observed, the sample of countries can be approximately divided into two groups: countries where counterfactual estimates track actual interest rates closely, and countries where the opposite holds. The first group comprises Germany, the Netherlands, Austria, Belgium, France, and Spain. Other countries, including Finland, Ireland, Italy, Portugal, and, most significantly, Greece, see a marked disconnect between estimated counterfactual interest rates and the actual rate. The relevance, that is, the magnitude and frequency of deviations between the two rates is reflected in the country-specific weights. In the case of Greece, Portugal, and Ireland, these member-states were among those experiencing a greater decline in inflation and short-term interest rates upon entering the EMU, as highlighted in Figure 1, and were, unambiguously, the countries hardest hit by the recession. Additionally, the paths of the augmented linear and non-linear rules predict higher rates than those using only inflation and the output gap, meaning that the capturing of further dynamics leads to an implied greater divergence *vis-à-vis* the actual rate.

Figure 2: Counterfactual interest rate paths

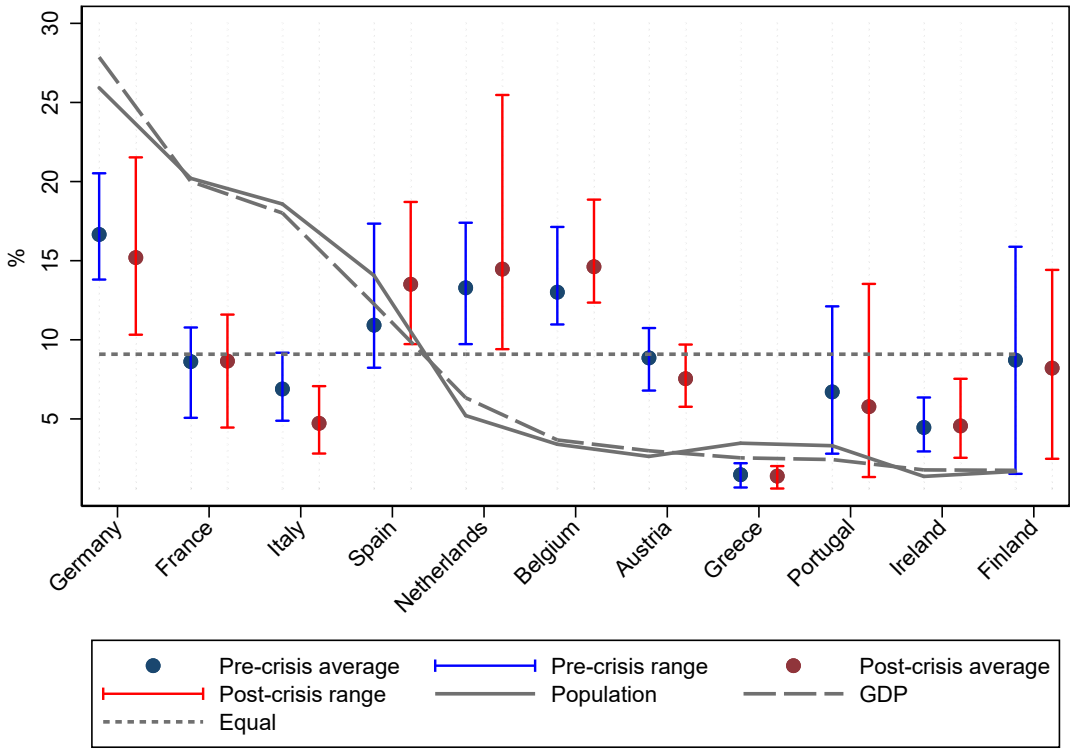


Source: Eurostat, OECD, and authors' calculations.

6.3 Implicit weight distribution

Using the estimated counterfactual monetary policy paths, we computed the weight measures and their relative frequencies for all member-states, which can be found in Appendix 3. Figure 3 plots the five implicit weight measures, containing both the pre- and post-crisis range of estimates. These are compared with the countries' weights according to their population and economic size, as well as an equal size series for comparative purposes. The estimates obtained are presented in Table 4 and similar graphical representations of each of the five estimated weight measures can be found in Figures 4, 5, and 6.

Figure 3: Average weight and maximum-minimum range of weight estimates



Source: Authors' calculations, Eurostat, and OECD.
Notes: The average weight estimate consists of the average of the five different implicit weight estimates, whereas the maximum-minimum range corresponds to the maximum and minimum weights of those estimated. The population and GDP series presented consist of the country-specific averages from 2010 to 2016.

In the baseline linear model, Finland, Germany, and Belgium have the largest estimated weights, whereas Greece, Ireland, and Italy have the smallest. During the crisis, namely between 2010 and 2016, Germany loses a considerable share of weight compared to other countries, while

Belgium experiences the opposite. However, as before, Ireland and, especially, Greece remain associated with the lowest estimated weights. The augmented linear specification confirms Germany's weight, followed by the Netherlands. Greece, Portugal, and Ireland are at the opposite end of the distribution. In both the baseline and the augmented linear models, we find that countries more keen on fighting inflation, such as Germany, Belgium, and the Netherlands, gain greater weight in the post-Euro period, suggesting that their preferred policy in the pre-Euro period was close to the preferences of the ECB in the post-Euro period. Our results are thus consistent with the ECB's mandate of maintaining price stability. Finally, a striking result is that the population and economic sizes do not predict the countries' estimated weights in the ECB's policy.

Considering the estimated weights using the baseline non-linear rule, we find a much more homogeneous implicit weight distribution across member-states than when using other estimation methods. Germany still exhibits the largest weight, followed by Portugal, Belgium, and the Netherlands, which all have very similar weights of around 11%. Greece and Ireland have the lowest weights in our sample. After 2010, Ireland, followed by Spain and Belgium, improve their weights, while the remaining countries experience the opposite, leaving Belgium as the heaviest member-state and pushing Finland to the bottom. The augmented non-linear specification presents a greater discrepancy of monetary weights across countries, similarly to the augmented linear case. This result derives from the fact that the inclusion of more contrasting dynamics, represented by the country-specific long-term interest rates or national share prices, translate into more divergent implied interest rates. Here, Germany, the Netherlands, Spain, and Belgium have the biggest weights (between 20% and 17%), with Greece, Portugal, Italy, Finland, and Ireland – especially after the crisis – presenting the smallest.

Finally, using a baseline linear rule with the simulated series for inflation and the output gap, Germany, the Netherlands, and Belgium arise as the countries with the greatest weights, which does not change after the crisis. Greece, Ireland, Portugal, and Italy have the lowest weights, with all of them losing weight in the post-crisis period, with the exception of Ireland. This exercise is of particular interest given that in the previous specifications we use observable data for inflation and the output gap in the context of the EMU, whereas here we use simulated data for those variables following their trajectories running-up to unification, thereby further deepening the counterfactual exercise.

Analyzing the results across the different estimation procedures, we confirm differing weight estimates across countries, with a few member-states given persistently higher weights, while

others remain in the bottom the distribution. Despite the existence of some outliers, the pattern observed is remarkably constant. Germany, closely followed by the Netherlands, Belgium, and Spain, are attributed the largest policy weights in the ECB's interest rate setting. On the other hand, Greece, Ireland, Portugal, and Italy systematically have smaller weights. After the financial crisis most countries lose weight, to the benefit of Spain, Belgium, and the Netherlands. Noticeably, Germany's centrality to policy-making wanes somewhat during the crisis. Our results can stem from the severity of the crisis for Southern European countries, which with the exception of Spain diverge from the path of Germany and other countries.

6.4 Output gaps and aggregate shocks

We now assess the relationship between the estimated implicit weights and a set of indicators of economic integration. For this purpose we use three economic integration measures, as previously mentioned: (i) the synchronization of the cyclical component of GDP, (ii) of supply shocks, and (iii) of demand shocks. We use Germany as a benchmark, as it is the largest economy in the Eurozone, and perceived as the anchor for the ECB's decision-making. We want to measure the extent to which country-specific weights reflect the degree of real integration with Germany.

The results are available in Table 1. Concerning the output gaps, in the period of 1980-1998, the Netherlands stands as the country with the highest output gap correlation with Germany, at 63%, closely followed by Austria, 61%, and Belgium, 53%. In the period of 1999-2009, output gaps across the Eurozone became considerably more correlated with Germany's, the exception being Greece, 24%. The pattern partially reverses in the period of 2010-2016, i.e. after the economic crisis, more noticeably for Greece, Ireland, Portugal, and Spain, precisely the countries with lower weights.

Table 1: Correlation of countries' output gaps, supply shocks, and demand shocks with Germany's

	1980-1998	1999-2009	2010-2016	1980-1998	1999-2009	2010-2016	1980-1998	1999-2009	2010-2016
Austria	0.613	0.920	0.896	0.644	0.911	0.930	0.267	0.317	0.563
Belgium	0.529	0.824	0.769	0.675	0.790	0.779	0.458	-0.156	0.028
Finland	-0.006	0.898	0.830	-0.265	0.892	0.963	0.283	0.246	0.311
France	0.365	0.925	0.887	0.394	0.860	0.742	0.420	-0.107	0.718
Greece	0.424	0.244	-0.512	0.363	0.609	-0.085	0.150	0.410	-0.427
Ireland	0.422	0.752	0.082	-0.068	0.505	-0.135	0.382	-0.274	0.240
Italy	0.453	0.940	0.700	0.513	0.889	0.888	0.003	0.287	0.537
Netherlands	0.637	0.853	0.679	0.163	0.921	0.753	0.112	-0.211	0.348
Portugal	0.209	0.754	0.092	0.300	0.830	0.731	0.452	0.041	0.217
Spain	0.404	0.845	0.188	0.208	0.774	0.686	0.648	-0.035	0.490

Source: Authors' calculations.

Analyzing aggregate disturbances, we find that countries' supply shocks become more correlated with Germany's from the period of 1980-1998 to 1999-2009. The lowest supply shock correlation with Germany is Ireland's, 50%, and Greece's, 61%. In the crisis period, supply shocks become more asymmetric for Greece and Ireland, and experience a slight decrease for all of the other countries. As for the demand shocks, results are less intuitive. Between the periods of 1980-1998 and 1999-2009, demand shocks between Germany and the remaining countries become more asymmetric, providing evidence against convergence. Interestingly, Greece is the only country whose demand shocks are negatively correlated with Germany's.

In conclusion, for the period as a whole, we observe that implicit weights are positively associated with greater correlation of output gaps and supply shocks between member-states and Germany, as can be see in Figures 7 and 8 in Appendix 4. On the other hand, implicit weights are negatively associated with the cross-country correlation of demand shocks, as in Figure 9 in Appendix 4. The first effect is quite intuitive: larger weights are associated with a deeper integration with Germany. However, the result on demand shocks contradicts the conventional reasoning. Nonetheless, as argued by Bayoumi and Eichengreen, 1992, demand disturbances are likely to be less informative than supply disturbances, as demand shocks reflect country-specific policies.

7 Conclusion

The economic and monetary union in Europe comprises countries with different economic fundamentals. This is a challenge for European institutions such as the European Central Bank, which sets policies that cannot accommodate differing, and sometimes diverging, economic paths. In this paper, we present a new method to estimate the implicit weights that guide the ECB's Governing Council policy choices on the reference interest rate for the Eurozone. We rely on aggregate macroeconomic data prior to the introduction of the Euro to estimate the different national monetary policy responses and then use the estimated response coefficients to produce counterfactual national monetary responses in the post-Euro period, after 1999. We use alternative methods, and compute, for each method, the distance between the counterfactual interest rate and the actual ECB reference interest rate.

Our findings are clear and robust to different specifications. First, we find that countries' implicit weights are not strongly correlated with a member-state's economic or population size. Germany and France receive large weights that are considerably below their shares of output and population in the Eurozone. Second, across different specifications – including linear, time-varying, and simulated data-based – countries receiving the greater weights are Germany, Belgium, and the Netherlands, with Greece and Ireland, closely followed by Portugal and Italy, showing the lowest weights. Third, countries receiving smaller weights are those whose output gaps and supply shocks reveal a lower correlation *vis-à-vis* Germany's.

Notwithstanding, our analysis has some limitations. First, we assume that each country's monetary authority would maintain their preferences regarding output and inflation in the post-Euro period as in the period prior to unification, thus responding in the same manner to macroeconomic developments. Additionally, any attempt to predict policy behavior based on historical data is subject to the Lucas critique, as policy-makers' decisions vary with changes in the structure of the data, thereby leading to policy-variant parameters.

The Eurozone is arguably the most important monetary policy experience ever, and the ECB's policy-making suffers frequent criticism regarding the perceived imbalances insofar as country economic fundamentals are taken into account differently. Our estimates suggest that such concerns over asymmetry do not follow from the obtained weights when compared to countries' economic and population sizes as a share of the EMU11. In sum, our results suggest that the different implicit country weights obtained from the ECB's behavior do not differ to a degree that constitutes a serious political liability to the future of European institutions. However, special

consideration of smaller countries' idiosyncratic circumstances, such as those arising in the wake of the SDC, are strongly advised.

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Appendices

Appendix 1 – Identification of aggregate shocks

We consider a bivariate VAR(2) representation for the first difference of the logarithm series of real GDP, y_t, and the GDP deflator, p_t, defined as

$$x_t = Ax_{t-1} + B\epsilon_t, \text{ with } x_t = \begin{bmatrix} \triangle y_t \\ \triangle p_t \end{bmatrix} \text{ and } \epsilon_t = \begin{bmatrix} \epsilon_{dt} \\ \epsilon_{st} \end{bmatrix} \tag{11}$$

where ϵ_t are the structural shocks and $B = P^{-1}$, with P being the triangular matrix that is used to obtain the structural shocks from the reduced-form residuals e_t such that $\epsilon_t = Pe_t$. The corresponding moving average representation is

$$x_t = (I - AL)^{-1}B\epsilon_t \tag{12}$$

with the cumulative long-run response of output and prices to structural shocks being

$$(I - AL)^{-1}B = \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \tag{13}$$

As previously stated, the considered framework implies that that supply shocks have permanent effects on both output and prices, while demand shocks have a temporary effect on output and a permanent one on prices. Thus, for identification, we impose that $\pi_{11}b_{11}+\pi_{12}b_{21} = d_{11} = 0$, i.e. the demand shock ϵ_{dt} has no long-run impact on output. This restriction, along with the other three imposed on the variance-covariance matrix $\sum_\epsilon$ – namely the normalization of the variances of ϵ_{dt} and ϵ_{st}, and the imposing of orthogonality between the structural shocks – allows for exact identification of the matrix B and, subsequently, of supply and demand shocks.

Appendix 2 – Parameter estimates

Table 2: Estimates of the baseline and augmented linear Taylor rule specifications

Countries	n	ρ	β	γ	α	λ_1	λ_2	λ_3	δ_1	Adjusted R^2
Austria	6	0.75***	1.37***	1.52***	2.73***	–	–	–	–	0.9591
	6	0.74***	1.67***	1.07***	-0.35	0.09**	-0.04	0.53***	–	0.9675
Belgium	6	0.93***	3.29***	1.47**	-1.47	–	–	–	–	0.9451
	4	0.81***	1.53***	0.20	-42.73***	-1.01***	2.52***	9.00***	–	0.9674
Finland	3	0.90***	1.50**	1.02***	2.51	–	–	–	–	0.9314
	0	0.43***	1.02***	0.64***	20.21***	-0.66***	0.19	-4.36***	–	0.9542
France	3	0.83***	1.83***	1.78***	3.11***	–	–	–	–	0.9255
	4	0.70***	1.02***	0.86***	-17.93***	-0.65***	1.65***	3.92***	–	0.9387
Germany	6	0.79***	1.49***	0.63***	2.27***	–	–	–	–	0.9613
	6	0.98***	3.26***	0.15	-95.31***	5.72***	1.16	14.32***	–	0.9743
Greece	0	0.64***	0.49***	1.12**	10.06***	–	–	–	58.96***	0.6347
	2	0.33***	0.78***	0.79***	12.86***	-2.00***	–	1.38**	25.09***	0.8292
Ireland	0	0.69***	2.20***	-0.06	2.22	–	–	–	–	0.7060
	2	0.35***	0.13***	0.40***	-6.61***	-0.48***	1.52***	1.39***	–	0.8829
Italy	0	0.66***	1.35***	0.91***	3.38***	–	–	–	–	0.9000
	2	0.63***	-0.23***	0.52***	14.88***	0.33***	0.68***	-3.29***	–	0.9721
Netherlands	4	0.89***	0.84*	2.91***	4.16**	–	–	–	–	0.9603
	2	0.88***	1.07***	1.42***	-51.69***	-0.62***	3.74***	8.41***	–	0.9918
Portugal	0	0.79***	0.95***	0.79***	3.26	–	–	–	–	0.9422
	4	0.28***	0.61***	0.25***	5.47***	-0.80***	0.79***	-0.50**	–	0.9874
Spain	0	0.77***	1.86***	0.62***	0.44	–	–	–	–	0.8940
	6	0.59***	0.22**	0.00	2.14	0.15**	1.05***	-1.35***	–	0.9272

Source: Authors' calculations.
Notes: ***, **, and * mean statistically significant at 1%, 5%, and 10% significance levels, respectively. The column n denotes the number of quarters-ahead considered for inflation, as in π_{t+n}.

Table 3: Estimates of the baseline and augmented non-linear Taylor rule specifications

Countries	n	ρ	β_1	γ_1	β_2	γ_2	α	λ_1	λ_2	λ_3	δ_1
Austria	6	0.83***	1.68***	1.86***	2.70***	-1.60**	0.99	–	–	–	–
	6	0.69***	0.54**	0.31	1.41***	-0.15	-2.92***	0.16*	0.49***	0.05***	–
Belgium	6	0.91***	1.85**	3.28***	3.28***	0.45	0.19	–	–	–	–
	2	0.66***	-0.57**	0.16	0.87**	-0.09	-5.79***	-0.10	1.28***	0.06***	–
Finland	0	0.71***	1.03***	0.17	2.19***	-0.51	2.08***	–	–	–	–
	6	0.61***	0.57***	-0.69***	0.72***	0.57***	-11.75***	-1.34***	2.25***	0.21***	–
France	2	0.80***	1.44***	1.45***	1.94***	1.42**	3.12***	–	–	–	–
	2	0.62***	0.67***	1.19***	0.96***	1.29***	0.49	-0.74***	1.04*	0.03	–
Germany	6	0.87***	0.73***	1.61***	1.73**	-3.64*	3.09***	–	–	–	–
	6	0.95***	0.96***	-2.08***	2.10***	1.96*	-21.52***	2.88***	0.13	0.12***	–
Greece	2	0.60***	0.30***	0.04	0.59***	1.81***	10.75*	–	–	–	47.81***
	6	0.27***	0.67***	0.36**	0.83***	1.39***	23.00***	-2.29***	–	0.00	24.27***
Ireland	0	0.76***	2.23**	0.41	2.17	-0.14	1.95	–	–	–	–
	0	0.28***	-0.15	0.38***	0.84***	0.18*	-3.84**	-0.39**	1.48***	0.01	–
Italy	2	0.76***	1.70***	0.96***	1.70***	0.82	1.72	–	–	–	–
	4	0.33***	-0.27**	0.24*	0.28***	-0.63***	-3.87	-0.12	0.72***	-0.01**	–
Netherlands	4	0.86***	-0.82	1.17	1.39***	0.69	5.47***	–	–	–	–
	6	0.87***	0.21***	0.21***	0.88***	1.60***	-6.82***	0.61***	0.92***	0.03***	–
Portugal	6	0.99***	8.85	26.96	29.80	249.96	-175.84***	–	–	–	–
	0	0.23*	0.09	-0.66	0.49*	0.07	2.19*	-0.68*	0.82***	0.02	–
Spain	0	0.81***	1.68**	1.40***	2.14	-0.66	0.54	–	–	–	–
	6	0.70***	0.31	-0.04	0.52*	-0.30	-7.75***	0.61**	1.07***	0.03	–

Source: Authors' calculations.
Notes: ***, **, and * mean statistically significant at 1%, 5%, and 10% significance levels, respectively. The column n denotes the number of quarters-ahead considered for inflation, as in π_{t+n}.

Appendix 3 – Implicit weight estimates

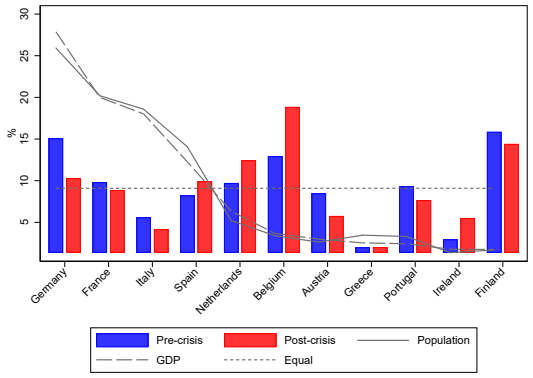
Table 4: Estimated weights for all considered specifications for the period of 1999 to 2016, %)

	1999-09	2010-16	1999-09	2010-16	1999-09	2010-16	1999-09	2010-16	1999-09	2010-16
Austria	8.48	5.77	10.74	9.70	9.77	8.98	6.79	7.42	8.51	5.85
Belgium	12.94	18.86	10.97	12.35	11.64	14.19	17.13	13.88	12.37	13.81
Finland	15.88	14.42	5.32	6.92	8.94	5.27	1.53	2.48	11.91	11.97
France	9.81	8.88	8.58	11.59	8.88	7.65	5.07	4.45	10.78	10.70
Germany	15.08	10.32	20.52	18.59	13.85	12.84	20.03	21.53	13.81	12.70
Greece	2.00	2.02	0.85	0.96	1.66	1.80	0.67	0.60	2.20	1.55
Ireland	2.95	5.52	5.21	2.83	3.56	7.54	6.36	2.54	4.23	4.37
Italy	5.60	4.17	8.09	3.60	9.18	7.07	4.88	2.81	6.71	5.96
Netherlands	9.73	12.45	15.01	12.80	11.57	9.41	17.40	25.47	12.72	12.22
Portugal	9.31	7.67	3.65	1.95	12.11	13.53	2.80	1.33	5.65	4.39
Spain	8.23	9.92	11.04	18.71	8.85	11.73	17.34	17.47	9.17	9.73

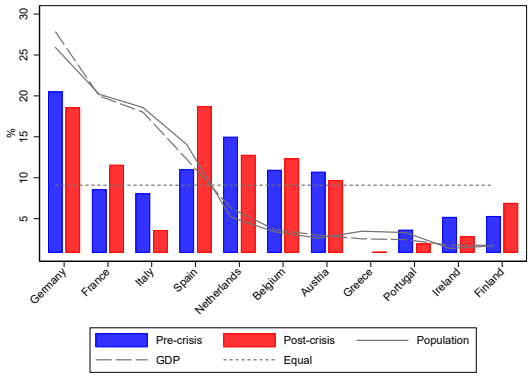
Source: Authors' calculations.
Notes: The implicit weight estimates presented were estimated using the following rules: (i) baseline linear rule, (ii) augmented linear rule, (iii) baseline non-linear rule, (iv) augmented non-linear rule and (v) simulated data-based linear rule.

Figure 4: Estimated weights using the baseline and the augmented linear Taylor rules

(a) Baseline specification



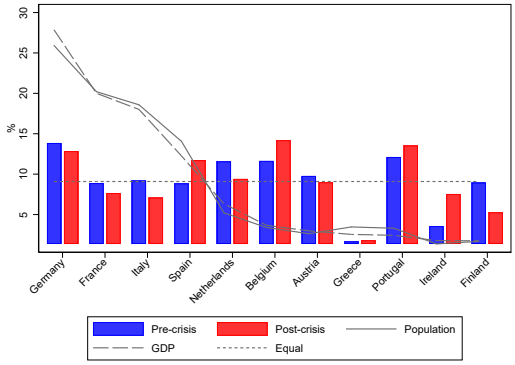
(b) Augmented specification



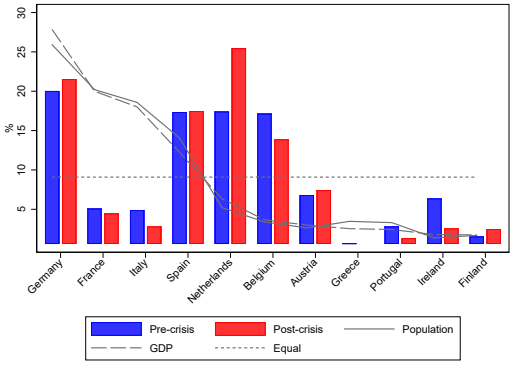
Source: Authors' calculations.

Figure 5: Estimated weights using the baseline and the augmented non-linear Taylor rules

(a) Baseline specification

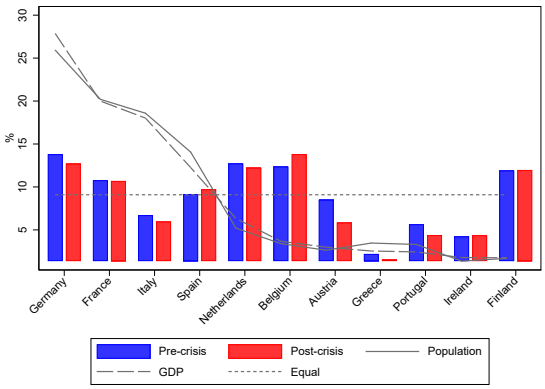


(b) Augmented specification



Source: Authors' calculations.

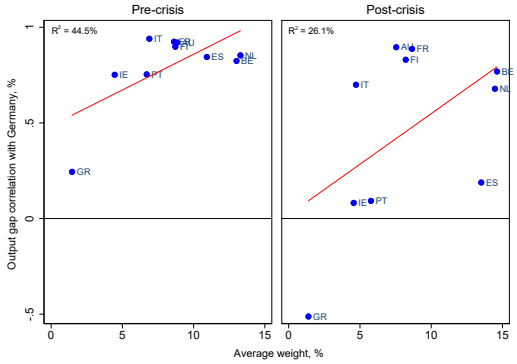
Figure 6: Estimated weights using a baseline linear Taylor rule with simulated data



Source: Authors' calculations.

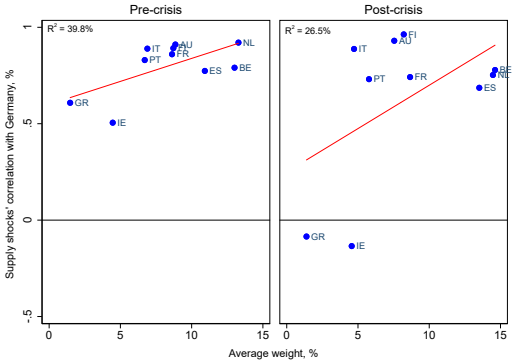
Appendix 4 – Implicit weights and economic integration

Figure 7: Average country weights and correlation between countries' output gaps and Germany's output gap



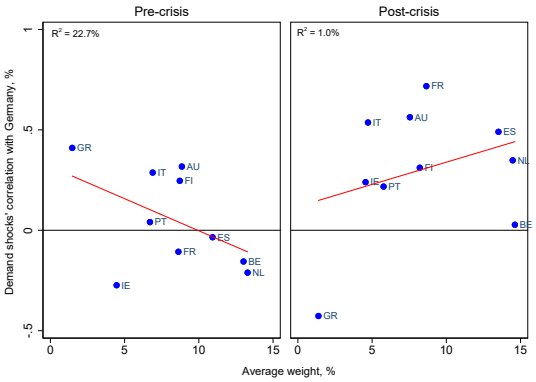
Source: Authors' calculations.

Figure 8: Average country weights and correlation between countries' supply shocks gaps and Germany's supply shocks



Source: Authors' calculations.

Figure 9: Average country weights and correlation between countries' demand shocks and Germany's demand shocks



Source: Authors' calculations.