Modeling interest rate setting at the European Central Bank with bargaining models and counterfactuals

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Abstract

I analyze country influence of euro-area member states over the interest rate decisions of the European Central Bank (ECB). Because voting records are unavailable, unobserved monetary policy preferences are based on hypothetical interest rate paths generated from monetary policy rules estimated in the pre-euro era. Comparisons of actual ECB interest rates to these counterfactual interest rates demonstrate that, overall, member countries appear to favor federal over national interests—consistent with the mandate of the organization—and provide little evidence that policy decisions favor the largest euro-area economies. However, I also present evidence of mixing between federal and national interests. In particular, there appears to be a divide between countries that consider only national interests and those that consider only federal interests. These findings contradict several recent studies which find that policy disproportionately favors the national objectives of larger member states. Two methodological differences account for this discrepancy. First, using a structural vector autoregression I model member states as small open economies so that monetary policy is influenced by fluctuations in the exchange rate as well as policy and economic conditions in other countries. Second, I account for the fact that Germany acted as the monetary policy leader during the estimation period and present an equilibrium condition to remove this influence from the counterfactual estimates.

Keywords: Monetary policy committee, European Central Bank.
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1 Introduction

Monetary policy at the European Central Bank (ECB) is conducted by the Governing Council, which is composed of the six members of the Executive Board as well as the Governors of each member's national central bank. Formally, interest-rate decisions are to be made with consideration for the entire euro area, a federal agenda. Yet, that each country sends a voting representative and strives to control seats on the Executive Board may suggest that national interests do play some role. Since 2007, seven new countries have joined the European Monetary Union, potentially increasing tension under the single monetary policy as the economic composition of its members becomes more diverse. As membership continues to evolve then, an understanding of the policy-making process of the ECB would seem important to anticipate future behavior. At the same time, existing research suggests that ECB policy favors the national interests of the largest member states, in which case the addition of new members, which tend to have smaller economies relative to existing euro members, may have little effect on the policy-making process. This paper tests the hypothesis that member countries with the largest economies enjoy disproportionate influence over ECB interest rate setting by comparing the actual interest rate with country-specific counterfactuals, while distinguishing between national, federal, and mixed agenda-setting.

Verification that monetary policy favors certain member countries has been elusive because, until recently, meetings of the Governing Council were conducted behind closed doors; voting records and policy deliberations were not available to shed greater light on the decision-making process. While the ECB has begun releasing summaries of council meetings, these do not contain sufficient information to infer member preferences, and voting records remain unavailable, in part because decisions are often officially reached by consensus.

Given these obstacles to directly studying decisions, I simulate hypothetical interest-rate paths for each country in the euro area based on monetary policy rules estimated with structural vector autoregressions in the pre-euro era. Using this method I distinguish between the optimal national and federal interest rates from each country's perspective by simulating these rules on either national or euro-area economic data. These hypothetical interest rates are then compared with actual ECB policy rates to determine country influence under several different bargaining schemes.

Contrary to previous studies, I do not find that ECB interest rates are best described by competing national interests. In most simulations, federal models—where countries base decisions on euro-area aggregate conditions—match the actual interest rate more closely than do national models. Beyond making up a larger fraction of euro-aggregate conditions I cannot conclude that the largest member states benefit disproportionately from interest-rate decisions made by the ECB. Mixture models, where countries bargain using both their national and federal counterfactuals, perform best overall. Although the overall degree of mixing is weighted towards federal counterfactuals in the best-fitting model, this shows that national interests do play some role. I also find that the optimal mixing weights between national and federal conditions is either zero or one for most countries, which indicates that most countries consider either national conditions or federal conditions, and only a few countries consider both.

2 Research context

The literature on ECB policy influence dates nearly to the inception of the euro. Early studies vary in their conclusions: von Hagen and Brückner (2003) find that the beginning stages of ECB policy placed higher weights on economic conditions in Germany and France than on those in other member states, while Berger and De Haan (2002) find the opposite—small member states exhibit too much influence over monetary policy. More recent research supports the hypothesis of large-member bias: Crowley and Lee (2009) find that the interest rate favors the largest euro member states with the most similar economic conditions—Austria, Belgium, France, and Germany—a result confirmed by Cancelo *et al.* (2011).

Because no voting records are available, these studies construct monetary policy preferences by first estimating a single ECB policy rule based on data for the whole euro area. National data for each country is then applied to this rule to generate hypothetical interest rates for each member. By construction this method assumes that all member states have the same underlying monetary policy decision rules, which may not be the case. Some countries may prefer a stronger response to increases in inflation, for example, than other member states. Because all countries have the same monetary policy rules this approach is also unable to test for the possibility that members do in fact vote with federal intentions, which is significant given that this is the very mandate they are required to follow.

A natural solution is to estimate historical monetary policy rules in the pre-euro period and take the simulations from these rules in the euro era as national interest-rate counterfactuals. This is the method proposed by Hayo and Méon (2013), who construct counterfactual interest rates for each euro member based on univariate Taylor rules. Their study presents evidence that ECB policy is best described by competing national interests—equal-weighted and GDP-weighted national preferences perform the best of their simulations, while federal constructions perform surprisingly poorly given the mandate behind ECB policy.

As Hayo and Méon (2013) point out, the means of all the simulated interest rates they consider are statistically larger than the mean of the actual interest rate over the same period. This can be explained by the Taylor rules used to construct the underlying interest rate preferences, which consistently call for higher interest rates than what the ECB actually set. Over the period 2003–2006, for example, nearly all national Taylor rules favored higher interest rates than the policy rate the ECB actually followed—the exceptions being Finland, the Netherlands, and Portugal. This may suggest that the estimated Taylor rules do not adequately reflect how monetary policy was actually conducted by the national central banks.

A potential explanation is that the estimation does not include all factors influencing monetary policy in the pre-euro era. Existing studies, for example, do not take into account that monetary policy during this period was not entirely independent. Beginning in 1979, most countries that would go on to adopt the euro belonged to the European Monetary

System, a currency peg regime aimed at keeping exchange rates stable in the region. Work by Baum and Barkoulas (2006) has shown that Germany acted as the European monetary policy leader during the European Monetary System era, heavily influencing other countries in the region. Reade and Volz (2011) suggest that this influence was so strong that Germany was actually the only country to lose monetary policy independence with the formation of the euro—all other countries gained a seat at the table.

An implication of this history is that monetary policy rules for many European countries estimated during this time will reflect the reality of this environment. Estimates of policy functions and counterfactual interest rates need to take outside influence into account, otherwise the interest rate counterfactuals will not characterize the monetary policy a national central bank would actually like to pursue.

In this paper I propose a multivariate model to identify the monetary policy reaction functions of euro-area countries based on the policies they followed before adopting the euro. Since Sims (1980) the structural vector autoregression (SVAR) has become a workhorse of empirical monetary policy analysis. In this framework the interest rate, the main instrument at the central banker's disposal, is determined simultaneously with a small set of macroeconomic variables, including measures of inflation and output. Jarociński (2010) uses a VAR to compare the effects of monetary policy in central-eastern and western European countries. His results suggest that central-eastern states have steeper Phillips curves, consistent with their recent history of higher inflation rates, a structural difference which could translate into different monetary policy preferences.

While it is not surprising that different countries might have unique monetary policy rules, even while belonging to the same monetary union, evidence that these preferences are incorporated into ECB interest-rate decisions would have important implications for the future of ECB policy, especially if membership in the currency union were to change. Despite the formal mandate that countries must consider only federal conditions when voting for ECB policy, it is often suggested that national interests play a significant role in general, with policy favoring the largest countries in particular. Speculation that some countries enjoy a disproportionate amount of influence increased when the ECB switched to a rotational voting system favoring its five largest members in January 2015, a shift from the principle of "one member, one vote". Heinemann and Huefner (2004) argue that such vote favoring would not be necessary if countries did not allow their national biases to influence their votes, an assumption implicit in the estimation technique employed by Cancelo *et al.* (2011).

But this view implies that all member states have the same monetary policy reaction functions, so that any voting at all reveals a bias towards national concerns. In reality, countries could conceivably disagree over the optimal policy for the union as a whole, even when considering the same federal economic conditions. The question is whether competing interests represent differing views about what the optimal federal policy looks like, or bargaining over policies to optimize national conditions. Estimating each member's unique monetary policy rule allows for competing views of the optimal federal interest rate, even when the same euro-area data is used in these rules.

3 Data sources and variable definitions

Data for the euro-area countries are from the European Commission's eurostat and the International Monetary Fund's International Financial Statistics (IFS) databases. Data for the United States interest rate and the oil price are from the Federal Reserve (FRED). Variables consist of s: exchange rate against the European Currency Unit (IFS); y: industrial production index (IFS); p: consumer price index (IFS); r: three-month domestic interbank lending rate (eurostat); r_{us}: US federal funds rate (FRED); and oil: the spot crude oil price of West Texas Intermediate (FRED). All variables are expressed as month-over-month differences of natural logs, except for interest rates which are converted to decimal percentages before being differenced to achieve stationarity. Euro-area aggregate consumer price index and industrial production data are from eurostat. Finally, data for real Gross Domestic Product (gdp), imports (im), and exports (ex) are annual and taken from the Organisation for Economic Co-operation and Development (OECD). I seasonally adjust the industrial production and consumer price indexes using the X-13 ARIMA method before log-differencing.

It may seem desirable to estimate monetary policy reaction functions using the actual policy variable of each central bank, rather than the three-month interest rate, but there are at least two challenges to this approach. First, in many cases the central banks did not have an explicit policy rate, for example during periods of money base targeting. The short-run interest rate can then be interpreted as a proxy for the underlying monetary policy stance. Second, differences between the individual policy rates could complicate aggregation of the interest rate rules in the simulation period. In an extensive review of monetary policy operating procedures at many central banks, Borio (1997) outlines different underlying policy variables for several of the central banks in my sample. How to aggregate these different interest rates in order to compare interest rate models against ECB policy rates will hence pose a challenging problem with no obvious solution. To avoid these issues, and also to follow Hayo and Méon (2013) as closely as possible, I use the three-month interest rate.

The pre-euro estimation period runs from March 1979, the start of the European Monetary System, until December 1998, the final period before each country adopted the euro. The one exception is Austria where the estimation begins in January 1980 because of missing data. Hypothetical interest rate paths are then simulated for each country throughout the euro period, from 1999 to 2013. I consider in this study only the original 11 euro member countries—Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Over the simulation period six new members did join the euro, the earliest being Greece in 2001. I do not include these countries because of data availability. Given that the objective of this research is to test the hypothesis that monetary policy at the ECB favors the preferences of the largest member states I do not believe that including these countries would substantially change my results.

During the estimation period, Luxembourgish francs were tied to the value of Belgian francs. Because monetary policy was effectively constrained to a fixed exchange rate regime, then, the framework outlined below cannot identify monetary policy preferences for Luxembourg. Instead I combine Belgium and Luxembourg into a single unit for the estimation period. To do this I combine data for each of the two countries based on their relative GDP in each year.

4 Method

Following Hayo and Méon (2013) I approach the question of country influence over ECB policy in two stages. In the first stage I estimate a monetary policy rule for each member country based on its policy decisions in the pre-euro era. In the second stage I use the counterfactual interest rates generated from these policy rules to test several hypotheses of ECB monetary policy decision making. These procedures are described in greater detail below.

4.1 Stage I: Monetary policy rules

Traditionally, the vector autoregression approach includes all model variables in the system and imposes no restrictions on lagged variables. In the current context this approach is infeasible; because of the large number of countries in this study I would quickly encounter the curse of dimensionality. Instead I estimate a monetary policy rule for each country separately within a multivariate framework. Consider the following structural VAR for country k:

$$A_k x_{k,t} = B_k x_{k,t-1} + D_k w_{k,t} + u_{k,t}, \tag{1}$$

where $x_{k,t}$ is a vector of endogenous variables, $w_{k,t}$ is a vector of exogenous variables making up a foreign sector, and $u_{k,t}$ a vector of error terms. The foreign sector captures spillovers from other European countries, as well as larger global trends.

The consensus view of monetary policy during the European Monetary System era, backed by evidence from Zhou (2003), Bergin and Jordà (2004), and Frömmel and Kruse (2015), is that the German Bundesbank acted as the effective European monetary policy leader, heavily influencing the policy decisions of the other member countries. In order to uncover the monetary policy preferences, then, the influence of the German interest rate must be accounted for.

While Germany acted as the effective leader of the European Monetary System, it also enjoyed significant autonomy from the policy decisions of the other European countries. To account for this, the structural VAR is constructed differently for Germany compared to the other member countries. In the German model $x_{k,t}$ consists only of domestic variables. This is in keeping with the evidence that German monetary policy was not influenced by other members of the European Monetary System, but allows for some outside influence through the foreign sector, $w_{k,t}$. For all other countries in the sample, $x_{k,t}$ will contain both domestic variables as well as the German interest rate, which accounts for the prominent role of German monetary policy in determining domestic interest rates. Specifically, letting $r_{g,t}$ denote the German interest rate, for a given country k, the vector of endogenous variables is given by:

$$x_{k,t} = \begin{cases} [s_{k,t}, r_{k,t}, p_{k,t}, y_{k,t}]', & \text{for Germany,} \\ [s_{k,t}, r_{k,t}, p_{k,t}, y_{k,t}, r_{g,t}]', & \text{otherwise.} \end{cases} \tag{2}$$

To uncover each country's underlying monetary policy preferences requires identification of the structural VARs with restrictions on the matrix of contemporaneous coefficients, A_k. I assume this matrix is upper triangular so that the slow-moving variables $p_{k,t}$ and $y_{k,t}$ do not respond contemporaneously to the domestic interest rate, the interest rate does not respond to contemporaneous values of the exchange rate, and the exchange rate responds to all variables in the system. This is similar to the identification approach outlined in Christiano *et al.* (1999) which divides the VAR into slow-moving variables which do not respond contemporaneously to changes in monetary policy, the policy variable, and fast-moving variables that respond to all variables. Here the only fast-moving variable is the exchange rate. In Section 7 I consider an alternative identification strategy that relaxes the restriction that the interest rate does not respond contemporaneously to the exchange rate and show it does not substantially alter my findings.

The foreign sector is constructed differently for each country to account for spillovers from neighboring countries within the euro area as well as larger global fluctuations. To account for global fluctuations I include the current values of the US interest rate and the price of oil and one lag of the US interest rate, the price of oil, US industrial production, and US consumer price index inflation. To account for spillovers from neighboring countries I include one lag of trade-weighted prices and industrial production from all other euro area countries in the sample. To be precise, let $im_{i,j,t}$ denote imports to country i from country j and $ex_{i,j,t}$ denote exports from country i to country j. I define trade weights between the two countries as:

$$\omega_{i,j,t} = \frac{ex_{i,j,t} + im_{i,j,t}}{\sum_{j=1}^{N}(ex_{i,j,t} + im_{i,j,t})}, \tag{3}$$

where N is the number of euro member states. Then foreign prices and industrial production for country k are:

$$p_{k,for,t} = \sum_{j=1}^{N} \omega_{k,j,t} p_{j,t}, \tag{4}$$

$$y_{k,for,t} = \sum_{j=1}^{N} \omega_{k,j,t} y_{j,t}, \tag{5}$$

and the vector $w_{k,t}$ is:

$$w_{k,t} = [r_{us,t}, oil_t, r_{us,t-1}, oil_{t-1}, p_{us,t-1}, y_{us,t-1}, p_{k,for,t-1}, y_{k,for,t-1}], \tag{6}$$

which accounts for both spillovers from other euro area countries as well as larger global trends.

In two cases large one-time currency devaluations resulted in big interest rate adjustments. Italy devalued the lira in October 1992 and Ireland devalued the pound in February 1993, both of which cause large errors that cannot be explained by the monetary policy rule. To ensure the estimated monetary policy rules for these countries are not influenced by these events I include dummy variables for the period the devaluation occurred and the period before the devaluation occurred. I treat a missing value for the Portuguese interest rate in June 1989 in the same way.

Estimation of the structural VARs yields a monetary policy rule for each country—the second equation from the system (1). Because of the role Germany played as monetary policy leader in the pre-euro era this rule takes a somewhat different form for Germany than the rest of the European countries. First, define $a_{k,i,j}$ as the row i column j element of matrix A_k from the VAR estimated for country k. The German monetary policy rule is then:

$$r_{g,t} = [0 \;\; 1 \;\; 0 \;\; 0] \left(\hat{B}_g x_{g,t-1} + \hat{D}_g w_{g,t} \right) - \hat{a}_{g,2,3} p_{g,t} - \hat{a}_{g,2,4} y_{g,t} + u_{g,r,t}, \tag{7}$$

where the selection vector $[0 \;\; 1 \;\; 0 \;\; 0]$ chooses the row of the VAR associated with the interest rate and, as above, $r_{g,t}$ denotes the German interest rate. The monetary policy rules for the remaining countries are slightly different because of the presence of the German interest rate:

$$r_{k,t} = [0 \;\; 1 \;\; 0 \;\; 0 \;\; 0] \left(\hat{B}_k x_{k,t-1} + \hat{D}_k w_{k,t} \right) - \hat{a}_{k,2,3} p_{k,t} - \hat{a}_{k,2,4} y_{k,t} - \hat{a}_{k,2,5} r_{g,t} + u_{k,r,t}. \tag{8}$$

Table 1 shows estimates of select parameters from each country's monetary policy rule. Because of the large number of parameters I show estimates only for the parameters of greatest interest. The table demonstrates that there are many cases where countries were heavily influenced by German monetary policy. This is particularly so for Central European countries, which matches the finding of Bergin and Jordà (2004). Recalling that the German interest rate is a left-hand-side variable, a negative coefficient estimate indicates a positive effect on the interest rate for country k, which is the case for most countries. There are also several cases where the exchange rate enters significantly, indicating the importance of accounting for each of these channels. The R^2 is lowest for Spain but this appears to be driven by a large outlier in May 1979. If that observation is accounted for with a dummy variable the R^2 would increase to 0.33.

The top row of the bottom panel shows p-values for the F-statistic associated with the joint test of significance of all variables in the foreign sector. In several cases the foreign sector parameters are jointly statistically significant, once again demonstrating the importance of accounting for outside influence in the monetary policy rules, which I do by including the German interest rate, the exchange rate, and global economic activity. The middle row of the bottom panel shows the p-value associated with the Durbin-Watson test for first-order autocorrelation in the residuals. The null hypothesis is not rejected for any model indicating no evidence of autocorrelation.

Table 1: Monetary policy rules

	Austria	Belgium & Luxembourg	Finland	France	Germany	Ireland	Italy	Netherlands	Portugal	Spain
$i_{k,t-1}$	-0.0266	-0.5240***	0.0364	0.0035	-0.1339**	0.29042***	0.2265***	-0.208153***	-0.0399	0.1129
	(0.0649)	(0.0588)	(0.0678)	(0.0659)	(0.0674)	(0.0663)	(0.0706)	(0.0660)	(0.0391)	(0.0685)
$i_{g,t}$	-0.0063	-0.2784**	-0.1305	-0.4635***	–	-0.1314	-0.0204	-0.6374***	0.0069	0.0493
	(0.0800)	(0.1081)	(0.1359)	(0.0973)		(0.1295)	(0.0824)	(0.0775)	(0.1184)	(0.1385)
$i_{g,t-1}$	0.4978***	0.3206***	-0.2206	0.1295	–	-0.0909	-0.0256	0.1737**	-0.1318	-0.1086
	(0.0805)	(0.1105)	(0.1421)	(0.1008)		(0.1309)	(0.0837)	(0.0841)	(0.1207)	(0.1453)
$s_{k,t-1}$	2.0141	19.1031***	-7.2126*	3.4956	13.9787***	5.5490	0.6288	8.4599	0.8572	-6.5568
	(5.6302)	(6.9103)	(3.8802)	(5.8272)	(4.9269)	(5.0661)	(3.0676)	(6.0450)	(4.1514)	(4.9407)
$pr(x > F_{for})$	0.7048	0.0018	0.0012	0.1670	0.0390	0.1210	0.1279	0.2510	0.6897	0.8130
$pr(x > DW)$	0.8339	0.7827	0.2335	0.3965	0.3593	0.8783	0.7597	0.7606	0.9778	0.3380
R^2	0.2261	0.3546	0.1414	0.1585	0.1333	0.4391	0.2277	0.4851	0.8095	0.0634

Note: Parameter estimates and their standard errors (in parentheses) for select coefficients from each country's monetary policy rule. The top row in the bottom panel is the p-value for the joint test of significance of all variables in the foreign sector. The second panel in the bottom panel is the p-value associated with the Durbin-Watson test statistic for first-order autocorrelation in the residuals. * denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

4.2 Stage II: Counterfactuals and interest rate models

The monetary policy rules estimated in the previous subsection can be used to construct interest rate counterfactuals representing the preferred interest rate for each country in the Euro era. For Germany this can be done simply by simulating equation (7) through the euro era:

$$\tilde{r}_{nat,g,t} = [0 \;\; 1 \;\; 0 \;\; 0] \left(\hat{B}_g x_{g,t-1} + \hat{D}_g w_{g,t} \right) - \hat{a}_{g,2,3} p_{g,t} - \hat{a}_{g,2,4} y_{g,t}, \tag{9}$$

which corresponds to the interest rate German policymakers would choose based on current economic conditions, according to their monetary policy preferences in the pre-euro era. In other words, this counterfactual takes no consideration for conditions in the rest of the monetary union except to the extent that they influence domestic conditions in Germany through the foreign sector. For that reason I call these the country's national counterfactuals, and denote them with the subscript *nat*.

By mandate, however, countries within the euro are supposed to base decisions only on euro-aggregate conditions, eschewing national concerns. To simulate counterfactuals that are consistent with this mandate, I apply the country's estimated monetary policy rule to euro-area, rather than national, variables. For Germany this results in the following hypothetical interest rate:

$$\tilde{r}_{fed,g,t} = [0 \;\; 1 \;\; 0 \;\; 0] \left(\hat{B}_g x_{euro,t-1} + \hat{D}_g w_{euro,t} \right) - \hat{a}_{g,2,3} p_{euro,t} - \hat{a}_{g,2,4} y_{euro,t}, \tag{10}$$

where the vectors $x_{euro,t}$ and $w_{euro,t}$ substitute euro-area aggregates for the corresponding prices and industrial production of Germany and the European foreign sector. I call these federal counterfactuals and denote them with the subscript fed. The federal counterfactuals use the coefficients from a country's estimated monetary policy rule along with euro-area aggregate data to represent the hypothetical situation where the country sets the interest rate for the euro area as if the same conditions held in their own country.

Constructing the counterfactual interest rates for the remaining countries belonging to the euro area is slightly more complicated because of the presence of the contemporaneous German interest rate in their monetary policy rules. As discussed above, Germany played the role of monetary policy leader in the pre-euro era, strongly influencing the interest rates of the other European countries, which motivated including the German interest rate in the structural VARs of all other member countries. We must also take this influence into account in order to uncover the country's underlying monetary policy preferences, as I now demonstrate.

Formally, let $r^*_{k,t}$ denote the preferred interest rate for country k. Then the actual interest rate policy can be expressed as a weighted average of the preferred interest rate and the German interest rate:

$$r_{k,t} = \alpha_k r_{g,t} + (1 - \alpha_k) r^*_{t,k}. \tag{11}$$

At one extreme the country is not influenced at all by German monetary policy so that $\alpha_k = 0$ and the policy rate is equal to the preferred interest rate. At the other extreme the country has no independent monetary policy so that $\alpha_k = 1$ and the German interest rate completely determines domestic interest rate policy. The objective is to strip out the influence of the German interest rate from equation (8) and uncover only the preferred interest rate. Equating the left-hand side variables of (8) and (11) and matching coefficients implies that $\alpha_k = -a_{k,2,5}$ and:

$$(1 - \alpha_k) r^*_{k,t} = [0 \;\; 1 \;\; 0 \;\; 0 \;\; 0] \left(\hat{B}_k x_{k,t-1} + \hat{D}_k w_{k,t} \right) - \hat{a}_{k,2,3} p_{k,t} - \hat{a}_{k,2,4} y_{k,t}. \tag{12}$$

This says that the preferred interest rate change for country k is equal to the part of the estimated interest rate rule that is not due to influence from the contemporaneous German interest rate, weighted by the relative degree of independence from German monetary policy. Making the substitution $\alpha_k = -a_{k,2,5}$ and dividing both sides of (12) by $(1 + \hat{a}_{k,2,5})$, national counterfactuals for all the other euro-member countries can then be constructed as:

$$\tilde{r}_{nat,k,t} = \frac{[0\ \ 1\ \ 0\ \ 0\ \ 0]\left(\hat{B}_k x_{k,t-1} + \hat{D}_k w_{k,t}\right) - \hat{a}_{k,2,3} p_{k,t} - \hat{a}_{k,2,4} y_{k,t}}{1 + \hat{a}_{k,2,5}}. \tag{13}$$

Federal counterfactuals are again constructed by simulating this same rule with euro-area variables in place of national variables:

$$\tilde{r}_{fed,k,t} = \frac{[0\ \ 1\ \ 0\ \ 0\ \ 0]\left(\hat{B}_k x_{euro,t-1} + \hat{D}_k w_{euro,t}\right) - \hat{a}_{k,2,3} p_{euro,t} - \hat{a}_{k,2,4} y_{euro,t}}{1 + \hat{a}_{k,2,5}}, \tag{14}$$

with $x_{euro,t}$ and $w_{euro,t}$ defined as before.

An alternative interpretation of the method used to extract the monetary policy counterfactuals for all the non-German countries in the sample is that the country understands that, when it is bargaining over which interest rate is to hold for the euro area it is effectively choosing both its domestic interest rate and the German interest rate. In other words, once the country has adopted the euro, interest rates across the area will be the same so that $r_{k,t} = r_{g,t}$ in equation (8). Imposing that condition and rearranging terms gives the same expression as equation (13) where the denominator, $1 + \hat{a}_{k,2,5}$, comes from restricting the country to choose the same interest rate for itself and Germany.

This same equilibrium condition, which restricts countries to choose the same interest rate for themselves and Germany, is used by Hayo (2007) in the context of appropriateness of ECB policy for its member states. The restriction reflects that countries do not pursue domestic policy in a vacuum. They understand that they are also choosing the interest rate for their neighbors and that the effects of the policy on other states will in turn feedback into their own economy. The simplifying assumption that only Germany can influence other countries permits tractability and is consistent with the notion that Germany acted as the European monetary policy leader during the estimation period.

Controlling for the influence of the European Monetary System and applying the equilibrium condition transforms the interest-rate paths of euro member states into monetary policy counterfactuals. National polices are generated by simulating each country's monetary policy rule using domestic variables whereas federal policies use euro-area aggregates in the monetary policy rules. This allows for the possibility that nations disagree over what the policy interest rate should be while still according with the mandate of decision making without a national bias.

Based on these counterfactuals I consider several different interest rate models to shed light on country influence over interest-rate policy. All of the models can be interpreted as bargaining models, where the change to the policy rate is determined as a weighted average of the preferred interest rate change of the euro members. In the simplest case each member is given an equal bargaining share so that the agreed-upon interest rate is the average of all members' counterfactual interest rates:

$$\tilde{r}^{eq}_{i,t} = \frac{1}{N} \sum_{k=1}^{N} \tilde{r}_{i,k,t}, \qquad \text{for } i = nat, fed. \tag{15}$$

In the second case, members are given a weight equal to their share of euro-area GDP in that year, $z_{k,t}$:

$$\tilde{r}^{gdp}_{i,t} = \sum_{k=1}^{N} z_{k,t}\, \tilde{r}_{i,k,t}, \qquad \text{for } i = nat, fed. \tag{16}$$

This allows for larger countries to exhibit more influence over the interest rate, which is commonly assumed to be the case, and is the main focus of this paper.

I also consider a model where the bargaining weights are determined from a regression of the true interest rate on the counterfactuals of all countries:

$$r_{euro,t} = \sum_{k=1}^{N} b_{i,k} \tilde{r}_{i,k,t} + v_{i,t}, \qquad \text{for } i = nat, fed, \tag{17}$$

$$\text{such that } \sum_{k=1}^{N} b_{i,k} = 1, \text{ and } b_{i,k} \in [0,1], \tag{18}$$

so that fitted values from (17), denoted $\tilde{r}^{reg}_{nat,t}$ and $\tilde{r}^{reg}_{fed,t}$, are the regression-weight national and federal bargaining models.

Of course, it is also possible that euro member countries bargain using some combination of both their federal and national counterfactuals. To account for this possibility I estimate several mixture models:

$$r_{euro,t} = \frac{1}{N}\sum_{k=1}^{N}(\gamma_{eq,k}\tilde{r}_{nat,k,t} + (1-\gamma_{eq,k})\tilde{r}_{fed,k,t}) + v_{eq,t}, \quad \text{such that } \gamma_{eq,k} \in [0,1]\,, \tag{19}$$

$$r_{euro,t} = \sum_{k=1}^{N} z_{k,t}(\gamma_{gdp,k}\tilde{r}_{nat,k,t} + (1-\gamma_{gdp,k})\tilde{r}_{fed,k,t}) + v_{gdp,t}, \quad \text{such that } \gamma_{gdp,k} \in [0,1]\,. \tag{20}$$

where the weights $\gamma_{eq,k}$ and $\gamma_{gdp,k}$ determine the how much emphasis country k places on its national preferences and these parameters are estimated to minimize the sum of squared residuals of (19) and (20). The overall weight allocated to each country is either the same for all countries or equal to that country's share of euro-area GDP, so that equations (15) and (16) can be thought of as special cases of (19) and (20) where countries are forced to only consider their national or federal preferences.

Finally, I also consider the mixture version of the regression model where both the bargaining weights and the mixing weights are estimated to minimize the sum of squared residuals of:

$$r_{euro,t} = \sum_{k=1}^{N} b_k(\gamma_{reg,k}\tilde{r}_{nat,k,t} + (1-\gamma_{reg,k})\tilde{r}_{fed,k,t}) + v_t, \tag{21}$$

$$\text{such that } \sum_{k=1}^{N} b_k = 1, b_k \in [0,1] \text{ and } , \gamma_{reg,k} \in [0,1]\,. \tag{22}$$

Fitted values from (19), (20), and (21), denoted $\tilde{r}^{eq}_{mix,t}$, $\tilde{r}^{gdp}_{mix,t}$, and $\tilde{r}^{reg}_{mix,t}$, are the equal-weight, GDP-weight, and regression-weight mixture bargaining models. Note that because Belgium and Luxembourg have the same underlying monetary policy rules they will also have the same federal counterfactuals, though different national counterfactuals. This results in a multicollinearity problem in the federal variant of equation (17) and equations (19) and (21) so I drop Luxembourg from those models.

Many other models, including explicit voting models, are possible. Hayo and Méon (2013) for example consider several voting and consensus models, while also accounting for the nationality of the president and members of the executive board. Riboni and Ruge-Murcia (2010) show that consensus voting models can explain the observed stickiness of policy interest rates for several central banks. However, the focus of this paper is not to provide evidence on the underlying interest rate setting mechanism but rather to examine the hypothesis that ECB policy favors the national interests of its largest members. If that is the case then a bargaining model that gives additional weight to the largest member countries should provide a good fit to the actual interest rate, regardless of the underlying procedure used to determine the interest rate. In addition, it is not clear how such voting models could be modified to accommodate mixture models, which allow countries to consider both national and federal preferences.

5 Performance of the different interest rate models

I compare the performance of the bargaining models by measuring how close the predicted interest rates from the bargaining models are to the actual interest rate set by the ECB over the $\tilde{T}$ months in the simulation period with the root mean squared error (RMSE),

$$\text{RMSE}_i^j = \left(\frac{1}{\tilde{T}} \sum_{t=t_1}^{t_1-1+\tilde{T}} (r_{euro,t} - \tilde{r}_{i,t}^j)^2 \right)^{1/2} \quad \text{for } i = nat, fed, mix \text{ and } j = eq, gdp, reg. \tag{23}$$

Table 2 compares the fit of the nine different models—the national, federal, and mixture variants of the equal-, GDP- and regression-weighted bargaining models. Because the GDP weights are time varying, none of the GDP-weight models are nested within the regression-weight models, so there is no guarantee that the regression models will offer the best fit.

Despite that, the regression-weight models do provide the best fit overall, with all three variants showing a lower RMSE than even the best performing GDP-weights model. The regression-weights mixture model performs best overall and when the regression-weights model is restricted to only national or federal counterfactuals we see that the federal model offers a better fit than the national model, not the result one would expect if ECB members formed policy by bargaining exclusively over their narrow national interests.

Table 2: Root mean squared error of bargaining models

	Equal weights			GDP weights			Regression weights		
	National	Federal	Mixture	National	Federal	Mixture	National	Federal	Mixture
1999–2013	0.1738	0.1680	0.1674	0.1625	0.1512	0.1499	0.1366	0.1334	0.1321
1999–2008	0.1956	0.1910	0.1868	0.1804	0.1701	0.1676	0.1519	0.1498	0.1477
2009–2013	0.1192	0.1086	0.1163	0.1194	0.1040	0.1035	0.0861	0.0835	0.0825

Note: Root mean squared error (RMSE) of different bargaining models given by equation (23). Equal-weights models give the same bargaining weight to each member country. GDP-weights models give a time-varying bargaining weight equal to each member's relative share of euro-area GDP in the given year. Regression-weights models estimate the bargaining weight by restricted least squares. National models use only national counterfactuals, federal models use only federal counterfactuals, and mixture models estimate the weight each country places on national relative to federal counterfactuals.

The GDP-weights models perform better than the equal-weights models in all cases but one, indicating that larger countries do appear to have more bargaining power than small countries. However, over all sample periods the federal models outperform the national models, which demonstrates that, even if larger member countries have more bargaining power within the ECB, they appear to make decisions with respect to the entire euro area rather than prioritize their own economic conditions. This is particularly the case for the regression-weights models where federal models outperform national models in all sample periods.

The best fitting models within each type of bargaining weight are the mixture models, which find the optimal combination between each country's national and federal counterfactuals. That the mixture models improve upon the performance of the national models indicates that federal counterfactuals play at least some role in interest rate decisions. This contrasts with Cancelo *et al.* (2011) and Hayo and Méon (2013) who find that policy favors the national preferences of the largest members of the monetary union. This is because the mixture models used by Hayo and Méon (2013) are based on simple averages between each country's national and federal preferences. As I show below, the regression weights I estimate indicate that most countries appear to consider only their national or federal preferences. In other words, the mixture is primarily between which countries vote nationally rather than federally, not each country mixing between their national and federal preferences.

Figure 1 shows how the performance of the nine different interest rate models varies over the sample period. The figure plots the one-year rolling root mean squared error for each model, calculated as:

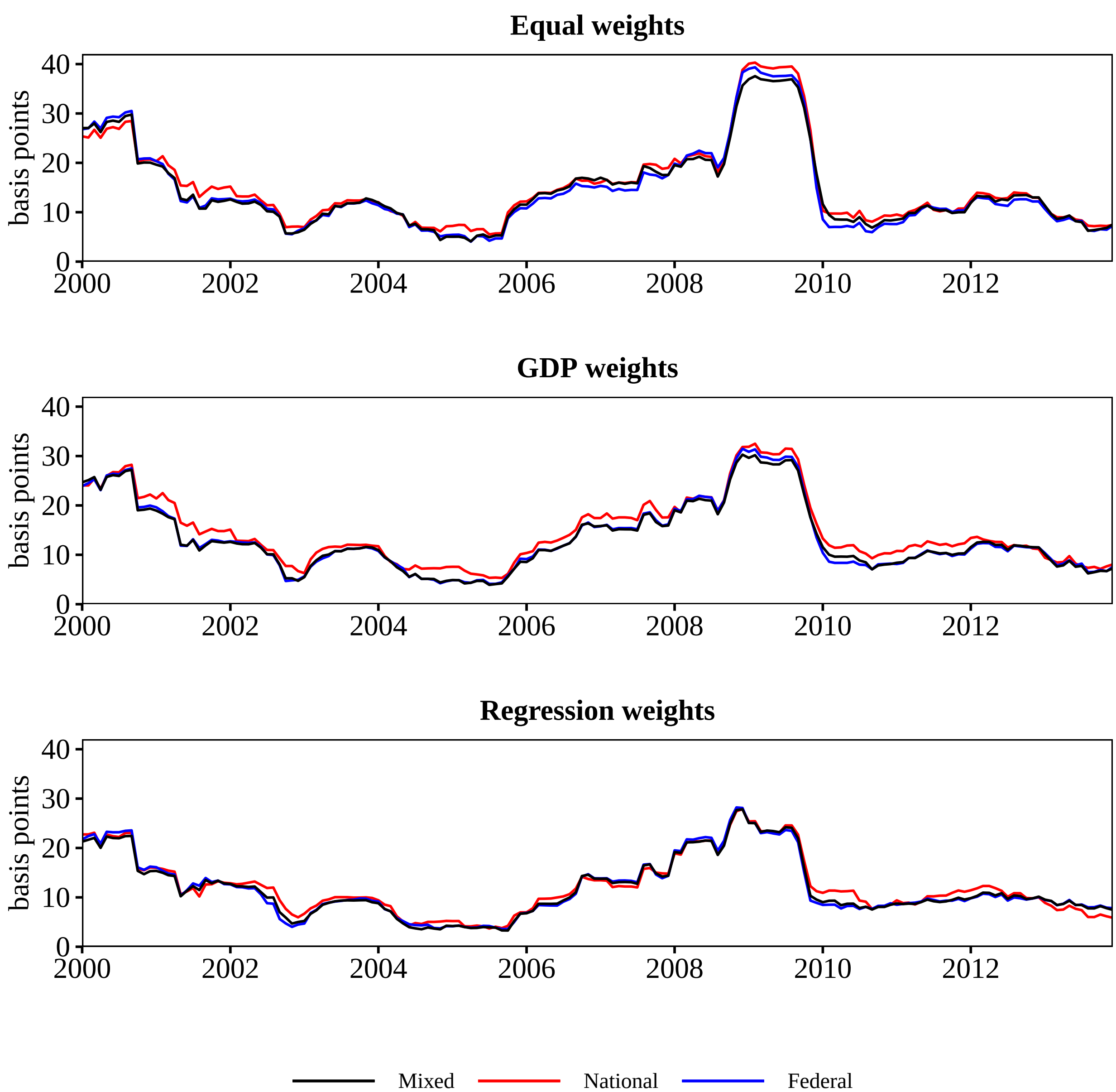
$$\text{RMSE}^j_{i,t} = \left(\frac{1}{12} \sum_{l=0}^{11} (r_{euro,t-l} - \tilde{r}^j_{i,t-l})^2 \right)^{1/2} \quad \text{for } i = nat, fed, mix \text{ and } j = eq, gdp, reg. \quad (24)$$

The fit of all models is best around 2005, when the RMSE is consistently below 10 basis points, but performance deteriorates from 2006 to 2009. Overall the fit of the national and federal models are quite similar, with the possible exception of the national GDP-weights model. The bottom panel emphasizes that the regression-weights models all have a very similar model fit over the sample period.

The relatively poor performance of the equal-weights federal model, which performs worst over the full sample among the three federal models and is the second worst performing model overall, is somewhat surprising. Given that in practice actual voting procedures at the ECB appear to occur only rarely, the equal-weights bargaining model coincides most closely with how ECB policy should actually be set. The poor performance of this model accords with the fact that the estimated regression weight is zero for most countries. This is confirmed in Figure 2 which shows point estimates and 90% confidence intervals for the coefficients in equation (17) using either the federal or national counterfactuals. The vertical line at $\frac{1}{11}$ gives the equal-weight value and the short vertical lines the average GDP weight between 1999 and 2013.

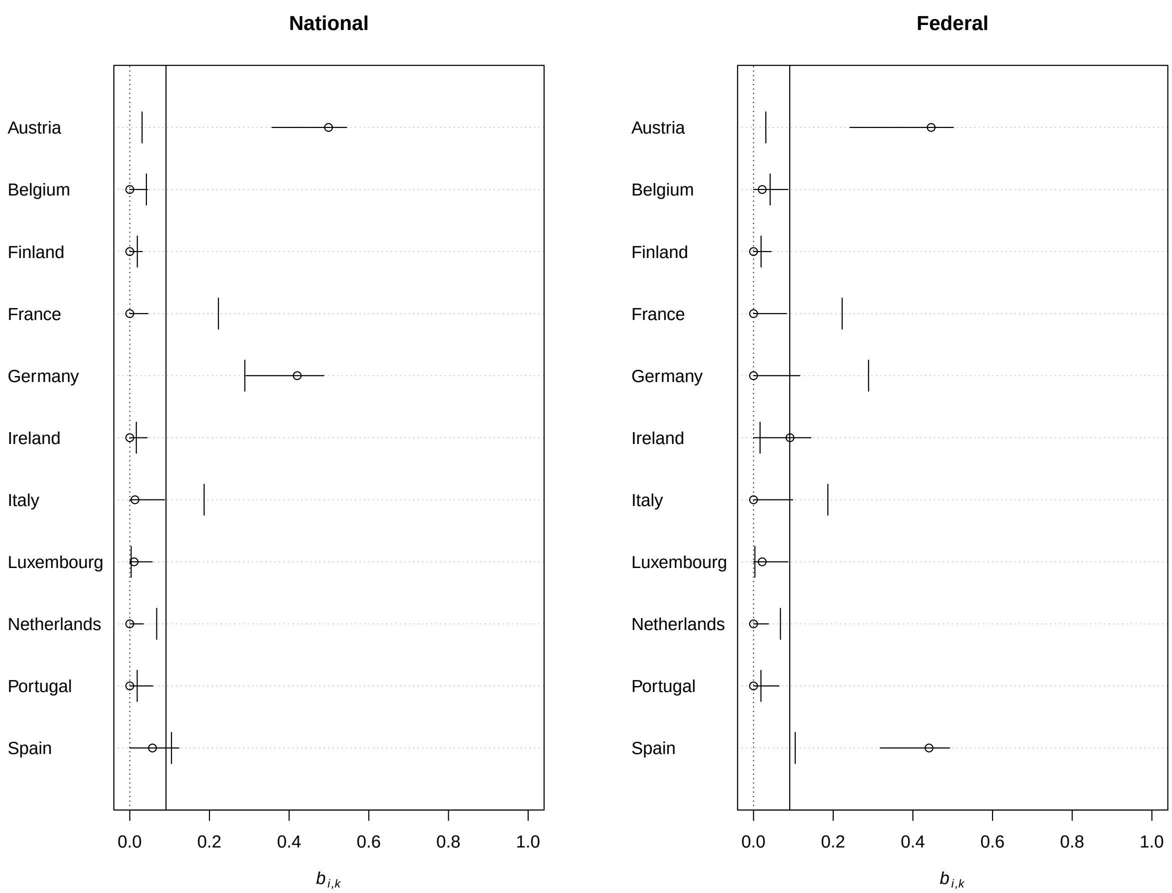
Because the counterfactuals are generated regressors I use a residual-based bootstrap to

Figure 1: Rolling root mean squared error



Note: Rolling root mean squared error for each of the nine competing bargaining models calculated over a 12-month window by equation (24). Equal-weights models give the same bargaining weight to each member country. GDP-weights models give a time-varying bargaining weight equal to each member's relative share of euro-area GDP in the given year. Regression-weights models estimate the bargaining weight by restricted least squares. National models use only national counterfactuals, federal models use only federal counterfactuals, and mixture models estimate the weight each country places on national relative to federal counterfactuals.

Figure 2: Comparison of different bargaining weights



Note: The dotted vertical line at 0.1 gives the equal value bargaining weight and the short vertical lines the average GDP weight between 1999 and 2013. GDP weights are calculated as the percentage share of euro-area GDP belonging to each country in a given year. The horizontal lines show the 90% confidence intervals from a regression of the European Central Bank policy rate on the national or federal counterfactual interest rates of all countries. Confidence intervals are calculated using a residual-based bootstrap from 999 bootstrap samples, as described in the text.

calculate confidence intervals. For each bootstrap replication I first re-estimate all vector autoregressions to generate new simulated counterfactual interest rates for each member country. I use these new counterfactuals to generate the bootstrap samples for equation (17) and finally re-estimate equation (17) to get bootstrap regression coefficients. Confidence intervals are the 5th and 95th percentiles of the resulting distributions of coefficients from 999 bootstrap samples. The confidence intervals are generally asymmetric around the point estimates because the regression coefficients are bounded between zero and one, and restricted to sum to one.

In the federal regression model six of the eleven countries have coefficients of zero, and the coefficients on the Belgium and Luxembourg counterfactuals are very small. Essentially, the best fit among federal models is a weighted average of the counterfactuals for Austria, Ireland, and Spain. I emphasize here that these coefficients do not have a causal interpretation, and should not be taken as evidence that Austria, Ireland, and Spain drive ECB policy decisions. A significantly positive parameter estimate simply indicates that the country's counterfactual and the true interest rate move together, not that the country is causing the interest rate to move in its preferred direction. But the small estimated coefficients for the largest euro-area economies—Germany, France, and Italy—goes against the notion that ECB policy is determined by the largest member states, at least in the case where members are restricted to considering only their federal preferences.

Most of the estimated coefficients in the national regression model remain statistically indistinguishable from zero. Compared with the federal model the estimated coefficients are smaller for Ireland and Spain and larger for Austria and Germany. The total weight given to Austria and Germany, calculated as the sum of the estimated coefficients on their national counterfactuals, is 0.92, indicating a large shift towards the preferences of Central European countries. Although the regression coefficient for Germany is large, the regression coefficients for France and Italy—the second and third largest economies in the euro area—are statistically indistinguishable from zero. I also emphasize that, while the national regression model suggests a large role for Germany in determining the euro area interest rate, Table 2 shows that it is the worst fitting of the three regression weight models.

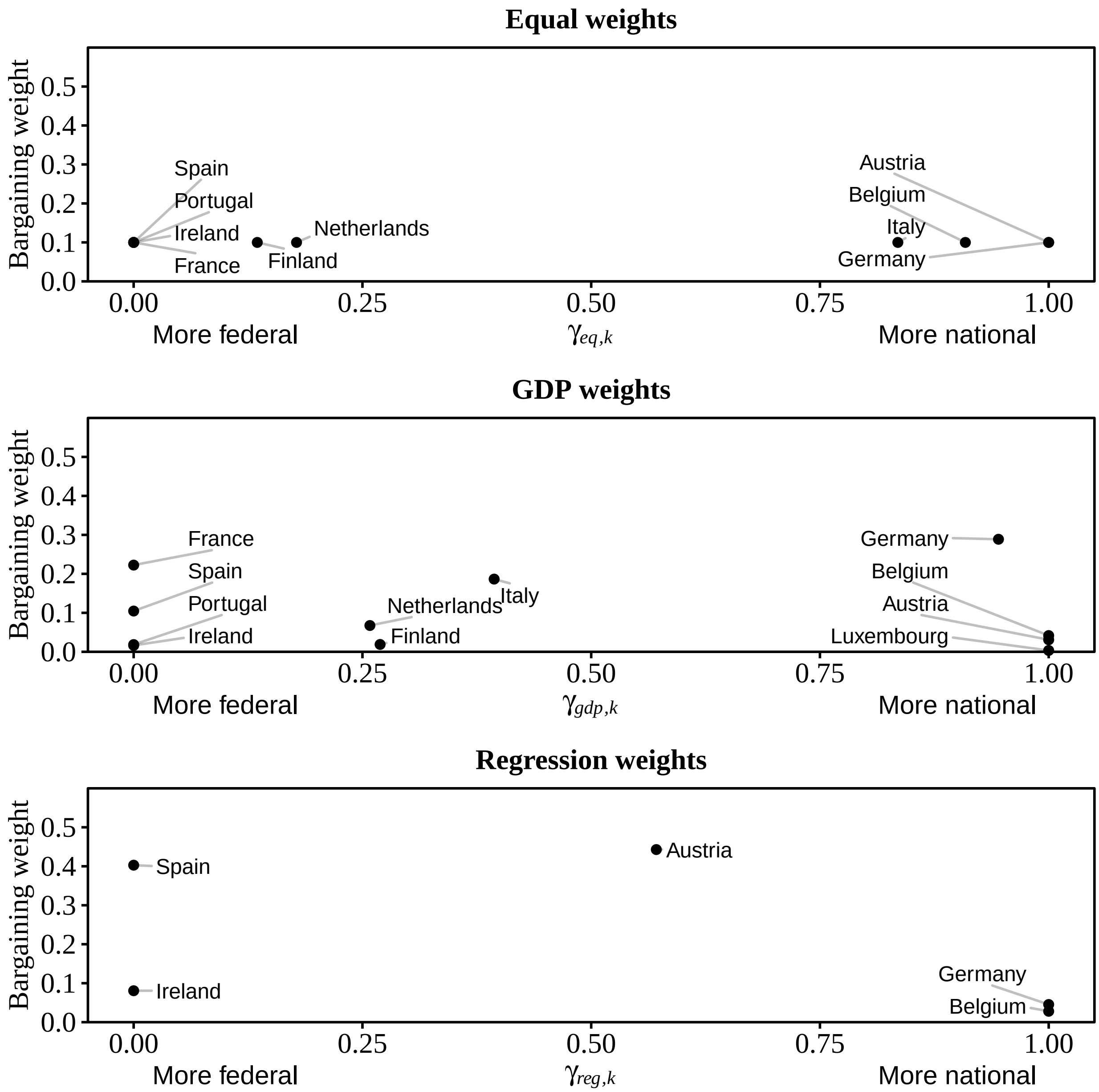
Given the strong performance of the mixture models, also of interest are the mixing weights—$\gamma_{eq,k}$, $\gamma_{gdp,k}$, and $\gamma_{reg,k}$ in equations (19), (20), and (21)—which determine the weight each country places on their national relative to federal counterfactuals. Figure 3 shows these estimates against the relevant bargaining weight for each of these three models. Estimates of $\gamma_{j,k}$ below 0.5 indicate that country k places more weight on their federal than national counterfactuals.

In all equal-weight and GDP-weight mixture models a majority of countries emphasize their federal rather than national counterfactuals. This is not the case for the regression-weight model where the three Central European countries with non-zero bargaining weights favor their national conditions over federal conditions, although the estimated bargaining weights for Belgium and Germany are very small. Note that $\gamma_{reg,k}$ is only identified when $b_k > 0$, which is the case for only five countries: Austria, Belgium, Germany, Ireland, and Spain.

The bottom panel of the figure shows that more than 90% of the estimated bargaining weights are allocated to Austria, Ireland, and Spain, none of which counts among the largest economies in the euro area. Again, these coefficients should not be interpreted as causal. Instead, this could indicate that monetary policy decisions are determined by coalitions of countries with common interests that align closely around the counterfactuals of these members. The estimates of $\gamma_{reg,k}$ in Figure 3 might indicate coalition building around common interests of Central, Northern, and Southern European countries, for example.

An interesting finding from Figure 3 is that countries tend to place all their weight on either their national or federal preferences, rather than mixing between them. This is the case in the equal-, GDP-, and regression-weights models and indicates that ECB policy can be best described by a bargaining model where some countries consider only federal economic conditions and others consider only their national economic conditions, with only

Figure 3: Bargaining and mixing weights



Note: Compares the equal, GDP, and regression bargaining weights with estimates of $\gamma_{eq,k}$, $\gamma_{gdp,k}$, and $\gamma_{reg,k}$ which determine the weight each country places on their national relative to federal counterfactuals in equations (19), (20), and (21).

a few countries considering both federal and national conditions.

One way to summarize the total weight placed on national counterfactuals is with the statistic:

$$\bar{\gamma}_{eq} = \frac{1}{N}\sum_{k=1}^{N} \gamma_{eq,k}, \tag{25}$$

$$\bar{\gamma}_{gdp} = \sum_{k=1}^{N} \bar{z}_k \gamma_{gdp,k}, \tag{26}$$

$$\bar{\gamma}_{reg} = \sum_{k=1}^{N} b_k \gamma_{reg,k}, \tag{27}$$

where $\bar{z}_k$ is country k's average share of euro-area GDP in the simulation period. I find that $\bar{\gamma}_{eq} = 0.4057$, $\bar{\gamma}_{gdp} = 0.4357$, and $\bar{\gamma}_{reg} = 0.3265$, which indicates that in all three mixture models a majority weight is placed on federal rather than national counterfactuals. This is especially true in the best fitting model, the mixture model with regression weights, where more than 67% of the total weight is allocated to federal counterfactuals. There is, however, a notable divide between the Central European countries, most of which favor national counterfactuals, and the Northern and Southern European countries, most of which favor federal counterfactuals.

6 Properties of the counterfactuals

I now present some properties of the counterfactual interest rate changes to lend support to the notion they can be interpreted as the interest rate preferences of the euro member countries. Table 3 shows summary statistics for the national and federal counterfactuals. Recalling that interest rates are expressed in differences, these are the mean, standard deviation, minimum, and maximum interest rate change, expressed in percentage points. Almost all countries have negative counterfactuals on average, indicating that they would have preferred lower interest rates on average. In most cases the mean is small in economic terms, less than ten basis points, indicating that desired interest rate adjustments are generally small, on average. The country with the largest average desired interest rate adjustments is Portugal, which on average would have preferred a rate cut of around 16 basis points.

Table 3: Summary statistics for counterfactual interest rates

	1999–2008				1999–2013			
National	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.	Min.	Max.
r_{euro}	0.001	0.184	-0.950	0.650	-0.016	0.175	-0.950	0.650
Austria	-0.040	0.148	-0.586	0.512	-0.049	0.159	-0.896	0.512
Belgium	-0.002	0.224	-0.571	0.621	-0.011	0.277	-1.461	0.621
Finland	-0.086	0.330	-1.447	0.631	-0.055	0.340	-1.447	1.321
France	-0.101	0.235	-1.058	0.383	-0.095	0.222	-1.058	0.394
Germany	-0.023	0.150	-0.982	0.239	-0.024	0.141	-0.982	0.239
Ireland	-0.039	0.261	-0.879	0.673	-0.042	0.249	-0.879	0.673
Italy	-0.081	0.174	-0.694	0.362	-0.095	0.174	-0.884	0.362
Luxembourg	0.004	0.214	-0.494	0.562	-0.008	0.268	-1.475	0.562
Netherlands	-0.026	0.291	-0.828	0.796	-0.007	0.299	-0.828	0.907
Portugal	-0.159	0.158	-0.685	0.193	-0.163	0.146	-0.685	0.193
Spain	-0.070	0.188	-1.224	0.246	-0.082	0.175	-1.224	0.246
	1999–2008				1999–2013			
Federal	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.	Min.	Max.
Austria	-0.042	0.141	-0.712	0.394	-0.054	0.153	-0.876	0.394
Belgium	-0.019	0.179	-0.416	0.558	-0.036	0.226	-1.376	0.558
Finland	-0.067	0.319	-1.017	0.809	-0.045	0.320	-1.017	1.149
France	-0.052	0.193	-0.910	0.333	-0.051	0.184	-0.910	0.333
Germany	-0.022	0.135	-0.831	0.221	-0.026	0.125	-0.831	0.221
Ireland	-0.031	0.230	-0.484	0.594	-0.037	0.218	-0.498	0.594
Italy	-0.085	0.157	-0.663	0.240	-0.099	0.160	-0.861	0.240
Luxembourg	-0.019	0.179	-0.416	0.558	-0.036	0.226	-1.376	0.558
Netherlands	-0.008	0.279	-0.900	0.715	0.011	0.270	-0.900	0.790
Portugal	-0.163	0.135	-0.714	0.119	-0.163	0.130	-0.714	0.119
Spain	-0.037	0.179	-1.150	0.362	-0.047	0.169	-1.150	0.362

Note: Summary statistics for national and federal counterfactuals given by equations (9) and (10) for Germany and equations (13) and (14) for all other countries.

For the most part, average interest rate changes are small and less than one standard deviation away from zero. That no country appears to be consistently bargaining for large interest rate changes indicates that none is typically very far from their preferred interest rate in the euro era. Table 4 shows the same summary statistics for the nine different bargaining models. As noted by Hayo and Méon (2013), the interest rate models should match closely the distribution of interest rate changes, not only the average interest rate change. All models match the average change of the actual interest rate quite closely, indicating good model fit along this dimension. The regression-weights mixture model matches the mean, standard deviation, and range closest overall, again providing support that both national and federal preferences are taken into account when forming policy decisions.

Table 4: Summary statistics for bargaining models

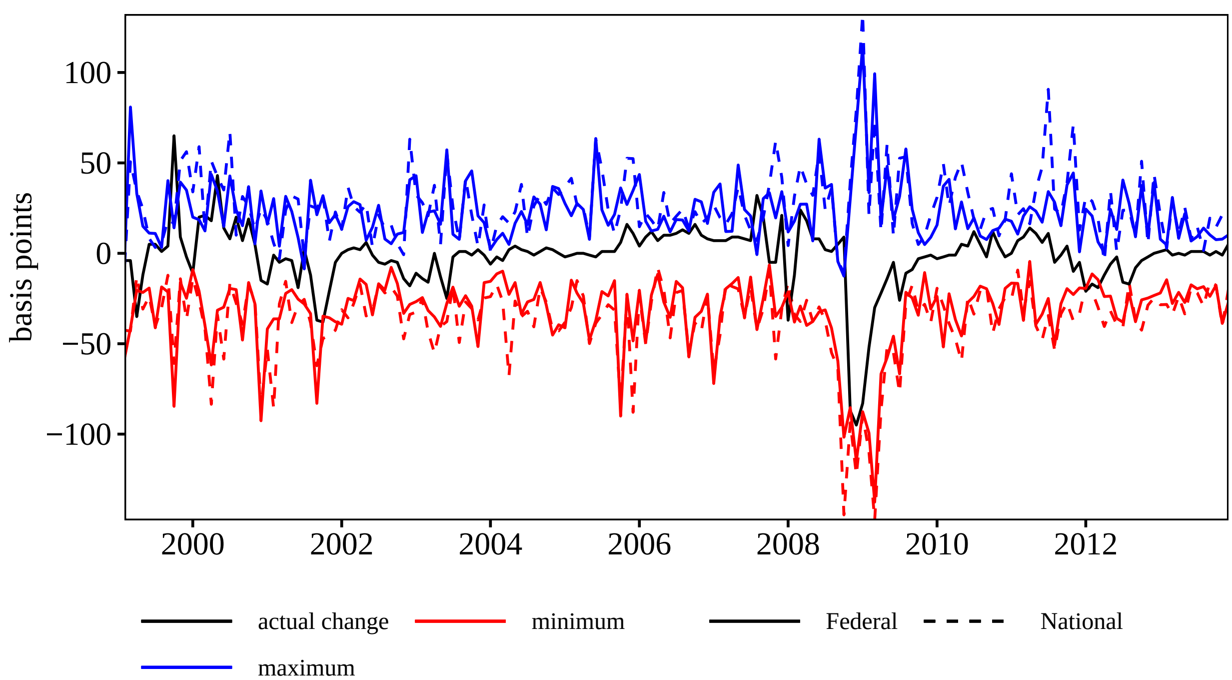
	1999–2008				1999–2013			
	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.	Min.	Max.
r_{euro}	0.001	0.184	-0.950	0.650	-0.016	0.175	-0.950	0.650
Equal-weights national	-0.057	0.095	-0.541	0.183	-0.057	0.096	-0.541	0.183
Equal weights federal	-0.050	0.086	-0.490	0.154	-0.053	0.087	-0.490	0.154
Equal-weights mixture	-0.051	0.096	-0.481	0.152	-0.052	0.091	-0.487	0.150
GDP-weights national	-0.060	0.110	-0.578	0.110	-0.062	0.104	-0.578	0.113
GDP-weights federal	-0.045	0.100	-0.555	0.125	-0.049	0.097	-0.555	0.125
GDP-weights mixture	-0.044	0.105	-0.604	0.122	-0.047	0.101	-0.596	0.128
Regression-weights national	-0.030	0.123	-0.815	0.163	-0.040	0.125	-0.779	0.205
Regression-weights federal	-0.038	0.129	-0.907	0.207	-0.049	0.125	-0.850	0.227
Regression-weights mixture	0.013	0.133	-0.877	0.300	-0.009	0.134	-0.862	0.337

Note: Summary statistics for different bargaining models. Equal-weights models give the same bargaining weight to each member country. GDP-weights models give a time-varying bargaining weight equal to each member's relative share of euro-area GDP in the given year. Regression-weights models estimate the bargaining weight by restricted least squares. National models use only national counterfactuals, federal models use only federal counterfactuals, and mixture models estimate the weight each country places on national relative to federal counterfactuals.

As alluded to previously, if the counterfactuals are to be interpreted seriously as the preferred interest rate changes of the euro member states then they should bound the actual change in the interest rate. It is hard to imagine, for example, the member countries agreeing to a change in the interest rate that is higher or lower than any of the individual members would actually want.

The blue and red lines in Figure 4 show, for a given period in time, the maximum and minimum interest rate counterfactuals of the euro member countries. Solid lines correspond with the set of federal counterfactuals and dashed lines the set of national counterfactuals. The black line gives the change in the interest rate that actually occurred in that period. The figure demonstrates that in the vast majority of cases the actual interest rate change falls within the span of the counterfactuals, which is a desirable property for the counterfactuals to have. Were this not the case, that would imply that, when euro member countries meet to decide on a policy change, they agree on a more extreme policy move than desired by any of the member countries—an indication that the counterfactuals are incorrect. Of the 179 months in the simulation period—February 1999 to December 2013—the actual interest rate falls out of the range of the national counterfactuals on 15 occasions and outside of the range of the federal counterfactuals on 17 occasions. Most of these occur within the first two years of euro adoption or in 2008 as the global economy entered a recessionary period.

Figure 4: Maximum, minimum, and actual change in interest rate



Note: The solid black line is that actual change in the euro-area interest rates. The solid (dashed) red line shows the smallest change among the federal (national) counterfactuals. The solid (dashed) blue line shows the largest change among the federal (national) counterfactuals.

Because it represents the range of policy preferences, Figure 4 also gives an indication of how the cross-sectional distribution of counterfactuals has evolved over time. The greater is the disagreement between the members the greater is the chance that the agreed upon policy will be unsuitable for some countries. Unsurprisingly, there is generally greater disagreement among the national than federal counterfactuals, but the difference is not sizable. The difference between the minimum and maximum policy change is relatively constant until 2008 where there is a large increase as the global economy entered a recession. Since 2010 the range of policy preferences has returned to pre-crisis levels, and if anything is somewhat narrower than in previous periods, indicating greater policy cohesion.

Another way to demonstrate the evolution of the distribution of the interest rate counterfactuals is to see how the cross-sectional standard deviation of the counterfactuals, $std(\tilde{r}_{i,k,t})$, has varied over time. Let

$$\sigma_{i,t} = \frac{1}{12} \sum_{l=0}^{11} std(\tilde{r}_{i,k,t-l}) \text{ for } i = nat, fed, \tag{28}$$

be the rolling mean of the cross-sectional variation in either the national or federal counterfactuals. Again this demonstrates periods when disagreement among the member countries is especially small or large. Figure 5 shows this statistic between 2000 and 2013. Overall the standard deviation is actually quite low in economic terms, typically varying just below twenty basis points. The standard deviation of the national counterfactuals is greater than that of the federal counterfactuals over the entire sample, which again is unsurprising. The standard deviation increases substantially between 2008 and 2010 but then quickly falls to levels lower than even pre-crisis values.

The identification strategy adopted in this paper hinges on the assumption that the parameters in each country's monetary policy rule have remained stable since the adoption of the euro. Were this not the case then the estimated monetary policy rules would no longer accurately represent the preferences of the member states. While this is not generally testable because the preferences are themselves unobservable I can provide some support for this assumption. First, were there some structural change in the underlying monetary policy preferences, we would expect to see deterioration of model fit over the sample period. However, the rolling RMSE shown in Figure 1 does not indicate that this is the case, outside of the period around 2009.

I provide additional evidence in support of this assumption by estimating the following

Figure 5: Rolling average cross-sectional standard deviation of counterfactuals

Note: Rolling average cross-sectional standard deviation of the national and federal counterfactuals, calculated by equation (28) for the national and federal counterfactuals.

regressions:

$$r_{euro,t} - \tilde{r}_{i,t}^{reg} = c_i + \sum_{l=1}^{m} \beta_l p_{euro,t-l} + \sum_{l=1}^{m} \delta_l y_{euro,t-l} + u_{i,t}, \quad \text{for } i = nat, fed, mix. \tag{29}$$

If the monetary policy preferences are unstable and no longer represent the preferences of the member states then we should expect lagged euro-area inflation and industrial production to enter equation (29) significantly. On the other hand, if the monetary policy preferences of the members are stable then they should already take this information into account and hence these variables should not help to predict the actual interest rate.

Table 5 shows p-values for the F-test of the joint hypothesis $\beta_l = \delta_l = 0 \; \forall \; l$ for two sample periods and a selection of lags. There is little evidence that euro-area industrial production or prices provide additional useful information to explain the interest rate beyond what is already contained in the counterfactuals from 1999–2008. This is true for the models based solely on national or federal counterfactuals, as well as the mixture model. At least through the first ten years of the euro era, then, the assumption that monetary policy preferences have remained stable seems reasonable.

As the sample is extended to include the recession beginning around 2009 there is now some evidence that there could have been a change in monetary policy preferences. Of course this could also represent a temporary change in preferences during an extraordinary period of economic turbulence. As demonstrated in Figure 1, although performance of all bargaining models decreased around the financial crisis, they have since returned to normal.

Table 5: Tests for significance of β_l and δ_l

	1999–2008			1999–2013		
lags	National	Federal	Mixture	National	Federal	Mixture
1	0.2166	0.1007	0.1345	0.2806	0.1723	0.1622
2	0.3794	0.1104	0.1910	0.1579	0.0605	0.0694
3	0.2884	0.1011	0.1324	0.0817	0.0457	0.0530
6	0.3565	0.2141	0.2125	0.0425	0.0550	0.0391
12	0.2655	0.2703	0.2479	0.0451	0.1040	0.0752

Note: p-values of the F-statistic for the joint significance of $p_{euro,t-l}$ and $y_{euro,t-l}$ in equation (29).

7 Robustness to alternative specifications

In this section I explore the robustness of the main results of this paper to changes to the vector autoregressions (1) used to estimate the monetary policy rules in the pre-euro era. I consider four alternative specifications. First, I increase the lag length to include three lags of all variables in the VAR. Second, I choose the lag length for each country to minimize the Akaike Information Criterion (AIC) of the interest rate equation of the reduced-form VAR. To do this I estimate by OLS a regression of a country's interest rate on all right-hand-side variables in (1) from one to a maximum of six lags and choose the lag length which minimizes the AIC. An alternative would be to choose the AIC to minimize the AIC of (1) directly. I think my approach is more appropriate in this context because I am interested in proper specification of the interest rate rule rather than the whole system of variables in the VAR. A third specification includes interest rates as levels rather than differences.

Finally, I consider an alternative identification approach for the matrix A_k in (1). I follow Cushman and Zha (1997) and restrict the coefficients based on the timing of when information is available to policymakers. Specifically, when interest rate decisions are made, current data on the price level or industrial production is not available, so that $a_{k,2,3} = a_{k,2,4} = 0$. However, current data on the exchange rate is available so policymakers are able to respond to contemporaneous fluctuations in the exchange rate, a channel not allowed in the Cholesky decomposition used in the benchmark model. Exchange rates are determined in an information sector and allowed to respond to all variables in the system. The remaining rows of A_k maintain the same zero restrictions imposed under the Cholesky decomposition used in the benchmark specification.

This changes the German monetary policy rule from equation (7) to:

$$r_{g,t} = [0 \;\; 1 \;\; 0 \;\; 0] \left(\hat{B}_g x_{g,t-1} + \hat{D}_g w_{g,t} \right) - \hat{a}_{g,2,1} s_{g,t}, \tag{30}$$

and likewise, for the remaining countries:

$$r_{k,t} = [0 \;\; 1 \;\; 0 \;\; 0 \;\; 0] \left(\hat{B}_k x_{k,t-1} + \hat{D}_k w_{k,t} \right) - \hat{a}_{k,2,1} s_{k,t}. \tag{31}$$

Of course, during the euro era exchange rates between the member countries are fixed so that the exchange rate terms—which are expressed as differences—will drop out, but this accounts for potentially important exchange rate pressure during the estimation period.

Table 6 shows the RMSE for the same interest rate models considered in Section 5 over the sample 1999–2013. The bottom four rows show the results for one of the alternative specifications and the top row shows the results for the benchmark model, for comparison. The first result is that none of the regression models from the alternative specifications achieves a lower RMSE than the benchmark model. This is true for the national, federal, and mixture counterfactuals under all three bargaining weights and implies that, overall, the benchmark counterfactuals can be combined to give the closest fit to the true interest rate.

Table 6: Comparison of interest rate models: alternative specifications

	Equal weights			GDP weights			Regression weights		
	National	Federal	Mixture	National	Federal	Mixture	National	Federal	Mixture
benchmark	0.1738	0.1680	0.1674	0.1625	0.1512	0.1499	0.1366	0.1334	0.1321
$m = 3$ lags	0.2060	0.2006	0.1897	0.1996	0.1864	0.1832	0.1520	0.1543	0.1505
lag selection	0.2106	0.2062	0.2010	0.2218	0.2119	0.2082	0.1434	0.1430	0.1412
levels	0.1935	0.1952	0.1926	0.2036	0.2087	0.2026	0.1531	0.1451	0.1451
timing restrictions	0.4442	0.4499	0.3064	0.4453	0.3878	0.3777	0.1424	0.1351	0.1329

Note: Root mean squared error (RMSE) of different bargaining models given by equation (23). Equal-weights models give the same bargaining weight to each member country. GDP-weights models give a time-varying bargaining weight equal to each member's relative share of euro-area GDP in the given year. Regression-weights models estimate the bargaining weight by restricted least squares. National models use only national counterfactuals, federal models use only federal counterfactuals, and mixture models estimate the weight each country places on national relative to federal counterfactuals.

When the lag length is increased—second and third rows—federal models continue to outperform national models among the equal- and GDP-weights models, as in the benchmark model. In the lag selection model the equal-weights bargaining models actually outperform the GDP-weights models, and the national counterfactuals with GDP bargaining weights performs worst, again contradicting the notion that ECB policy favors the national interests of its largest members. With three lags the regression-weights model with national counterfactuals does outperform the regression-weights model with federal counterfactuals, but the difference is small, only 0.23 basis points, and both are dominated by the mixture model.

When interest rates are expressed in levels, rather than differences, the GDP-weights models are worst performing overall. National models perform better than federal models for the equal- and GDP-weights models, but not the regression-weights models. Finally, under the alternative identification strategy the RMSEs of the equal- and GDP- weights models increase considerably. In particular, the RMSEs of GDP-weights models are approximately three times as large as for the regression-weights models.

Overall, the results of these alternative specifications support the conclusions of the benchmark model. There is little evidence to support the notion that countries favor their national economic conditions over the conditions of the entire euro area or that monetary policy favors the preferences of the largest countries.

8 Conclusion

Contrary to the results of several previous studies, this paper does not find evidence that ECB monetary policy favors the national preferences of member countries. Instead, the results show that mixture models, which take into consideration both national and federal preferences, provide the closest fit to the true interest rate. Furthermore, the optimal mixing weights tend to favor federal over national counterfactuals, especially when the bargaining weights are estimated by regression. An interesting caveat is that individual countries appear to consider either their national or federal economic conditions, rather than mixing between them. Hench, there appears to be a divide between a group of ECB member countries who consider federal conditions, and a separate group that consider only national conditions. This finding may be of interest to researchers aiming to estimate more explicit voting procedures at the ECB, beyond the bargaining models I consider in this paper.

I also find little evidence that monetary policy favors the preferences of the largest euro member countries. Although GDP-weight bargaining models outperform equal-weight bargaining models, the best fitting model places more than 90% of the estimated weights on the counterfactuals of only three countries: Austria, Ireland, and Spain, none of which count among the largest economies in the euro area. Instead, this may indicate coalition-building around common interests of Central, Northern, and Southern European countries. Taken together, these findings suggest that, to the extent that larger countries benefit disproportionately from membership in the euro this appears to be because they constitute such a large fraction of euro-area economic conditions that what is optimal for the euro area tends to be favorable for them as well.

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