Rotation Scheme of the ECB Governing Council: Monetary Policy Effectiveness and Voting Power Analysis*

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Abstract

We analyze the impact of a rotation system on the effectiveness of monetary policy and the distribution of voting power among the ECB Governing Council members. We apply the models based on either New Keynesian or Neo-Keynesian framework and run simulations to find that volatility of output and inflation declines with a decrease in the home bias of the GC members. It thus strongly suggests that decision-makers should concentrate on the developments in the euro area as a whole and not pursue national interests. Moreover, we show that in most cases there is no significant difference between the two frameworks. We also find that a change in the rotation frequency should not influence the performance of the voting system. Introducing the rotation system significantly improves the economic performance only when Board members focus on the the euro-wide economic developments, whereas NCB governors concentrate on the situation in their country of origin. Strengthening position of the Board is confirmed by the voting power analysis. However, an increase in the Board's power is lower if we allow for the possibility of coalitions among decision-makers, which we identify in the study. We conclude that the reform of the voting modalities in the ECB Governing Council will only partly solve the difficulties that the enlargement process was to impose on the functioning of the old framework.

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1 Introduction

The process of EU enlargement brings a lot of opportunities as well as challenges. The latter relate, inter alia, to the effective functioning of the institutional settings at the European level. In particular, an increasing number of the euro-area member states induced the reform of the voting modalities in the ECB Governing Council (GC). Its underlying rationale has been to maintain the GC's capacity for efficient and timely decision-making in an enlarged monetary policy committee. This goal is to be achieved through the introduction of a rotation scheme.

The new voting system has, however, often come in for a criticism. It is said to be intransparent, violating the "one member, one vote" principle, and not providing conditions for an efficient decision-making. Most importantly, the rotation system is criticized for cultivating thinking in national categories and re-nationalizing European monetary policy.

The latter argument, however, is at odds with the legal framework of the euro-zone, which states that both the members of the Executive Board and the NCB governors in the GC should not act as national representatives but in a fully independent personal capacity. In their decisions they should thus concentrate on the developments in the euro area as a whole and not to pursue national interests.

Nevertheless, empirical literature seems to confirm the existence of regional bias in the voting behavior of various decision-making bodies. More importantly, research indicates that pursuing regional interests could influence the performance of the monetary policy conduct in an adverse manner.

Therefore, it should be investigated if the reform of the voting modalities in the ECB Governing Council copes with a potential problem of voting behavior being influenced by regional rather than euro-wide developments. Moreover, the influence of the rotation system on the position of individual NCB governors and the Executive Board should be of particular interest to the member states, not least those that had no opportunity to shape the new framework. In addition, it would be desirable to analyze those details of the new voting system that have not yet been specified, the frequency of rotation being a major example. It would increase the likelihood that any possible amendments to the voting scheme would enhance its effectiveness.

In this study we investigate the impact of the rotation system on the effectiveness of monetary policy, both for the euro area as a whole and individual member states. The analysis is based on the outcomes of simulations, in which we allow for, inter alia, various frequency of rotations, hetereogeneity of economic developments in the euro area members and a different degree of home bias in the voting behavior of the Governing Council members.

For the simulation purposes, we apply the model that comprises the IS curve, the Phillips curve, and the nominal interest rate (Taylor rule) equations.

Moreover, in order to account for the heterogeneity of the currency union member states, for each of the 27 countries considered in the study the separate set of the above equations is constructed. In addition, we extend the IS curve by the competitiveness channel, as well as the output gap in the trading partners' economies. Finally, depending on the importance we assign to forward against backward looking mechanisms, we consider models based on either New Keynesian or Neo-Keynesian framework, respectively.

We also analyze the consequences of the new framework for the distribution of voting power among the ECB Governing Council members. We contribute to the literature by dropping the simplistic approach based on the use of voting frequencies as intertemporal weights and, instead, taking into account the fact that under the rotation system the ”voting game” is played only between those members that at a given time have a right to vote. Moreover, we extend the analysis by allowing for the existence of precoalitions between the Governing Council member states.

The paper is organized as follows. Section 2 reviews the literature on the role of heterogenous preferences of decision-makers in the monetary policy conduct, as well as on the impact of the rotation system on the voting power distribution in the Governing Council. In section 3 voting modalities in the ECB Governing Council are discussed, including the rationale underlying the reform and its criticism. Section 4 investigates the influence of the rotation system on the effectiveness of monetary policy. It disusses the methodology, including the models applied, and then presents the simulation results. Section 5 analyzes the effects of the new system on the basis of voting power analysis. The final section concludes.

2 Literature overview

The literature that investigates the role of heterogenous preferences of decision-makers in the monetary policy conduct is of particular relevance to the objective of this study. The reason is that in multinational institutions, such as the ECB, policy-makers' decisions may be influenced by economic developments in the country of their origin. On the one hand, this assumption is at odds with the legal framework of the euro-zone, which states that both the members of the Executive Board and the NCB governors in the GC should not act as national representatives but in a fully independent personal capacity.[1] In their decisions they should thus concentrate on the developments in the euro area as a whole and not to pursue national interests.

On the other hand, however, there are a number of arguments that the regional bias may indeed be present in the GC members' decisions. Firstly, should all

[1]See Article 108 of the Consolidated versions of the Treaty on European Union and of the Treaties Establishing the European Community.

policy-makers vote in the interest of the euro area as a whole, the need for an adjustment of the voting system would not be that urgent. Indeed, one of the often quoted arguments in favor of the reform was the concern that new member states (with most likely higher inflation rates driven by the catching-up process) would exert too much influence on the ECB decisions (see, e.g., Baldwin et al., 2001; Grauwe, 2003). This, of course, is at variance with the assurance that the GC members do not pursue their national interests.

Secondly, several studies indicate that monetary policy conduct is indeed influenced by the decision-makers' regional bias. Meade and Sheets (2005) analyze the available details on the course of meetings and voting records of the Federal Reserve monetary policy committee and investigate whether the voting behavior of decision-makers has been influenced by information about regional economic developments. The authors find that data on regional unemployment do influence the voting behavior of the Fed policy-makers, which is more evident in the case of the members of the Board of Governors than the Reserve Bank Presidents.[2] These findings turn out to be robust to a variety of different specifications of the voting equation[3]. A similar study by Berger and Haan (2002) investigates the voting behavior of the decision-makers in the German Bundesbank. It shows that economic situation in various German states did affect the way that individual policy-makers voted.

The hypothesis of regional bias has also been tested by Heinemann and Huefner (2004) in the context of the euro area monetary policy. On the one hand, their estimates of reaction functions with a different size of regional bias assigned to the GC members are inconclusive as to whether the euro area or a national interest is more relevant for the ECB voting. On the other hand, the results of the probit model for the GC's interest rate decisions in the first years of the euro area seem to provide some evidence that voters' behavior is influenced by divergences of national data from euro-wide indicators.

A number of studies investigate the possible impact of those regional biases on the monetary policy effectiveness. Aksoy et al. (2002) apply a standard New Keynesian model with an accelerationist Philips curve to derive the optimal feedback rule for the eleven EMU countries. The authors assume that the heterogeneity of the GC members' preferences regarding the desired level of interest rates may stem from different preferences over macro-economic goal variables[4], (country-specific) differences in the transmission of interest rates

[2]Federal Open Market Comimitee, which is a decision-making body of the Federal Reserve System, comprises seven members of the Board of Governors, the President of the Federal Reserve Bank of New York and four of the remaining eleven Reserve Bank Presidents, who serve one-year terms on a rotating basis.

[3]The authors quote also two other studies, which test the hypothesis that the regional factors impact on the voting of the FOMC members. On the one hand, Gildea (1992) provides the evidence that the Reserve Bank Presidents that represent regions with higher unmeployment rates or with a larger percentage of democratic voters tend to favor more expansionary monetary policy. On the other hand, however, the study by Tootell (1991) provides no empirical support for this hypothesis.

[4]Here we mean the preferences over the relative weight of output and inflation stabilisation

into these variables, the actual situation and structure of the economy and stochastic shocks that alter the state of the economy. Optimal interest rates for each country in the sample are derived on the basis of the estimated coefficients of the model equations and different assumptions as regards the GC members' preferences over goal variables in the central bank loss function. Next, the outcomes of a collective decision-making process under simple majority rule and various assumptions about the way country-specific and euro-wide developments influence the desired interest rate levels are derived and compared with each country's optimal interest rate. The authors find that the EB can effectively conduct monetary policy, even if NCB representatives follow their partisan interests. They also show that the stronger the incentive of decision makers to stabilize output in their country of origin, the lower the correlation between desired and actual interest rates. Finally, the results suggest that adopting a euro-wide perspective improves the welfare relative to the situation when the EB members exhibit home bias in their voting behavior.

The impact of regional biases on monetary policy outcomes has also been studied in the context of the rotation voting scheme that the ECB is to introduce. This issue is investigated by, inter alia, Bénnasy-Quéré and Turkisch (2005) and Paczyński (2006). The former calculate the desired (time-invariant) interest rate for each country with the use of the standard Taylor rule. Various decision-making rules are then applied to determine the outcome of the GC voting. According to the authors, the introduction of the rotation scheme will have little impact on the decisions made by the GC in the enlarged Eurozone, because the interest rate chosen will be close to that desired by the EB, which in turn is assumed to follow euro-wide interests. Bénnasy-Quéré and Turkisch (2005) also claim that the relatively low frequency of rotation would be favorable to the "old" member states because they would be able to determine lower interest rates compared to scenarios with less frequent rotations. These findings are, however, highly questionable due to the static approach adopted by the authors, which neglects the endogeneity of future paths of inflation and output gap with respect to the chosen interest rates.

Paczyński (2006) also uses the standard Taylor rule to determine the GC members' preferences in the enlarged Eurozone.[5] However, contrary to Bénnasy-Quéré and Turkisch (2005), Paczyński calculates the desired level of interest rates on the basis of either historical paths of output gap and inflation in the analyzed countries or constructed counterfactual output and inflation data.[6]

in the central bank's loss function.

[5]In the baseline scenario, inflation targets for the analysed 25 countries are set as the average of the inflation rate implied by the Balassa-Samuelson effect (estimation taken from the literature) and actual inflation performance over the period 1997-2004. These targest are subsequently normalised so that the EMU12 target is set to 2 per cent. Natural rates of interests are set by adjusting the 2 per cent level by half of the difference between 2 per cent and assumed inflation target.

[6]The counterfactual data for Germany, Poland, Greece, and Lithuania are constructed with the use of a standard New Keynesian three-equation model with the parameter values taken from the literature. For the remaining countries, forecasts from the estimated vector

Different degrees of regional biases are then considered and voting outcomes under various decision rules are evaluated. The analysis shows that if the EB members pursue the interest of the euro area as a whole, the divergence of the actual interest rate decision from the optimal level is small. However, if all GC members exhibit a home bias, it leads to substantial policy errors both under the old and the new voting scheme. This finding is confirmed irrespective of whether the EMU consists of 12 or 25 countries. The author thus concludes that the rotation model does not appear to be well suited to alleviate the potential problems related to regional biases in the GC members' preferences.

Another strand of the literature analyzes the reform of the ECB voting scheme in terms of its impact on the voting power distribution in the GC after euro area enlargement. Studies investigating that issue are based on the use of either intertemporal voting shares (Berger et al., 2004) or voting power indices (Belke and Styczynska, 2006; Fahrholz and Mohl, 2006; Ullrich, 2004). They differ, however, on the grounds of methodological details, which are of particular interest to our paper.

Ullrich (2004) and Belke and Styczynska (2006) consider the decision-making in the GC as an inter-temporal cooperative game. It is assumed that the GC members form coalitions that persist over several meetings. The authors argue that this should stress the importance of the average number of votes that a decision-maker has rather than the fact that a vote is formally taken only during certain meetings. Consequently, they use the frequencies of countries' voting, implied by their assignment to different rotation groups, as their voting shares. On the basis of these inter-temporal voting shares, the power indices are subsequently calculated. Fahrholz and Mohl (2006) criticize this approach and argue for computing power indices first and then re-weighting them with respective voting frequencies.[7] However, these authors themselves apply quite an implausible approach by assuming that the voting game is played *each time* between all GC members, whereas under rotation it will be played only between those members that at a *given time* have a right to vote. Another difference between the above quoted studies concerns the assumptions about the EB preferences. In particular, only the work by Ullrich (2004) provides for the possibility of regional bias among the Board members.

Despite various differences in the methodologies applied for the calculation of power indices, the authors arrive at similar conclusions. They indicate that all GC members should be loosing power throughout the euro area enlargement process. The position of the Board, however, should be strengthened by the introduction of the rotation scheme. The new system should also increase the

autoregressive model are derived. The endogenous variables in the model are inflation and output gap, whereas the exogenous variables are inflation and output gap in Germany.

[7] The authors point out that with an additional voter being, with a very small but positive probability, a "dictator" he would become a dummy player in case of re-weighting and the power of other voters would not be altered when adding such a player. However, this voter would be pivotal in some cases, so his vote should affect other players' power, even though to a small extent.

power of the biggest euro area economies, although this increase will be relatively small.

In their voting power analysis, Belke and Styczynska (2006) highlight two additional implications of the new voting scheme, which are assessed as negative. Firstly, the rotation model leads to “sharp shifts” in the allocation of power during the early stages of euro area enlargement. Secondly, since the new system reduces the voting power of acceding countries (relative to the ”old” voting scheme), it may result in “re-nationalization” of the euro area monetary policy.

The above overview of the literature indicates that the research analyzing the impact of the rotation system on the conduct of monetary policy is still relatively scarce. Moreover, various studies that have dealt with this issue are not free of methodological drawbacks. Our paper aims to fill this gap, as well as to contribute to the literature on the effectiveness of the new voting scheme in a number of other aspects.

3 Voting modalities in the ECB Governing Council

3.1 Legal Framework

The most important and strategically significant decisions on the euro area monetary policy are made by the Governing Council of the ECB. The Statute on the ESCB and the ECB (henceforth the Statute) envisages that the Governing Council formulates monetary policy of the Eurosystem, including decisions relating to the intermediate monetary objectives and key interest rates. The implementation of the guidelines and the decisions laid down by the Governing Council is entrusted to the Executive Board of the ECB.

The Governing Council (GC) consists of the Executive Board of the ECB and the governors of national central banks (NCB) of the countries that have adopted the euro. The Executive Board (EB) comprises six members: the President, the Vice-President and four other members. The members of the EB are appointed for the eight-year term, which is non-renewable[8]. According to the Statute, only nationals of the member states may be members of the ECB EB. Furthermore, the Board members should be appointed by common accord of the governments of the member states at the level of heads of state or government, on a recommendation from the Council, after it has consulted the European Parliament and the GC of the ECB[9]. The NCB governors are appointed at the

[8]The country of origin and the end of the term in office of the current Executive Board members are as follows: France (31.10.2011), Greece (31.05.2010), Austria (31.05.2011), Spain (31.05.2012), Italy (31.05.2013) and Germany (31.05.2014).

[9]The Treaty of Lisbon envisages that the EB members should be appointed by the European Council, acting by a qualified majority, upon recommendation by the Ecofin Council and upon consultation of the European Parliament and the ECB Governing Council.

national level.

Prior to March 21, 2003, the Statute had envisaged that each member of the GC should have one vote and that the GC should decide on the key euro area interest rates acting by a simple majority (with a casting vote of the President in case of a tie). However, the forthcoming EU enlargement that called for a reform of the EU institutional settings in various areas, induced also the reform of the voting modalities in the Governing Council. The basis for a required change was provided by the Treaty of Nice, which came into force on February 1, 2003. The Treaty amends the Article 10.2 of the Statue, which lays down the voting rules at the GC. The Treaty envisaged that Article 10.2 of the Statute "may be amended by the Council meeting in the composition of the Heads of State or Government, acting unanimously either on the recommendation of the ECB and after consulting the European Parliament and the Commission, or on a recommendation from the Commission and after consulting the European Parliament and the ECB". According to the Treaty, such adjustments have to be ratified by all member states of the European Union in accordance with their respective constitutional requirements. The Treaty further specifies that any ECB recommendation of a possible amendment shall require a decision by the GC acting unanimously.

The GC decided upon the proposal of the voting modalities adjustment and submitted its recommendation to the Council on 3 February, 2002. The recommendation was subsequently adopted by the meeting in the composition of heads of states and governments of EU member countries on March 21, 2003. The amended article 10.2 of the Statute lays down that each member of the GC shall have one vote. When the number of the GC members exceeds 21, a rotation scheme shall be introduced. Each member of the EB will continue to have one vote under those new settings. Yet, the number of NCB governors with voting rights will be limited to 15. Those 15 voting rights will be assigned on a rotation basis, which shall proceed as follows:

- for $n_{NCB} \in < 16, 21 >$ (where n_{NCB} stands for the number of the NCB governors in the GC), a two-group rotation scheme will be in force. The first group will comprise five governors and the second group - the remaining NCB presidents. Four voting rights will be assigned to the first group and eleven to the members of the second group. The Statute specifies, however, that the frequency of the voting rights allocated to the second group should not exceed that of the first group.

- for $n_{NCB} \geq 22$, a three-group rotation model will be in force. The first group will consist of five governors and have four voting rights. The number of governors in the second group will be equal to the half of the total number of NCB governors, with any fraction rounded up to the nearest integer. There will be eight voting rights assigned to the second group. The third group will comprise the remaining NCB governors and will be assigned with three voting rights.

Table 1: Rotation Groups in the enlarged euro area (EMU27)

	Group I	Group II	Group III
Voting frequency	80%	57%	38%
Countries	Germany, the United Kingdom, France, Italy, Spain	The Netherlands, Belgium, Sweden, Austria, Poland, Denmark, Ireland, Greece, Finland, Portugal, the Czech Republic, Romania, Luxembourg, Hungary	Slovakia, Slovenia, Bulgaria, Latvia, Lithuania, Cyprus, Estonia, Malta

Source: Eurostat, ECB, Bank of England

The NCB governors will be allocated to the respective groups according to the ranking based on the composite GDP/TABS-MFI indicator. This indicator has a weight of $\frac{5}{6}$ assigned to the share of the given country in the aggregate gross domestic product at market prices (GDP) and a weight of $\frac{1}{6}$ assigned to the share in the total aggregated balance sheet of monetary financial institutions (TABS-MFI) of the member states that have adopted the euro. The composition and the size of the groups will be adjusted whenever the number of governors increases or at times the aggregated domestic product at market prices is adjusted (i.e. every five years). Table 1 presents the classification of countries to the respective rotation groups, as well as voting frequencies associated with those groups in a hypothetical Eurozone comprised of 27 countries. The assignement is based on the GDP and TABS-MFI data for the year 2007.

The Statute envisages that the GC, acting by a two-thirds majority of all its members, may postpone the start of the rotation system until the moment when the number of the NCB governors exceeds 18. This would be consistent with the requirement that the frequency of the voting rights allocated to the second group should not exceed that of the first group. Furthermore, the Statute specifies that the GC should take all measures necessary for the implementation of the above described principles also acting by a two-thirds majority.

3.2 Reform of the voting system - its rationale and criticism

The underlying rationale of the voting modalities reform has been to maintain the GC's capacity for efficient and timely decision-making in an enlarged euro area. In the Council's assessment, the rotation scheme is an *equitable and efficient* way of assigning voting rights among the governors in the GC and it reflects the following five fundamental principles (European Council, 2003):

- *one member, one vote*, which is said to be the GC's core decision-making principle. According to the Council, this principle applies to the new voting scheme since all members of the GC will have a voting right.

- *ad personam participation*. This principle relates to the fact that all GC members will still participate in the Council meetings.
- *robustness*. The new voting scheme is assessed to be robust due to its ability to accommodate any euro area enlargement.
- *representativeness*. The introduction of the new voting scheme eliminates the possibility that those member states whose NCB governors have a right to vote at a given time will be unrepresentative of the euro area as a whole.
- *transparency*.

Despite the numerous virtues of the reform that its advocates have repeatedly assured of, adjustment of the voting modalities in the GC has come in for a severe criticism (Belke et al., 2003). Firstly, it has been argued that the new framework does not provide conditions for an efficient decision-making as the number of governors participating in a discussion on interest-rate decisions will be growing with new countries joining the euro area. The mere limitation of voting rights will not ensure that the interest-rate meetings will not be excessively long, not least when governors without a voting right at a given meeting will compensate themselves for that by exercising their right to speak. It has also been pointed out that even if the number of members participating in the GC meeting were limited to 21, it would still be too large for an effective monetary policy conduct.[10]

Secondly, the new voting scheme is regarded to be violating the "one member, one vote principle" because this principle will only apply to those governors who are allowed to vote at a given time.

Thirdly, the rotation model is said to create "a notion of a two or three-tier Europe"(Friedrich, 2003), cultivate thinking in national categories and re-nationalize European monetary policy (Belke, 2003) by conditioning the composition of rotation groups on the basis of the relative size of respective countries.

Fourthly, the new voting scheme is assessed as being highly intransparent. In particular, it has been argued that the adopted solution is too complex to be easily understood by the public (Belke et al., 2003). Moreover, the exact procedures related to the rotation scheme (e.g. how often rotation will take place, how many governors will rotate at a time, whether the rules for rotation will be the same for all groups, in what order should the governors rotate? etc.)

[10]Gros (2003) notes that no modern central bank has a decision-making body of such considerable size. In particular, he points to the example of the Bundesbank, which was reformed because it had been assessed that any number exceeding 20 decision-makers within such an institution would make the effective policy conduct unfeasible.

are still not specified. It is even unclear when the new voting scheme will be introduced. The provision that the frequency of voting rights of the governors allocated to the second group cannot exceed that of the first group implies that the new system cannot be introduced until $n_{NCB} = 19$. The reason is that for $n_{NCB} = 16$, $n_{NCB} = 17$, $n_{NCB} = 18$, the voting frequency of the governors from the first group would be equal to 80 per cent, whereas the voting frequencies of the governors from the second group would amount to 100, 92 and 85 per cent respectively.

Furthermore, the fact that assignment to rotation groups may change over time with a shift of countries' position in the GDP/TABS-MFI ranking is another factor that reduces the transparency of the new voting system. In addition, the use of the TABS-MFI indicator itself attracts a lot of criticism. In principle, the use of an indicator measuring the size of the financial sector should reflect the importance of this sector for the conduct of monetary policy. However, it is often emphasized that the TABS-MFI indicator is biased towards banking assets and does not cover the whole financial sector. There are also allegations that this indicator has been chosen in order to boost the position of Luxembourg (Belke, 2003; Meade, 2003) - a country, whose banking sector accounts for a considerable share of deposits from EU institutions and from other member states.

Therefore, there is much controversy about the reform of the GC voting modalities. New EU member states did not have an opportunity to shape the framework of the voting scheme that is to be introduced. Still, some particulars of the rotation system have not been specified. This allows the new countries to influence some details of the voting scheme, e.g. those related to frequency of rotation. Any such proposals should, however, be preceded by a thorough analysis of the rotation framework. Therefore, in the next section we scrutizine the impact of the new voting scheme on the effectiveness of monetary policy, both for the euro area as a whole and individual member states. It is followed by the section, where we analyze the consequences of the rotation system for the distribution of voting power among the ECB Governing Council members.

4 Rotation scheme and monetary policy effectiveness

In this section we investigate the impact of the new voting scheme on the effectiveness of monetary policy. The analysis is based on the outcomes of simulations, in which we allow for, inter alia, different frequency of rotations, hetereogeneity of economic developments in the euro area members and a different degree of home bias in the voting behavior of the Governing Council members.

4.1 Model

For the simulation purposes, we apply the model that comprises the IS curve, the Phillips curve, and the nominal interest rate (Taylor rule) equations. Moreover, in order to account for the heterogeneity of the currency union member states, for each of the 27 countries considered in the study the separate set of the above equations is constructed. In addition, we extend the IS curve by the competitiveness channel, as well as the output gap in the trading partners' economies. Finally, depending on the importance we assign to forward against backward looking mechanisms, we consider models based on either New Keynesian or Neo-Keynesian framework, respectively.

4.1.1 Forward-looking model

The forward-looking version of the model draws on Torój (2008) and is an extension to a standard New Keynesian specification considered i.a. by Lindé (2005) with 3 equations for output gap (hybrid IS curve), inflation (hybrid Phillips curve) and nominal interest rate (Taylor rule).

Following Galí and Gertler (1999)[11], we apply a hybrid Phillips curve, which comprises both lagged and rationally expected inflation rate, as well as the current level of the output gap:

$$\pi_{j,t} = \omega_{f,j} E_t \pi_{j,t+1} + \omega_{b,j} \pi_{j,t-1} + \gamma y_{j,t} \tag{1}$$

We restrict the parameters of past and expected inflation to sum to unity in our simulations, which allows our steady state to replicate from period to period in the absence of shocks.

The output gap equation for country j resembles the standard hybrid specification considered by Goodhart and Hofmann (2005), including expected future and lagged output gap, as well as the difference between current *ex ante* real interest rate $(i_t - E_t \pi_{j,t+1})$ and the natural rate of interest in country j (r_j^*).

$$\begin{aligned} y_{j,t} \quad = \quad & \beta_{f,j} E_t y_{j,t+1} + \beta_{b,j} y_{j,t-1} - \beta_{r,j} \left(i_t - E_t \pi_{j,t+1} - r_j^* \right) + \\ & - \beta_{c,j} \left(\theta_j^* + P_{j,t} - P_{-j,t} - t \cdot 0.25 \cdot \left(\pi_j^* - \pi_{-j}^* \right) \right) - \beta_s y_{-j,t} + \varepsilon_{y,j,t} \end{aligned} \tag{2}$$

$P_{j,t}$ stands for a cumulated price growth since entering the monetary union and evolves according to the following:

$$P_{j,t} = P_{j,t-1} + 0.25 \cdot \pi_{j,t} \tag{3}$$

[11] The only exception being that we replace real marginal cost, that Galí and Gertler (1999) apply, with the current level of the output gap.

and for $t = 0$, $P_{j,t} = 0$. Variables $(y,\ \pi,\ P)$ that are associated with all countries of the monetary union except j are subscripted $-j$ and constructed as a weighted average of these countries:

$$y_{-j,t} = \frac{\sum_{k,k\neq j} w_k y_k}{\sum_{k,k\neq j} w_k} \tag{4}$$

$$\pi_{-j,t} = \frac{\sum_{k,k\neq j} w_k \pi_k}{\sum_{k,k\neq j} w_k} \tag{5}$$

$$P_{-j,t} = \frac{\sum_{k,k\neq j} w_k P_{k,t-1}}{\sum_{k,k\neq j} w_k} + \frac{\sum_{k,k\neq j} w_k \cdot 0.25 \cdot \pi_{k,t}}{\sum_{k,k\neq j} w_k} \tag{6}$$

One should note two additional regressors included in the IS curve, which account for the economy's openness with respect to other member states of the monetary union. This extension is necessary to replicate properly the features of EMU macroeconomic adjustment and remain in line with the main logic of New-Keynesian open economy framework, as emphasized by Clarida et al. (2001), namely that small country's output gap depends on external demand, as well as prices of domestic goods in foreign currency.[12]

The IS curve equation thus includes the output gap in the rest of the currency union $(y_{-j,t})$, which controls for the change in the external demand with respect to country j. Furthermore, the competitiveness term $(P_{j,t} - P_{-j,t})$, expressed as a price log-level difference against the rest of the monetary union, incorporates the real exchange rate channel into the model, lowering the output gap when cumulative price growth in country j is excessive.[13]

However, a change in relative prices does not always affect the competitiveness of a country. Indeed, the real convergence between member states of the currency union requires - through the Balassa-Samuelson effect - real appreciation (or depreciation) of the exchange rate as a part of the equilibrium process in a relatively less (more) developed economy. Distinct equilibrium paths of relative prices are reflected in the differences between implicit inflation targets of currency union member states (π_j^*). We account for this fact in simulations by assuming that a quarterly price growth consistent with the annualized real exchange rate appreciation (or depreciation) of $\left(\pi_j^* - \pi_{-j}^*\right)$ is an equilibrium phenomenon and does not influence the output gap of a country j.

There is one more term in the competitiveness channel, θ_j^*, which reflects the one-off adjustment in the level of real exchange rate of country j, necessary to

[12]However, whereas in the framework of Clarida et al. (2001) the nominal exchange rate plays a critical role in restoring equilibrium, it is no longer valid in the monetary union regime, which is considered in our study.

[13]Since in the currency union nominal exchange rates are irrevocably fixed, a shift in relative prices is tantamount to the change in the real exchange rate relative to other member states.

restore the equilibrium after shifting from the independent monetary policy into the new regime of a currency union. The "new equilibrium" stems from the need to counter the destabilizing effect of the real interest rate channel. Since euro area membership entails the common nominal interest rate for all countries, the real interest rate channel becomes procyclical. For example, a rise in $E_t\pi_{j,t+1}$ requires a higher interest rate. However, in the currency union, the country j itself has little impact on the conduct of monetary policy. Consequently, if interest rates do not change, the real interest rate in the country j will fall leading to increasing output gap and adding to inflation pressure and, most likely, still higher inflation expectations. Provided that the ECB maintains its interest rate at the unchanged level, this would further lower the real interest rate in the country j, reinforcing the procyclical effects of this channel. This mechanism may, of course, also work in a reverse direction, hampering economic growth via too high a level of the real interest rate. This procyclicality of the real interest rate channel has been dubbed "the Walters critique" and is often quoted as a major argument against giving up an autonomous monetary policy and adopting the euro.

This procyclical, and thus destabilizing, effect of the real interest rate channel may, however, be compensated for by the adjustment via the competitiveness channel. For example, too low an interest rate would lead to inflation pressure out of equilibrium and thus deteriorate the competitiveness of the domestic producers. The latter in turn would stifle economic activity in country j and reduce the inflation pressure.

In the steady state, that is with a zero output gap and inflation at the target level, the ECB nominal interest rate $i_t = \pi^* + r^*$ would hardly ever equal $\pi_j^* + r_j^*$ for any j country. Consequently, on the country-level, the real interest rate channel works procyclically even in the equilibrium. Therefore, in order to close the output gap, an appropriate appreciation or depreciation of the real exchange rate is necessary. θ_j^* stands for that one-off necessary adjustment in the real exchange rate to restore the equilibrium in the new steady state under monetary union regime. This adjustment may be carried out either by an amendment to the nominal conversion rate of the domestic currency into the euro or by the change in the level of relative prices:

$$\theta_j^* = \Delta P_j^* - \Delta P_{-j}^* \tag{7}$$

Contrary to the steady state in a country with an independent monetary policy, neither the real interest rate nor the competitiveness channel are neutral in the monetary union. Instead, they cancel each other out so that the equlibrium is secured with the zero output gap and inflation at the target level (π_j^*).

4.1.2 Backward-looking model

In the backward-looking version of the inflation equation, our departure point is the new Phillips curve:

$$\pi_{j,t} = E_t \pi_{j,t+1} + \gamma y_{j,t} \tag{8}$$

whereby, following Gerlach and Svensson (2003), we assume that inflation expectations are a function of inflation target and lagged deviation of inflation from this target:

$$E_t \pi_{j,t+1} = \pi_j^* + \lambda(\pi_{j,t-1} - \pi_j^*) \tag{9}$$

which yields a purely backward-looking Phillips curve specified as:

$$\pi_{j,t} = (1-\lambda)\,\pi_j^* + \lambda \pi_{j,t-1} + \gamma y_{j,t} \tag{10}$$

In the case of the IS curve equation, we drop the term of rational expectations of the future output gap and alter the β_b parameter value (see Subsection 4.2.1). We also replace rational inflation expectations from (2) with the backward-looking definition of inflation expectations from (9), which yields:

$$\begin{aligned} y_{j,t} \quad = \quad & \beta_b y_{j,t-1} - \beta_r \left(i_t - (1-\lambda)\,\pi_j^* - \lambda \pi_{j,t-1} - r_j^* \right) + \\ & -\beta_{c,j} \left(\theta_j^* + P_{j,t} - P_{-j,t} - t \cdot 0.25 \cdot \left(\pi_j^* - \pi_{-j}^* \right) \right) - \beta_s y_{-j,t} + \varepsilon_{y,j,t} \end{aligned} \tag{11}$$

4.1.3 Monetary policy

We use a simple Taylor (1993) rule with smoothing to approximate the ECB monetary policy decisions:

$$i_t = (1-\rho)(r^* + \pi^* + \gamma_\pi (\pi_t - \pi^*) + \gamma_y y_t) + \rho i_{t-1} \tag{12}$$

where ρ is the smoothing parameter; γ_π and γ_y - relative weights assigned to current inflation and output gap, respectively; r^* - the natural rate of interest for the aggregate euro area and π^* - the inflation target of the ECB. We assume the natural interest rate and the inflation target to be invariant over time.

In case of the ECB policy conducted for and focused on macroeconomic developments in the euro area as a whole, y_t and π_t in (12) stand for the aggregate euro area's output gap and inflation, respectively, calculated as a weighted average over all the member states:

$$\pi_t = \sum_j w_j \pi_{j,t} \tag{13}$$

$$y_t = \sum_j w_j y_{j,t} \tag{14}$$

where w_j denotes the share of country j in the euro area in terms of GDP. In the simulations, we use weights corresponding to the shares in the EU-27 GDP, in the year 2007.

However, the members of the GC may exhibit a home bias in their decisions, i.e. put more weight on developments in the country of their origin. In an extreme case, they Taylor rule followed by a voter from a country j only responds to output gap and inflation deviations in that particular economy:

$$i_{j,t} = (1-\rho)(r^* + \pi^* + \gamma_\pi \left(\pi_{j,t} - \pi_j^*\right) + \gamma_y y_{j,t}) + \rho i_{t-1} \tag{15}$$

Note that (15) cannot be treated as a Taylor rule approximating decisions of an independent monetary policy led by a country *j*. This is because $r^* + \pi^*$, the euro area's equilibrium nominal interest rate, is used instead of $r_j^* + \pi_j^*$ that autonomous monetary policy would otherwise target. The reason is that each country has already adjusted to the new steady state in the regime of a currency union. This has been achieved by a one-off shift of in the real exchange rate, equal θ_j^*, which has allowed every member state to restore the equilibrium with a zero output gap and inflation at the target level (π_j^*). Therefore, an attempt made by a country's j representative to revert to the Taylor rule with an "old" equilibrium nominal rate of interest, $r_j^* + \pi_j^*$, would result in a temporary, and possibly quite long-lasting, additional volatility in the country's j output and inflation. We thus assume that no single home-biased voter would be willing to change the euro area's nominal interest rate once every country's economy is in equilibrium $\left(\bigwedge_j y_{j,t} = 0 \wedge \pi_{j,t} = \pi_j^*\right)$, despite the fact that $r^* + \pi^*$ most likely differs from $r_j^* + \pi_j^*$.

One should note that voting of every NCB governor or a member of the Board can be led by either the euro-area situation (according to (12)) or developments in their country of origin (according to (15)). Let us denote the degree of the latter home bias as α, where $\alpha \in [0;1]$. The nominal interest rate preferred by a voter from country *j*, with a home bias equal α, would thus amount to:

$$\tilde{i}_{j,t} = \alpha i_{j,t} + (1-\alpha)\, i_t \tag{16}$$

The outcome of voting is approximated as an average[14] over the 21 voters' such defined preferences:

[14] Despite the fact that median would be better approximation of the outcome of voting, we use the average because it allows the model to remain linear. In the backward-looking version, this allows us to find an analytical solution; in the forward-looking one, it additionally enables us to apply the framework for solving out rational expectations.

$$\bar{i}_t = \frac{1}{21}\sum_v \tilde{i}_{v,t} \tag{17}$$

with a subscript v indexing all the participants assigned with a voting right in the period t. In our framework, it is more convenient to index over voters' countries of origin rather than voters themselves, so let us rewrite (17) equivalently as:

$$\bar{i}_t = \sum_j \tilde{w}_{j,t}\tilde{i}_{j,t} \tag{18}$$

with j indexing countries and $\tilde{w_{j,t}}$ corresponding with a relative weight of a country j, conditional upon international composition of the voting body at time t so as to make (17) and (18) equivalent. Substituting (16), (12), (15), (13) and (14) into (18) and denoting $\boldsymbol{w} = \begin{bmatrix} w_1 & w_2 & \dots & w_{27} \end{bmatrix}^T$, $\boldsymbol{\tilde{w}_t} = \begin{bmatrix} \tilde{w}_{1,t} & \tilde{w}_{2,t} & \dots & \tilde{w}_{27,t} \end{bmatrix}^T$, $\boldsymbol{\pi_t} = \begin{bmatrix} \pi_{1,t} & \pi_{2,t} & \dots & \pi_{27,t} \end{bmatrix}^T$,$\boldsymbol{\pi^*} = \begin{bmatrix} \pi_1^* & \pi_2^* & \dots & \pi_{27}^* \end{bmatrix}^T$, $\boldsymbol{y_t} = \begin{bmatrix} y_{1,t} & y_{2,t} & \dots & y_{27,t} \end{bmatrix}^T$ we obtain:

$$\begin{aligned} \bar{i}_t &= (1-\alpha)\, i_t + \alpha \textstyle\sum_{j=1}^{27} \tilde{w}_j i_{j,t} = \\ &= (1-\rho)\left(r^* + \pi^* + \left((1-\alpha)\,\boldsymbol{w^T} + \alpha\boldsymbol{\tilde{w}_t}^{\boldsymbol{T}}\right)\gamma_{j\pi}\left(\boldsymbol{\pi_t} - \boldsymbol{\pi^*}\right) + \left((1-\alpha)\,\boldsymbol{w^T} + \alpha\boldsymbol{\tilde{w}_t}^{\boldsymbol{T}}\right)\gamma_y \mathbf{y_t}\right) + \\ &\quad +\rho i_{t-1} \end{aligned} \tag{19}$$

In various simulation exercises described in Subsection 4.2.2, we alter α and the time path of $\boldsymbol{w_t}$ to reflect our assumptions on the institutional setup associated with voting in the ECB.[15]

4.1.4 Steady state solution

The steady state solution to the model replicates from period to period in the absence of shocks. Output gaps are zero and each country's inflation rate is equal to the country-specific target (π_j^*). Every member state has its own natural rate of interest (r_j^*) and we know pairwise differences between countries' own inflation targets, which stem from the assumption that price levels in their countries will converge completely over the next thirty years.[16]

Given exogenous values of $\pi_j^* - \pi_1^*$ for countries 2, 3, ..., 27 and π^* as an inflation target for the entire monetary union (which is assumed to equal 2.0 per cent), we simply solve for π_i^* for a member state.

[15] Note that (19) encompasses the pro-euro scenario (with $\alpha = 0$) and the benchmark scenario with monetary policy focused on country's j needs (with $\alpha = 1$ and $\boldsymbol{\tilde{w}_t} = \boldsymbol{\tilde{w}} = \boldsymbol{e_j}$; see Subsection 4.2.2) as special cases.

[16] The initial level of the price gap between member states is based on the CPL data for the year 2006.

$$\boldsymbol{\pi}^* = \begin{bmatrix} \pi_1^* \\ \pi_2^* \\ \vdots \\ \pi_{26}^* \\ \pi_{27}^* \end{bmatrix} = \begin{bmatrix} -1 & 1 & 0 & \dots & 0 \\ -1 & 0 & 1 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ -1 & 0 & 0 & \dots & 1 \\ w_1 & w_2 & w_3 & \dots & w_{27} \end{bmatrix}^{-1} \begin{bmatrix} \pi_2^* - \pi_1^* \\ \pi_3^* - \pi_1^* \\ \vdots \\ \pi_{27}^* - \pi_1^* \\ \pi^* \end{bmatrix}$$

Taking additionally r_i^* for n countries, we solve for the equilibrium value of i^* for the whole currency union and single countries' price level deviations from the weighted average price level in other member states. We do this by setting variables to their steady state values in all output gap equations:[17]

$$\begin{bmatrix} i^* \\ \Delta P_1^* - \Delta P_{-1}^* \\ \Delta P_2^* - \Delta P_{-2}^* \\ \dots \\ \Delta P_{27}^* - \Delta P_{-27}^* \end{bmatrix} =$$

$$= \begin{bmatrix} -\beta_{r,1} & -\beta_{c,1} & 0 & \dots & 0 \\ -\beta_{r,2} & 0 & -\beta_{c,2} & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ -\beta_{r,27} & 0 & 0 & \dots & -\beta_{c,27} \\ 0 & w_1(1-w_1) & w_2(1-w_2) & \dots & w_{27}(1-w_{27}) \end{bmatrix}^{-1} \begin{bmatrix} -\beta_{r,1}(\pi_1^* + r_1^*) \\ -\beta_{r,2}(\pi_2^* + r_2^*) \\ \vdots \\ -\beta_{r,27}(\pi_{27}^* + r_{27}^*) \\ 0 \end{bmatrix}$$

One may note that differences in the level of inflation targets and natural rates of interest impinge only on the value of θ_j^*, which is a one-off adjustment to the new steady-state after entering the monetary union. Therefore, assigning different levels of these variables (i.e. π_i^* and r_i^*) to various member states would not influence the conclusions drawn from the simulation results, presented in 4.2.4.

4.1.5 Solving the RE model

To solve the model with rational expectations, we apply an algorithm proposed by Söderlind (1999). We write the model as

$$A_0 \begin{bmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{bmatrix} = A_1 \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} - BF \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + \begin{bmatrix} \eta_{t+1} \\ 0 \end{bmatrix} \tag{20}$$

[17] The first 27 equations are based on IS curves with equilibrium values. The last one reflects the arithmetical fact that the (weighted) sum of deviations from the (weighted) average is zero. Knowing that $\Delta P_{-j}^* = \frac{\sum_{k,k\neq j} w_k \Delta P_k^*}{\sum_{k,k\neq j} w_k} = \frac{\sum_{k,k\neq j} w_k \Delta P_k^*}{1-w_j}$, we can write $\Delta P_j^* - \Delta P_{-j}^* = \Delta P_j^* - \frac{\sum_{k,k\neq j} w_k \Delta P_k^*}{1-w_j}$. Multiplying this by $1-w_j$ yields $\Delta P_j^* - \sum_j w_j \Delta P_j^*$, which is a deviation of ΔP_j^* from the weighted average over j. A weighted sum of these deviations equals zero.

and use the matrix $A = A_0^{-1}(A_1 - BF)$ as an input into the procedure, based on the Schur decomposition. Technical details are provided in Appendix A.

4.2 Simulations

4.2.1 Calibration of the model

The values that we assign to the model parameters are largely consistent with the consensus of the New-Keynesian literature (see e.g. Lindé, 2005 for a survey-based set of values) and are partly based on the estimates discussed in Torój (2008). We assume that parameters of the inflation and output gap equations are homogenous among the member states.[18] γ and β_r have been calibrated to 0.05 in order to reflect rigidities of markets and limited responsiveness of the output gaps to country-specific real interest rates, respectively. Values of β_c and β_s are close to the median of estimates for 12 euro area countries. We weigh both forward- and backward-looking components of the IS and Phillips curves equally in the hybrid version of the model. In the backward-looking version, we follow the estimations of Goodhart and Hofmann (2005) and use $\beta_b = 0.85$. As regards λ, we assing it with a value of 0.75, implying a limited degree of anchoring inflation expectations at the country-specific target.

On top of that, we assume a conservative Talyor rule with a stronger response to inflation deviation from the target than to current output gap. Following the estimates of Sauer and Sturm (2003), we include the nominal interest rate smoothing parameter of 0.8. The set of parameters used in the simulations are summarized in Table 2.

[18] Consequences of possible heterogeneity are discussed in Torój (2008).

Table 2: Model calibration

Parameter	Value
ω_f	0.5
ω_b	0.5
β_f	0.5
β_b (forward-looking)	0.5
β_b (backward-looking)	0.85
γ	0.05
β_r	0.05
β_c	0.06
β_s	0.06
γ_π	1.5
γ_y	0.5
λ	0.75
ρ	0.8

4.2.2 Simulations with different voting schemes

Before running a simulation we need to make a number of assumptions as regards voters' preferences and the voting scheme, including the way that possible rotation takes place. At the most general level, we split our analysis into the "new" and "old" voting system.

New system

The new voting scheme introduces rotation into the system. We consider three possible frequencies of rotation among the GC members, i.e. every three, six, and twelve months. The composition of rotation groups coincides with that presented in Table 1. Moreover, we assume that every time rotation takes place, all voters are replaced with the "new" ones. As regards the members of the Governing Board, we assume their eight-year tenure, which has been practice to date, and that the Board comprises three, two and one member from the first, second, and third rotation group, respectively.

Since preferences of the GC members impinge on the way they vote, we consider the following scenarios: (1) that all NCB presidents focus exclusively on the situation of the euro area as a whole, and ignore developments in the country of their origin ($\alpha = 0$); (2) that NCB governors' preferences are determined solely by their country's situation ($\alpha = 1$); (3) an intermediate scenario ($\alpha = 0.5$). As regards the Board members we consider situations when they focus on the euro area only or vote in the same way as their country's NCB governor. Altogether it gives five possible scenarios:

- $\alpha_{NCB} = \alpha_{Board} = 0$
- $\alpha_{NCB} = \alpha_{Board} = 0.5$
- $\alpha_{NCB} = \alpha_{Board} = 1$
- $\alpha_{NCB} = 0.5$ and $\alpha_{Board} = 0$
- $\alpha_{NCB} = 1$ and $\alpha_{Board} = 0$

Technically, in the last 2 cases, $\alpha \boldsymbol{\tilde{w}}_t^{\boldsymbol{T}} + (1-\alpha)\, \boldsymbol{w^T}$ in 19 should be replaced with:

$$\frac{6}{21}\boldsymbol{w^T} + \frac{15}{21}\left(\alpha \boldsymbol{\tilde{w}_t}^{\boldsymbol{T}} + (1-\alpha)\, \boldsymbol{w^T}\right) = \left(\frac{6}{21} + \frac{15}{21}(1-\alpha)\right)\boldsymbol{w^T} + \frac{15}{21}\alpha \boldsymbol{\tilde{w}_t}^{\boldsymbol{T}} \quad (21)$$

Assumptions on $\boldsymbol{\tilde{w}_t}$ depend on the model's specification.

In the forward-looking model, $\tilde{w}_{j,t} = \tilde{w}_j$ is a relative frequency of country's j participation in the GC, rescaled so that $\sum_{j=1}^{27} \tilde{w}_j = 1$. Constant weights solve the problem of rotation in the GC, including the Board, and roughly represent a country's presence in the voting body in the long term. Imposing this constancy allows us to solve the model with rational expectations.[19]

In the backward-looking model:

$$\tilde{w}_{j,t} = \frac{Board \cdot b_{j,t} + c_{j,t}}{Board \cdot 6 + 15} \quad (22)$$

where $Board = 1$ if we assume that Board members follow the pro-euro Taylor rule and 0 in the opposite case; $b_{j,t} = 1$ if country's j representative is a member of the Board in quarter t and 0 otherwise; $c_{j,t} = 1$ if the country's j NCB governor has a voting right in the GC in quarter t and 0 in the opposite case.

Old system

In order to assess the effectiveness of voting modalities we compare the outcome of the rotation system with that of the "old" voting scheme. We thus consider a scenario in which all the 27 NCB governors have a right to vote in every period. As regars voters' preferences we make two alternative assumptions:

1. $\alpha_{NCB} = \alpha_{Board} = 1$
2. $\alpha_{NCB} = 1$ and $\alpha_{Board} = 0$

[19]Including time-varying $\boldsymbol{\tilde{w}_t}$ in the forward-looking model would result in a time-varying matrix F in 20. The framework of Söderlind (1999), applied by Torój (2008) for the pro-euro case, is not applicable here with nonzero α.

Although NCB governors have a permanent right to vote, there is still rotation of the Board members (in the backward-looking model). In this case, $\tilde{\boldsymbol{w}}_{\boldsymbol{t}}$ evolves according to

$$\tilde{w}_{j,t} = \frac{Board \cdot b_{j,t} + 1}{Board \cdot 6 + 27} \tag{23}$$

with $Board$ and $b_{j,t}$ as in (22).

In the forward looking model, $\tilde{w}_{j,t} = \tilde{w}_j$, as previously, stands for a relative frequency of country's j representation in the GC, including the Board, rescaled so that $\sum_{j=1}^{27} \tilde{w}_j = 1$.[20] Additionally, when we assume a pro-euro voting by the Board ($Board = 1$), a correction analogous to (21) takes the following form:

$$\frac{6}{33}\boldsymbol{w^T} + \frac{27}{33}\left(\alpha\tilde{\boldsymbol{w}}_{\boldsymbol{t}}{}^{\boldsymbol{T}} + (1-\alpha)\,\boldsymbol{w^T}\right) = \left(\frac{6}{33} + \frac{27}{33}(1-\alpha)\right)\boldsymbol{w^T} + \frac{27}{33}\alpha\tilde{\boldsymbol{w}}_{\boldsymbol{t}}{}^{\boldsymbol{T}} \tag{24}$$

Note that there is no difference between the old and the new system if we assume $\alpha = 0$ for every voter.

Benchmark scenario

For each country $j = 1, 2, ..., 27$, we treat a hypothetical ECB's rule of $i_t = i_{j,t}$ as a benchmark scenario in which all GC members focus on the situation of the j country only. This approach allows us to compare, for example, the loss in terms of output gap and inflation volatility in France in various scenarios against the situation in which all voters behave as if they were French with a maximum home bias. This is represented by $\alpha = 1$ and $\tilde{\boldsymbol{w}}_{\boldsymbol{t}} = \tilde{\boldsymbol{w}} = \boldsymbol{e_j}$, where $\boldsymbol{e_j}$ is a versor with a value 1 at the position j and 0 elsewhere.

In case we compare the outcome for the euro area as a whole, and not for a particular country, the benchmark scenario is that with $\alpha_{NCB} = \alpha_{Board} = 0$, i.e. when all voters focus on the situation of the euro area without any home bias.

4.2.3 Stochastic parameters

On the basis of the above-outlined assumptions, for each scenario considered we can construct a rotation scheme matrix and a vector of voting weights. We then simulate paths of inflation[21] and output gap, in each case using the same series of exogenous demand shocks. In our framework, demand shocks are random disturbances to the IS curves of 27 countries (see (2) or (11)). These shocks (as a vector of 27 country-specific demand disturbances) are

[20] This time, however, every NCB governor votes every quarter, so limited cross-country differences stem only from various relative frequency of their presence in the Board.

[21] As deviations from the country-specific target.

drawn independently in every period from a multivariate normal distribution with the expected value $\boldsymbol{\mu} = \mathbf{0_{27\times1}}$ and variance-covariance matrix $\mathbf{\Sigma_{27\times27}}$, which has been either estimated or assumed to be diagonal, i.e. that demand shocks between the euro-area member states are uncorrelated.

The approach based on estimation benefits from Konopczak (2008). We build a variance-covariance matrix of demand shocks in the euro-area countries by decomposing production and inflation dynamics into symmetric (common) and asymmetric (idiosyncratic) components, which are subsequently divided into supply and demand shocks. Drawing upon Kouparitsas (1999) and Ide and Moës (2003) we do it as follows:

$$\begin{bmatrix} y \\ \pi \\ y_i \\ \pi_i \end{bmatrix} = \begin{bmatrix} a_{11}(L) & a_{12}(L) & a_{13}(L) & a_{14}(L) \\ a_{21}(L) & a_{22}(L) & a_{23}(L) & a_{24}(L) \\ a_{31}(L) & a_{32}(L) & a_{33}(L) & a_{34}(L) \\ a_{41}(L) & a_{42}(L) & a_{43}(L) & a_{44}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_S \\ \varepsilon_D \\ \varepsilon_{S,i} \\ \varepsilon_{D,i} \end{bmatrix}$$

Vector of endogenous variables in the above-outlined VAR model consists of the GDP growth and inflation for the euro-area and country i. Using the infinite vector moving average representation each of these endogenous variables can be expressed as a combination of current and lagged values of four structural shocks: common demand (ε_D) and supply (ε_S) shocks, as well as idiosyncratic demand ($\varepsilon_{D,i}$) and supply ($\varepsilon_{S,i}$) disturbances ($a_{kl}(L)$ stands for a polynomial lag operator of infinite order). For the purpose of identification of different types of shocks we impose the following restrictions:

- $a_{13}(L) = a_{14}(L) = a_{23}(L) = a_{24}(L) = 0$, which allows us to distinguish symmetric and asymmetric shocks, on the assumption that in the long term euro-area variables are determined by common shocks only;
- $a_{12}(L) = a_{32}(L) = a_{34}(L) = 0$ in order to identify demand and supply disturbances (standard Blanchard and Quah (1989) decomposition).

The above-outlined approach allows us to obtain series of demand and supply shocks for each of the 27 countries analyzed in this study. Consequently, on the basis of these series, we can construct a variance-covariance matrix of demand shocks in the euro-area countries, which enables us to determine how shocks are spread among the currency union members.

In the backward-looking model, we run simulations for 8960 quarters, which corresponds with the least common multiple of various countries' cycles of rotation among the NCB governors and the Board members. In the forward-looking framework we use the horizon of 10 000 quarters.

4.2.4 Results

The simulation results are reported in Tables 3-10. The numbers indicate the change in the volatility (approximated by standard deviation) of output gap and inflation against the benchmark scenario, as defined in section 4.2.2. Every scenario is considered with the use of both forward- and backward-looking model. Moreover, each simulation is run with demand shocks being either correlated (according to the estimated variance-covariance matrix of demand shocks, as described in section 4.2.3) or uncorrelated among the euro-area member states. Results discussed in this section are based on scenarios with a six-month rotation frequency.

Table 3: Simulation Results: Forward-looking model

α_{Board}	α_{NCB}		**Euro-area**	**average**	**Poland**	**max**		**min**	
= α_{NCB}	0	output gap	0.00%	12.98%	10.85%	23.42%	Malta	4.46%	Hungary
	0.5		4.55%	14.80%	12.36%	24.98%	Malta	5.30%	Hungary
	1		9.51%	16.96%	14.25%	27.07%	Greece	6.60%	Hungary
0	0.5		3.20%	14.24%	11.88%	24.51%	Malta	5.01%	Hungary
	1		6.63%	15.69%	13.12%	25.72%	Malta	5.80%	Hungary
= α_{NCB}	0	inflation deviation	0.00%	16.86%	10.90%	30.87%	Greece	2.92%	Hungary
	0.5		6.72%	19.22%	12.72%	34.67%	Greece	3.62%	Hungary
	1		14.35%	22.33%	15.30%	38.97%	Greece	5.25%	Hungary
0	0.5		4.67%	18.47%	12.11%	33.52%	Greece	3.33%	Hungary
	1		9.85%	20.47%	13.72%	36.45%	Greece	4.22%	Hungary

Table 4: Simulation Results: Forward-looking model (uncorrelated shocks)

α_{Board}	α_{NCB}		**Euro-area**	**average**	**Poland**	**max**		**min**	
= α_{NCB}	0	output gap	0.00%	23.40%	24.54%	25.64%	Greece	19.98%	Estonia
	0.5		10.31%	25.11%	26.19%	28.46%	Italy	20.66%	Estonia
	1		21.79%	27.58%	28.62%	33.82%	Germany	22.21%	Estonia
0	0.5		7.23%	24.54%	25.64%	27.31%	Italy	20.38%	Estonia
	1		15.10%	26.08%	27.14%	30.47%	Germany	21.22%	Estonia
= α_{NCB}	0	inflation deviation	0.00%	30.46%	29.94%	35.41%	UK	25.41%	Estonia
	0.5		15.47%	32.61%	31.91%	43.85%	Germany	25.86%	Estonia
	1		33.45%	36.44%	35.52%	54.32%	Germany	27.19%	Bulgaria
0	0.5		10.75%	31.82%	31.18%	41.09%	Germany	25.53%	Estonia
	1		22.92%	34.05%	33.27%	48.18%	Germany	26.26%	Bulgaria

Table 5: Simulation Results: Backward-looking model

α_{Board}	α_{NCB}		Euro-area	average	Poland	max		min	
$= \alpha_{NCB}$	0	output gap	0.00%	5.10%	5.80%	6.55%	Romania	2.98%	Germany
	0.5		0.41%	5.26%	5.89%	6.54%	Romania	3.43%	Germany
	1		0.86%	5.45%	6.02%	6.70%	Malta	3.92%	Germany
0	0.5		0.38%	5.23%	5.87%	6.54%	Romania	3.32%	Germany
	1		0.77%	5.37%	5.97%	6.68%	Malta	3.68%	Germany
$= \alpha_{NCB}$	0	inflation deviation	0.00%	8.23%	9.11%	11.08%	Romania	5.48%	Germany
	0.5		0.54%	8.50%	9.65%	11.08%	Romania	6.15%	Germany
	1		1.08%	8.74%	9.65%	11.28%	Malta	6.81%	Germany
0	0.5		0.54%	8.44%	9.65%	11.08%	Romania	6.15%	Germany
	1		1.08%	8.62%	9.65%	11.28%	Malta	6.15%	Germany

Table 6: Simulation Results: Backward-looking model (uncorrelated shocks)

α_{Board}	α_{NCB}		Euro-area	average	Poland	max		min	
$= \alpha_{NCB}$	0	output gap	0.00%	6.02%	5.10%	7.21%	Bulgaria	4.85%	Germany
	0.5		0.49%	6.16%	5.32%	7.22%	Bulgaria	5.32%	Poland
	1		1.02%	6.35%	5.59%	7.29%	Bulgaria	5.31%	Luxembourg
0	0.5		0.40%	6.13%	5.24%	7.22%	Bulgaria	5.24%	Poland
	1		0.83%	6.26%	5.40%	7.26%	Bulgaria	5.37%	Luxembourg
$= \alpha_{NCB}$	0	inflation deviation	0.00%	9.96%	8.76%	11.61%	Bulgaria	8.04%	Germany
	0.5		0.73%	10.15%	9.09%	11.61%	Bulgaria	9.01%	Netherlands
	1		1.50%	10.43%	9.54%	11.67%	Bulgaria	9.16%	Portugal
0	0.5		0.57%	10.11%	8.96%	11.61%	Bulgaria	8.91%	Germany
	1		1.19%	10.30%	9.22%	11.67%	Bulgaria	9.22%	Poland

Table 7: Comparing performance of the voting systems: Forward-looking model

α_{Board}	α_{NCB}		Voting system	Euro-area	average	Poland	max		min	
1	1	output gap	New	9.51%	16.96%	14.25%	27.07%	Greece	6.60%	Hungary
			Old	10.47%	17.51%	14.56%	27.43%	Greece	6.88%	Hungary
0	1		New	6.63%	15.69%	13.12%	25.72%	Malta	5.80%	Hungary
			Old	9.51%	17.07%	14.19%	26.91%	Greece	6.45%	Hungary
1	1	inflation deviation	New	14.35%	22.33%	15.30%	38.97%	Greece	5.25%	Hungary
			Old	15.74%	23.11%	15.58%	39.47%	Greece	5.50%	Hungary
0	1		New	9.85%	20.47%	13.72%	36.45%	Greece	4.22%	Hungary
			Old	14.26%	22.45%	15.08%	38.63%	Greece	4.88%	Hungary

The most striking observation is that in all the simulation scenarios volatility of output and inflation declines with a reduction in the voters' home bias. This finding is confirmed for the euro-area as a whole, as well as for the (arithmetic) average volatility of all member states, including the Polish economy. It thus strongly suggests that discussion within and decisions of the ECB GC should be driven by the situation in the euro-area as a whole, while voters should abstain from emphasizing particular developments in their country of origin.

A composition of countries with a maximum or a minimum increase in output and inflation volatility relative to the benchmark scenario varies with a model and scenarios considered. Based on that criterion, the costs of giving up an independent monetary policy in Poland is similar to the the arithmetic average for the EMU-27 countries. The only exception occurs in one of the forward-looking scenarios (Table 3), where costs in terms of inflation volatility is signficantly lower than, on average, in other members states.

Since introduction of the rotation system aims at improving the current voting scheme, tables 7-10 compare the performance of the new and old systems. One may note that in the vast majority of scenarios considered in the study there is hardly any difference between the outcomes of the two voting schemes, with the results being only slightly more favorable for the rotation system. The only significant difference is reported for the forward-looking scenario, when the Board members focus on the situation of the euro-area exclusively ($\alpha_{Board} = 0$), whereas NCB governors take into account solely developments in their country of origin ($\alpha_{NCB} = 1$). In this case the new system produces much lower volatility than the old voting scheme. This is particularly evident in the case of the euro-area as a whole, and to a lesser extent in individual countries, including Poland. This finding provides a moderate support for the idea that the rotation system should strengthen the role of the Board, which is often believed to be more focused on the euro-area situation rather than developments in their country of origin.

Table 8: Comparing performance of the voting systems: Forward-looking model (uncorrelated shocks)

α_{Board}	α_{NCB}		Voting system	Euro-area	average	Poland	max		min	
1	1	output gap	New	21.79%	27.58%	28.62%	33.82%	Germany	22.21%	Estonia
			Old	22.58%	27.76%	28.34%	34.28%	Germany	22.23%	Estonia
0	1		New	15.10%	26.08%	27.14%	30.47%	Germany	21.22%	Estonia
			Old	20.22%	27.20%	27.78%	32.97%	Germany	21.87%	Estonia
1	1	inflation deviation	New	33.45%	36.44%	35.52%	54.32%	Germany	27.19%	Bulgaria
			Old	34.71%	36.73%	35.04%	55.12%	Germany	28.19%	Estonia
0	1		New	22.92%	34.05%	33.27%	48.18%	Germany	26.26%	Bulgaria
			Old	30.96%	35.83%	34.16%	52.68%	Germany	27.60%	Estonia

Table 9: Comparing performance of the voting systems: Backward-looking model

α_{Board}	α_{NCB}		Voting system	Euro-area	average	Poland	max		min	
1	1	output gap	New	0.86%	5.45%	6.02%	6.70%	Malta	3.92%	Germany
			Old	1.02%	5.56%	6.04%	6.86%	Latvia	4.08%	Germany
0	1		New	0.77%	5.37%	5.97%	6.68%	Malta	3.68%	Germany
			Old	0.97%	5.52%	6.02%	6.75%	Latvia	3.92%	Germany
1	1	inflation deviation	New	1.08%	8.74%	9.65%	11.28%	Malta	6.81%	Germany
			Old	1.08%	8.86%	9.65%	11.28%	Malta	6.81%	Germany
0	1		New	1.08%	8.62%	9.65%	11.28%	Malta	6.15%	Germany
			Old	1.08%	8.84%	9.65%	11.28%	Malta	6.81%	Germany

Table 10: Comparing performance of the voting systems: Backward-looking model (uncorrelated shocks)

α_{Board}	α_{NCB}		Voting system	Euro-area	average	Poland	max		min	
1	1	output gap	New	1.02%	6.35%	5.59%	7.29%	Bulgaria	5.31%	Luxembourg
			Old	1.25%	6.42%	5.68%	7.25%	Bulgaria	5.39%	Luxembourg
0	1		New	0.83%	6.26%	5.40%	7.26%	Bulgaria	5.37%	Luxembourg
			Old	1.12%	6.36%	5.55%	7.23%	Bulgaria	5.42%	Portugal
1	1	inflation deviation	New	1.50%	10.43%	9.54%	11.67%	Bulgaria	9.16%	Portugal
			Old	1.80%	10.52%	9.61%	11.63%	Finland	9.10%	Portugal
0	1		New	1.19%	10.30%	9.22%	11.67%	Bulgaria	9.22%	Poland
			Old	1.60%	10.44%	9.41%	11.61%	Bulgaria	9.16%	Portugal

Interestingly, simulations conducted for scenarios with a three-month and twelve-month rotation frequency do not produce results that would in any respect change the above-outlined conclusions. Therefore, for brevity of the study, we do not present them here.[22]

To sum up, we find that members of the Governing Council should by all means avoid the presence of home bias in their voting behavior. This should be done for the sake of all member states, since we provide the evidence that volatility of output and inflation increase with the rise in the degree of voters' home bias. When it comes to comparing the rotation system with the old voting scheme, we conclude that in most cases there is no significant difference between the two frameworks. The only exception relates to the situation when NCB governors concentrate on the situation in their country of origin, but the Board members focus on the euro-wide economic developments. In such circumstances introducing the rotation system may significantly improve the economic performance (in terms of output and inflation volatility), not least for the euro area as a whole. This finding provides a moderate support for the argument that the new voting scheme should strengthen the role of the Board. In the next section, we analyze this and other issues related to the consequences of the voting modalities reform in terms of its impact on voting power distribution in the enlarged ECB Governing Council.

5 Voting power in the enlarged ECB Governing Council

5.1 Power indices

In this section we assess the consequences of introducing the new voting system in terms of its impact on the distribution of power among the GC members. This issue is approached with the use of *power indices*. Power indices measure the relative *a priori* voting power and are used for both positive and normative analyses of voting bodies. However, prior to fleshing out the concept of power indices, we first introduce the notion of *simple voting game*, which is used to model the voting process in the GC of the ECB.

For each decision-making body, which takes decisions by voting, there exist a set of rules determining which subsets of all voters can ensure the acceptance of a proposal. Let N be the set containing all members of a voting body. We will call a *winning coalition* a subset of N, which can ensure the acceptance of a proposal, and a *loosing coalition* a subset that cannot achieve that goal. A *simple voting game* can be defined as a pair $(N,\ v)$, where $v:\ 2^N \rightarrow \{0,\ 1\}$ is a characteristic function that maps each subset of N (i.e. a *coalition of voters*) to either 0 (if it is a loosing coalition) or 1 (if it is a winning coalition). The characteristic function of a simple voting game satisfies the following conditions:

[22]They are, however, available from the authors upon request.

- $v(\varnothing) = 0 \wedge v(N) = 1$
- $\forall S,\ T \subseteq N;\ \ S \subseteq T \rightarrow v(S) \leq v(T)$

A special case of a simple voting game is a *weighted voting game*. It is a sequence of non-negative numbers $[q;\ w_1, ...,\ w_n]$, where w_i stands for a number of votes, or *weight* of player i and q is a threshold or a quota needed by a coalition to win voting. The characteristic function for such game takes the following form:

$$v\ (S) = \begin{cases} 1 & \text{if} \quad \sum_{i \in S} w_i \geq q \\ 0 & \text{if} \quad \sum_{i \in S} w_i < q \end{cases}$$

We may now introduce the concept of a *power index*. The share of votes of a given decision-maker often fails as a measure of voting power. For example, it often happens in legislative bodies that a party with fewer seats is regarded more important than parties with higher number of votes. The reason is that it may be the former that tips the balance in favor of or against the decisions considered. Therefore, the actual voting power of a decision maker is not the number of votes *per se*, but the ability to *significantly* influence the decisions taken. The thus-defined power of a decision-maker can be approximated by *power indices*. They measure the power of a voter as *a priori* probability that he will play a key role in a process of choosing from available alternatives. Power indices are, therefore, statistical measures that allow us to summarize certain properties of a given voting game. Formally, let $\mathbf{w} = (w_1, ..., w_n)$ be the allocation of weights in a decision-making body of a size n. Further, let the

$$\mathbb{G} = [(q, \mathbf{w}) \in \mathbb{R}^{n+1} \colon \sum_{i=1}^{n} w_i = 1;\ w_i \geq 0;\ 0 \leq q \leq 1]$$

be the space of all voting bodies and let the

$$E = [\mathbf{e} \in \mathbb{R}^n \colon \sum_{i \in N} e_i = 1;\ e_i \geq 0 \quad for \quad i = 1, ..., n]$$

be the unit simplex.

The power index is a vector valued function $\phi \colon \mathbb{G} \rightarrow E$, which maps the space of all voting bodies $\mathbb{G}$ into the unit simplex E. We will denote by $\phi_i(q,\ \mathbf{w})$ a share of power that an index grants to the member i of the voting body with a quota q and distribution of vote shares $\mathbf{w}$.

Two of the most widely used power indices are the Shapley-Shubik and Banzhaf indices. *The Shapley-Shubik index* (henceforth S-S index) is based on the notion of a *pivot*. Let $\sigma = (\sigma_1, ..., \sigma_n)$ be a permutation defined on the set of all n members of a voting body. We say that the player σ_i is a pivot of a permutation σ if $\{\sigma_1, \sigma_2, ..., \sigma_{i-1}\}$ is a loosing coalition and $\{\sigma_1, \sigma_2, ..., \sigma_{i-1}, \sigma_i\}$

is a winning coalition. Assuming that all permutations have the same probability $\frac{1}{n!}$ the S-S index of player i is given as follows:

$$\phi_i^{S-S}(q,\ \mathbf{w}) = \frac{1}{n!} \sum_{S:S\in W, S\setminus\{i\}\notin W} (s-1)!(n-s)!$$

where s denotes the number of elements in the subset S. Thus the S-S index totals all the theoretical situations in which a given voter can be a decisive one[23] and divides this sum by all possible voters permutations.

The Banzhaf index (henceforth the B-z index) is based on a notion of a *swing*. A pair of coalitions $(S+\{i\}, S)$ is called a swing for a player i, if $S+\{i\}$ is a winning and $S \subseteq N\setminus\{i\}$ is a loosing coalition. Assigning the probability $\frac{1}{2^{n-1}}$ to each coalition $S \subseteq N\setminus\{i\}$, we can compute the swing probability, i.e. the *absolute Banzhaf index*:

$$\phi_i^{Bz}(q,\ \mathbf{w}) = \frac{1}{2^{n-1}} \sum_{S\subseteq N\setminus\{i\}} (v\ (S+\{i\}) - v(S))$$

Since it does not add up to one, we use the *normalized Banzhaf index*:

$$\phi_j^{NBz}(q, \mathbf{w}) = \frac{\phi_j^{Bz}(q, \mathbf{w})}{\sum_{i=1}^{n} \phi_i^{Bz}(q, \mathbf{w})}$$

In contrast to the S-S index, which treats all possible orderings of players as equiprobable, the B-z index assumes that all possible coalitions (with players being arranged in no particular order) are equally probable. In this case, a player's power is approximated by the number of swings expressed either as a fraction of the total number of coalitions (measuring the probability of a swing), in case of the absolute Bz index, or the fraction of the total swings for all players (measuring the player's relative capacity to swing), in case of the normalized B-z index (Leech, 1998).

5.2 Properties of power indices in light of the ECB voting scheme

There is much controversy in the literature as regards the relative appropriateness of the above-outlined indices for the assessment of voting power distribution in the GC. A part of the debate focuses on the distinction, made by Felsenthal and Machover (1998), between indices reflecting power as "influence" and those that describe power in terms of "prize" (Fahrholz and Mohl, 2006). The former (called I-power indices) focus on the extent to which a given voter can influence the outcome of a decision-making process. The latter group of

[23] i.e. his vote can turn a loosing coalition into winning.

indices (P-power) concern the voter's expected relative share in some sort of "prize" received by the winning coalition.

Felsenthal and Machover (1998) argue that the S-S index belongs to P-power indices, whereas the B-z is an example of an I-power index. Based on this distinction, Fahrholz and Mohl (2006) claim that the B-z index is more appropriate for the evaluation of voting power distribution in monetary policy committees. The reason is that monetary policy decisions are "public goods" as they affect both the winning and the loosing coalition. Moreover, no prize can be assumed to be obtained by the winning coalition of GC members. However, Turnovec et al. (2004) show that this distinction between the S-S and B-z indices is only apparent, since both can be interpreted either in terms of P-power or I-power.

Comparison of the S-S and B-z indices also focuses on the probabilistic assumptions underlying those measures. The distinction relates to the degree of statistical independence among voters. The S-S index relies on the assumption that the individual probability distributions over all voting outcomes are homogenous across decision-makers, whereas the B-z index assumes that those distributions are independent from each other. The homogeneity assumption is said to approximate well situations, in which each player stands a fair chance of convincing other players to his point of view. The heterogeneity assumption, in turn, suits the situation when convincing other players is very difficult. The former may be true for large voting bodies, whereas the latter for bodies comprised of a relatively small number of voters (Mangano, 1998). Among the factors contributing to the satisfaction of the homogeneity assumption for the enlarged GC one may list an intensive communication among its members, e.g., during informal meetings ahead of the official sessions, as well as active formation of coalitions within this decision-making body (Belke and Styczynska, 2006). On the other hand, economic heterogeneity of the enlarged euro area may speak against the use of common evaluation standards during the voting procedure. It may thus favor application of the B-z instead of the S-S index.

After balancing the pros and cons of the indices considered, we have decided to use the S-S measure[24], for it satisfies certain criteria that are of particular importance to our study. In particular, the S-S index is the only measure that fulfills the "bloc postulate" (Felsenthal and Machover, 1998). It states that if one of the players joining a bloc of other players turns out significant (i.e. his power is greater than 0), the power index of a bloc should be greater than the power index of the other player alone. This postulate has an intuitive appeal: any voter that unites with another voter, who is needed in a coalition, expects an increase in his own influence on the decision-making process (Jasinski, 2004).

We use power indices to evaluate the distribution of power in the GC of the euro area that comprises 27 countries. Our calculations are made under various assumptions as regards the preferences of decision-makers.

[24]For some of the considered scenarios we have also calculated the B-z index. The differences between the values of the S-S and B-z indices have, however, turned out to be negligible.

First, power indices are computed under the hypothesis of symmetric voters. It assumes that each possible coalition within the GC can be formed with an equal probability, i.e. GC members are expected to be *ex ante* neutral as regards the choice of coalition partners. This approach thus disregards the fact that in reality coalitions are more likely between those GC members, whose countries of origin are in the similar economic situation. Nevertheless, since at this stage we want to assess the "formal" characteristics of the new institutional arrangements in the GC, we consider the "symmetric" scenario. By computing symmetric power indices we assume that EB members vote either in the interest of their country of origin or in the interest of the whole euro area. In the former case, if the EB member's country of origin is the same as that of the NCB governor, we sum their votes. Therefore, we would have up to six players[25] with two votes each. In the scenario with the Board focused exclusively on developments in the euro area as a whole, we sum the votes of all EB members, which translates into one big player with six votes.

The second approach that we adopt consists in imposing the "proximity" structure on the analyzed set of voters and then computing power indices for the GC members. We follow the approach of Owen (1977) and give up the assumption that each voter is willing to enter into a coalition with any other voter. Instead, it is supposed that there exist pre-coalitions' structures between voters with similar preferences. Those pre-coalitions are subsets of voters with similar preferences. A GC member from a given pre-coalition will thus enter into coalition with another member from this pre-coalition with a higher probability than with any member from outside that pre-coalition.

Assignement of voters to different pre-coalitions is based on the results of simulations that we have conducted. We apply the model, described in section 4.1, and run simulations assuming that the desired interest rate for the NCB governor is determined by the Taylor rule, in which interest-rate smoothing parameter is set to 0.[26] Simulations are carried out both for the case of the euro-wide focus of the EB, as well as for the "pure home bias" of the Board members. NCB governors are assumed to vote always in the interest of their country of origin. The desired interest rates are rounded to the nearest multiple of 25 basis points.

Next, for each pair of countries we calculate the frequency of situations when their representatives vote in the same way (for an increase, for a decrease or for "no change" in the interest rate level). Pre-coalitions are assumed to be formed by the countries for which frequency of common voting with any other country from the pre-coalition exceeds the value of the 75th percentile of the respective frequencies for all possible pairs of countries. It is also required that a

[25] There are six members of the Executive Board.

[26] We view the case of $\rho = 0$ as the most appropriate for the assessment of voting power distribution in the GC. High values of ρ would imply that preferences of each country in the period t are to a large extent determined by the level of the ECB nominal interest rate in the period $t - 1$. This in turn would blur the heterogeneity of voters' preferences and thus make their assignement to respective groups less transparent.

country belonging to a certain pre-coalition has the highest frequency of common voting with either a country from the same pre-coalition or with a country not belonging to any other pre-coalition.[27] We also apply a less restrictive approach to pre-coalition determination by allowing for a possibility that some countries within a given pre-coalition have the frequency of common voting with at most two countries from the same pre-coalition below the value of the 75th, but above the value of the 50th percentile of all common voting frequencies.

In every scenario considered we calculate the indices for two voting schemes: (1) the new system that introduces rotation of voting rights and, for the sake of comparison, (2) the ”old” voting scheme, which is based on the “one member, one vote” principle. Contrary to the previous research that has applied power indices to the assessment of the new voting system, in our study we account for the fact that under rotation only 21 GC members have the right to vote at a given time. The indices for each country, or group of countries, are first calculated for games with the total number of votes amounting to 21 and then re-weighted by the respective probability of a certain game being played. Determination of such probabilities is straightforward for the case when all EB members vote in the interest of the euro area as a whole, NCB governors vote in the interest of their country of origin and no precoalitions are formed between the NCB representatives. If these conditions are not satisfied, certain simplifying assumptions have to be made in order to compute power indices. We apply here the same set of assumptions as for the model-based simulations. Rotation thus takes place every two quarters and is carried out in order of a country’s size as determined by its GDP/TABS-MFI indicator.[28]

In case of the Board members exhibiting a “home bias”, we assume that three members of the EB come from countries belonging to the first rotation group, two from the second group and one from the third group country. The replacement of the EB members after eight-year term in office follows the same rules as the re-assignment of voting rights among countries from a given rotation groups.

Finally, the indices are calculated for 8960 games[29] with the use of the IOP 2.0 programme (Bräuninger and König, 2005). The value of power index for a player (country, the EB or a group of countries) is computed as an average of power indices calculated for those 8960 games.

[27] Whenever the term of “pre-coalition” is used we mean the subset of the players’ set comprised of more than one player.

[28] We assume that every time rotation takes place, one NCB governor from the first group, six governors from the second group and three NCB representatives from the third group among the currently voting NCB governors are replaced with the governors from respective groups who at a given time do not have the right to vote.

[29] This number corresponds with the least common multiple of various countries’ cycles of rotation among the NCB governors and the Board members.

5.3 Voting power of the ECB Governing Council members - results

One of the arguments quoted in the discussion on the need to introduce the new voting scheme for the GC was to assure that big economies, accounting for a large share in the euro area GDP, would not loose too much influence on the outcomes of the decision-making process. It is, therefore, interesting to compare the distribution of voting power as measured by the S-S index with the distribution of relative economic weights of the EMU27 member countries, both under the old voting scheme and under rotation.

Table 11 presents the calculations of the symmetric S-S index under the assumption that all voters are home-biased. Figures reported in the table show that under the old voting scheme the six biggest countries (based on their share in the EU27 GDP) would be underrepresented in terms of their voting power, whereas all remaining member countries would be overrepresented. Relative to the economic meaning of a country, the biggest overrepresentation would occur in the case of Malta, whose voting power would be almost eighty times higher than its share in the euro area GDP. In contrast to the Maltese example, Germany, whose political weight would amount only to one fourth of its economic weight, would suffer from the strongest underrepresentation.

Table 11 shows also that the general picture does not change much with the introduction of the rotation scheme. On the one hand, for five of the six countries, significantly underrepresented under the old voting scheme, the relative discrepancy between the economic and political meaning diminishes. Moreover, for eight of the nine smallest economies the degree of their overrepresentation is reduced. On the other hand, however, both underrepresentation of the biggest and and overrepresentation of the smallest economies remain considerable. The extreme cases are once again Malta, with a political power more than fifty times larger than its economic importance, and Germany, with a voting power four times smaller than its share in the aggregate euro area GDP.

The analysis of the characteristics of new institutional arrangements in the GC shows that the introduction of rotation will not affect Poland's *ex ante* voting power. The value of Poland's Shapley-Shubik index under the old voting scheme would equal 3.5%, whereas under rotation it would be lower by 0.1 percentage point only. Under both voting schemes the political weight of Polish representatives in the GC is higher than the country's economic importance.

We also consider the situation, in which $\alpha_{Board} = 0$, $\alpha_{NCB} = 1$ and no pre-coalitions between NCB governors exist. Similarly to the previous research (see section 2), we confirm the finding that introduction of the rotation scheme strengthens considerably the voting power of the EB as compared to the old system (Table 12). Under the "one member, one vote" principle, the Shapley-Shubik index for the Board (in the GC comprised of 33 members) equals 21.2% and the introduction of the rotation scheme raises this value to

Table 11: Voting power vs. economic importance of the member states

Countries	Share in GDP of EU 27	OLD VOTING SCHEME			ROTATION VOTING SCHEME		
		Shapley-Shubik index	Absolute discrepancy between economic and political weight (Political weight - Economic weight)	Relative discrepancy between economic and political weight (Political weight/Economic weight)	Shapley-Shubik index	Absolute discrepancy between economic and political weight (Political weight - Economic weight)	Relative discrepancy between economic and political weight (Political weight/Economic weight)
Germany	19.7%	4.9%	-14.8	0.25	6.8%	-12.9	0.34
United Kingdom	16.4%	4.9%	-11.5	0.30	6.8%	-9.6	0.41
France	15.4%	4.9%	-10.5	0.32	6.8%	-8.6	0.44
Italy	12.5%	4.9%	-7.6	0.39	6.8%	-5.7	0.54
Spain	8.5%	4.9%	-3.6	0.58	6.8%	-1.8	0.79
Netherlands	4.5%	3.5%	-1.1	0.76	3.4%	-1.2	0.74
Sweden	2.7%	3.5%	0.8	1.28	3.4%	0.7	1.25
Belgium	2.7%	3.5%	0.8	1.28	3.4%	0.7	1.26
Poland	2.5%	3.5%	1.0	1.40	3.4%	0.9	1.35
Austria	2.2%	3.5%	1.2	1.57	3.4%	1.2	1.53
Greece	1.9%	3.5%	1.6	1.85	3.4%	1.5	1.82
Danemark	1.9%	3.5%	1.6	1.86	3.4%	1.5	1.83
Ireland	1.5%	3.5%	1.9	2.29	3.4%	1.9	2.24
Finland	1.5%	3.5%	2.0	2.36	3.4%	1.9	2.31
Portugal	1.3%	3.5%	2.1	2.61	3.4%	2.1	2.55
Czech Republic	1.0%	3.5%	2.4	3.33	3.4%	2.3	3.26
Romania	1.0%	3.5%	2.5	3.50	3.4%	2.4	3.42
Hungary	0.8%	3.5%	2.6	4.20	3.4%	2.6	4.11
Slovakia	0.4%	3.4%	2.9	7.62	2.4%	1.9	5.29
Lithuania	0.2%	3.4%	3.2	14.90	2.4%	2.1	10.36
Slovenia	0.3%	3.4%	3.1	12.45	2.4%	2.1	8.64
Luxemburg	0.3%	3.5%	3.2	11.75	3.4%	3.1	11.50
Bulgaria	0.2%	3.4%	3.2	14.45	2.4%	2.1	10.03
Latvia	0.2%	3.4%	3.2	20.95	2.4%	2.2	14.56
Cypr	0.1%	3.4%	3.3	26.84	2.4%	2.2	18.63
Estonia	0.1%	3.4%	3.3	26.86	2.4%	2.2	18.65
Malta	0.0%	3.4%	3.3	77.35	2.4%	2.3	53.70

Source: own calculations

Table 12: Voting power distribution with a ”pro-european” Board

	Shapley-Shubik index	
	Old voting scheme	Rotation voting scheme
Board	21.2%	68.8%
Countries from Group I	2.9%	1.7%
Countries from Group II	2.9%	1.2%
Countries from Group III	2.9%	0.8%

Source: own calculations

68.8%. This increase in the EB voting power is much higher than other empirical studies would indicate. For instance, Belke and Styczynska (2006) show that the Board's power is ”only” doubled when the “one member, one vote” principle is replaced with the rotation system. This discrepancy between our study and previous research stems from the fact that we consider sequences of different games depending on the varying composition of the GC instead of repeated games with an invariant makeup of the GC. Moreover, and in contrast to our approach, other authors use voting frequencies as inter-temporal voting weights for the calculation of power indices, which results in a large underestimation of the Board position in the Council.

In the next step we allow for the existence of pre-coalitions in the analysis of voting power distribution. Drawing on the common voting patterns, derived from the simulation results, we are able to distinguish up to four groups comprised of countries that vote more often with each other than with countries from outside of these groups. With $\alpha = 1$ and $\rho = 0$ for all Council's members, the frequencies of common voting ranged from 21% for Malta and Latvia to 62% for Greece and the United Kingdom. The median and the 75th percentile of common voting frequencies amounted to 35% and 39% respectively. Assuming that each country from a given pre-coalition has to have the common voting frequency with any other country from the same pre-coalition above the value of the 75th percentile, the following pre-coalitions could be distinguished within the GC (*Scenario I*):

- Pre-coalition I.1: Greece, Malta, Slovenia, the United Kingdom
- Pre-coalition I.2: Cyprus, the Czech Republic, France, Italy
- Pre-coalition I.3: Estonia, Finland, the Netherlands, Portugal
- Pre-coalition I.4: Lithuania, **Poland.**

The remaining member states are treated as separate players. Applying less restrictive conditions to pre-coalitions' determination (compare section 5.1) we can identify the following groups of countries with common voting patterns (*Scenario II*):

Table 13: Voting power distribution with precoalitions - Scenario I

Pre-coalitions	Shapley-Shubik index	
	Old voting scheme	Rotation voting scheme
Greece, Malta, Slovenia, United Kingdom	16.1%	15.8%
Cyprus, Czech Republic, France, Italy	18.1%	21.4%
Estonia, Finland, Netherlands, Portugal	14.5%	12.9%
Lithuania, Poland	6.7%	5.5%
Latvia	3.2%	2.2%
Austria	3.2%	3.3%
Germany	4.6%	6.3%
Sweden	3.2%	3.3%
Spain	4.6%	6.3%
Slovakia	3.2%	2.2%
Denmark	3.2%	3.3%
Luxembourg	3.2%	3.3%
Belgium	3.2%	3.3%
Bulgaria	3.2%	2.2%
Romania	3.2%	2.2%
Ireland	3.2%	3.3%
Hungary	3.2%	3.3%

Source: own calculations

- Pre-coalition II.1: Greece, Malta, **Poland**, Slovenia, the United Kingdom
- Pre-coalition II.2: Cyprus, the Czech Republic, France, Italy, Spain
- Pre-coalition II.3: Estonia, Finland, Ireland, the Netherlands, Portugal
- Pre-coalition II.4: Bulgaria, Romania.

Tables 13 and 14 present voting power distribution as measured by the Shapley-Shubik index for the "home biased" Council, within which pre-coalitions' structures have been identified. Introducing rotation turns out not to change considerably the voting power of any of the players identified in the *Scenario I.* The biggest absolute gain (3.4 percentage points) is for the largest pre-coalition in economic terms, i.e. Pre-coalition I.2, whose share in the aggregate GDP of the euro area amounts to 29%. The remaining pre-coalitions are loosing in power under rotation, yet those changes are very modest. It is worth noting that in the case of pre-coalitions I.3 and I.4 rotation reduces their political overrepresentation, but at the same time the underrepresentation of the pre-coalition I.1 is aggravated.

Scenario II points to a somewhat greater impact of new institutional arrangements on the voting power distribution in the Council. The degree of underrepresentation of the biggest pre-coalition (II.2), which this time acounts for about 38% of the euro area GDP, is considerably reduced due to rotation. Similarly to the *Scenario I,* rotation increases the degree of underrepresentation of Pre-coalition II.1.

Table 14: Voting power distribution with precoalitions - Scenario II

Pre-coalitions	Old voting scheme	Rotation voting scheme
Greece, Malta, Poland, Slovenia, United Kingdom	20.0%	19.3%
Cyprus, Czech Republic, France, Italy, Spain	24.1%	30.4%
Estonia, Finland, Ireland, Netherlands, Portugal	18.3%	16.0%
Bulgaria, Romania	6.0%	5.0%
Austria	3.1%	3.0%
Belgium	3.1%	3.0%
Lithuania	3.0%	2.0%
Denmark	3.0%	3.0%
Germany	4.3%	5.6%
Hungary	3.1%	3.0%
Latvia	3.0%	2.0%
Luxembourg	3.1%	3.0%
Slovakia	3.0%	2.0%
Sweden	3.1%	3.0%

Source: own calculations

Furthermore, we identify pre-coalitions within the GC where the Board exhibits a pro-european attitude and is treated as one player owning six votes. In this case, the lowest frequency of common voting is observed for Malta and Estonia (21%) and the highest for Greece and the United Kingdom (60%). The median and the 75th percentile are equal to 35% and 39%, respectively. Taking the value of the 75th percentile of common voting frequencies as the threshold for pre-coalition determination, we distinguish the following groups (*Scenario III*):

- Pre-coalition III.1: Greece, Malta, Slovenia, the United Kingdom
- Pre-coalition III.2: Cyprus, the Czech Republic, France
- Pre-coalition III.3: Estonia, Finland, the Netherlands, Portugal
- Pre-coalition III.4: Lithuania, **Poland**.

For a less restrictive threshold for pre-coalition members, we construct the following groups (*Scenario IV*):

- Pre-coalition IV.1: Greece, Malta, **Poland**, Slovenia, the United Kingdom
- Pre-coalition IV.2: Cyprus, the Czech Republic, France, Italy
- Pre-coalition IV.3: Estonia, Finland, Ireland, the Netherlands, Portugal.

Assuming that the Board members focus on the euro area situation as a whole, the introduction of the rotation system leads to significant changes in the voting power distribution within the GC. Both *Scenarios III* and *IV* confirm the previous findings about the impact of rotation on the voting power of the Board

Table 15: Voting power distribution with precoalitions - Scenario III

Pre-coalitions	Old voting scheme	Rotation voting scheme
Greece, Malta, Slovenia, United Kingdom	12.5%	9.3%
Cyprus, Czech Republic, France	9.0%	7.6%
Estonia, Finland, Netherlands, Portugal	12.5%	9.2%
Lithuania, Poland	5.8%	4.0%
Board	20.5%	36.8%
Italy	2.8%	3.4%
Austria	2.8%	2.4%
Belgium	2.8%	2.4%
Bulgaria	2.8%	1.6%
Denmark	2.8%	2.4%
Germany	2.8%	3.4%
Hungary	2.8%	2.4%
Ireland	2.8%	2.4%
Latvia	2.8%	1.6%
Luxembourg	2.8%	2.4%
Romania	2.8%	1.6%
Slovakia	2.8%	1.6%
Spain	2.8%	3.4%
Sweden	2.8%	2.4%

Source: own calculations

(Tables 15 and 16). The new system strengthens considerably the position of the Board in the enlarged Council, which is confirmed by an increase in the value of the Board's Shapley-Shubik index by almost 80% relative to the old voting scheme. The scale of this increase is, however, much lower than in the scenario with no pre-coalitions between member states. Nevertheless, the Board is by far the biggest player in the GC with a voting power three times higher than that of the remaining significant players[30] in the GC. In contrast to the Board, all identified pre-coalitions, including those formed by Polish representatives, loose power upon introducing the rotation system.

To sum up, voting power analysis indicates that if GC members exhibit a home bias and do not focus on the situation of the euro area as a whole, the introduction of the new voting scheme will not exert much influence on voting power distribution in the Council. In particular, under rotation the influence of the Polish representatives on the voting outcomes will not change relative to the old system.

However, if the Board members' decisions are determined exclusively by the euro area situation, introduction of rotation will significantly strengthen the position of the EB in the enlarged Governing Council. At the same time, it reduces the voting power of NCB governors, including the Polish representative. The scale of the increase in the Board's voting power differs from findings in other studies, which - in our view - underestimate that effect due to the use of voting frequencies as inter-temporal voting weights. We also show that an increase in

[30] i.e. pre-coalitions that we have identified.

Table 16: Voting power distribution with precoalitions - Scenario IV

Pre-coalitions	Old voting scheme	Rotation voting scheme
Greece, Malta, Poland, Slovenia, United Kingdom	15.7%	12.0%
Cyprus, Czech Republic, France, Italy	12.0%	11.2%
Estonia, Finland, Ireland, Netherlands, Portugal	15.7%	12.1%
Board	19.8%	35.0%
Austria	2.6%	2.4%
Belgium	2.6%	2.4%
Bulgaria	2.6%	1.6%
Denmark	2.6%	2.4%
Germany	2.6%	3.3%
Hungary	2.6%	2.4%
Latvia	2.6%	1.6%
Lithuania	2.6%	1.6%
Luxembourg	2.6%	2.4%
Romania	2.6%	2.4%
Slovakia	2.6%	1.6%
Spain	2.6%	3.3%
Sweden	2.6%	2.4%

Source: own calculations

the Board's voting power is much weaker if pre-coalition structures, similar to those identified in our study, exist.

6 Conclusion

The underlying rationale of a reform of the voting modalities in the Governing Council was to ensure timely and efficient decision-making in an enlarged monetary policy committee. The advocates of the new system have assured of its virtues, including the following five principles: *one member, one vote; ad personam participation; robustness; representativeness; transparency.*

Contrary to the above-outlined position, the rotation scheme has often come in for a criticism. It is said to be intransparent, violating the "one member, one vote" principle, and not providing conditions for an efficient decision-making. Most importantly, at least for this study, the new system is criticized for cultivating thinking in national categories and re-nationalizing European monetary policy.

The results of our study show that if the latter argument turned out to be valid, it could badly influence the performance of the ECB conduct. Indeed, with the use of the models based on New Keynesian and Neo-Keynesian frameworks, we provide the empirical evidence that the presence of home bias in the voting behavior of policy makers reduces the welfare. In particular, the simulation results indicate that volatility of output and inflation in the euro-area countries declines with a decrease in the home bias of the GC members. This finding remains valid for the euro-area as a whole, as well as for the average volatility of all member states, including the Polish economy. It thus strongly suggests that decision-makers should concentrate on the developments in the euro area as a whole and not to pursue national interests.

Comparison of the rotation system with the old voting scheme shows that in most cases there is no significant difference between the two frameworks. Interestingly, we also find that a change in the rotation frequency should not influence the performance of the voting system. The only exception that emphasizes the effects of the new framework relates to the situation when NCB governors concentrate on the situation in their country of origin, but the Board members focus on the euro-wide economic developments. In such circumstances introducing the rotation system may significantly improve the economic performance (in terms of output and inflation volatility), not least for the euro area as a whole. This finding provides a moderate support for the argument that the new voting scheme should strengthen the role of the Board.

The above results are largely confirmed by the voting power analysis. In this part of the study we contribute to the literature by dropping the simplistic approach based on the use of voting frequencies as intertemporal weights. Instead, we take into account the fact that under the rotation system the ”voting game” is played only between those members that at a given time have a right to vote. Moreover, we extend the analysis by allowing for the existence of precoalitions between the Governing Council member states.

The results indicate that the new voting scheme reduces the political underrepresentation of the biggest economies and overrepresentation of the smallest member states in the Governing Council. These ”distortions”, however, remain significant. Similarly to the outcome of our simulations, we show that the rotation system does strengthen the voting power of the ”pro-european” Board compared to the old decision-making framework. We find that this ”power premium” is much higher than other studies would suggest, which may be the consequence of the methodological amendments that we have introduced. Strengthening of the Board position is, however, much lower if we allow for the possibility of forming coalitions within the ECB Governing Council.

Provided that the rotation system does not alter the degree of home bias in the voters’ behavior, the new voting scheme helps to deal with some weakness of the old decision-making framework. In particular, it strengthens the role of the pro-european Board when NCB governors pursue their national interests. In these circumstances, introducing the rotation system significantly improves the economic performance of the euro area. Nevertheless, in most cases considered in this study, there is no significant difference between the two frameworks. This finding remains valid not only for the euro-area as a whole, but also for (most) member states, including the Polish economy. It, therefore, indicates that the reform of the voting modalities in the ECB Governing Council will only partly solve the difficulties that the enlargement process was to impose on the functioning of the old decision-making system.

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Appendix A - Solving the model with rational expectations

To solve the model, we follow Torój (2008) in applying an algorithm proposed by Söderlind (1999). We write the model as

$$A_0 \left[\begin{array}{c} x_{1,t+1} \\ E_t x_{2,t+1} \end{array} \right] = A_1 \left[\begin{array}{c} x_{1,t} \\ x_{2,t} \end{array} \right] - BF \left[\begin{array}{c} x_{1,t} \\ x_{2,t} \end{array} \right] + \left[\begin{array}{c} \eta_{t+1} \\ 0 \end{array} \right]$$

with

$$\boldsymbol{x_{1,t}} = \left[\begin{array}{c} 1 \\ t \\ P_{1,t} \\ \vdots \\ P_{27,t} \\ \varepsilon_{\pi,1,t} \\ \vdots \\ \varepsilon_{\pi,27,t} \\ \varepsilon_{y,1,t} \\ \vdots \\ \varepsilon_{y,127,t} \\ \varepsilon_{R,t} \\ \pi_{1,t} \\ \vdots \\ \pi_{27,t} \\ y_{1,t} \\ \vdots \\ y_{27,t} \\ i_t \end{array} \right] \qquad \boldsymbol{x_{2,t}} = \left[\begin{array}{c} \pi_{1,t} \\ \vdots \\ \pi_{27,t} \\ y_{1,t} \\ \vdots \\ y_{27,t} \end{array} \right] \qquad \boldsymbol{\eta_{t+1}} = \left[\begin{array}{c} \mathbf{0_{29\times 1}} \\ \eta_{\pi,1,t+1} \\ \vdots \\ \eta_{\pi,27,t+1} \\ \eta_{y,1,t+1} \\ \vdots \\ \eta_{y,27,t+1} \\ \eta_{i,t+1} \\ \mathbf{0_{55\times 1}} \end{array} \right]$$

$$A_0 = \left[\begin{array}{ccccccccccc} 1 & & & & & & & & & & \\ & 1 & & & & & & & & & \\ & & \boldsymbol{I_{27}} & & & & & & & & \\ & & & \boldsymbol{I_{27}} & & & & & & & \\ & & & & \boldsymbol{I_{27}} & & & & & & \\ & & & & & 1 & & & & & \\ & & & & & & \boldsymbol{I_{27}} & & & & \\ & & & & & & & \boldsymbol{I_{27}} & & & \\ & & & & & & & & 1 & & \\ \boldsymbol{c_\pi} & & & & & & & & & \boldsymbol{\omega_f} & \\ \boldsymbol{c_y} & \boldsymbol{t_y} & & & & & & & & \boldsymbol{\beta_r} & \boldsymbol{\beta_f} \end{array} \right]$$

$$A_1 = \begin{bmatrix} 1 & & & & & & & & & & \\ 1 & 1 & & & & & & & & & \\ & & \mathbf{0_{27\times 27}} & & & & & & & & \\ & & & \boldsymbol{\rho_\pi} & & & & & & & \\ & & & & \boldsymbol{\rho_y} & & & & & & \\ & & & & & \rho_i & & & & & \\ & & & & & & & & & \boldsymbol{I_{27}} & \\ & & & & & & & & & & \boldsymbol{I_{27}} \\ & & \mathbf{0_{1\times 27}} & & & & & & & & \\ & & & -\boldsymbol{I_{27}} & & & -\boldsymbol{\omega_b} & & 0 & \boldsymbol{I_{27}} & -\gamma \\ & & & & -\boldsymbol{I_{27}} & & & -\boldsymbol{\beta_b} & & & \boldsymbol{\beta_{\mathrm{s}}} \end{bmatrix}$$

$$B = \begin{bmatrix} & \\ & \\ \boldsymbol{I_{27}} & \\ & \\ & \\ & \\ & \\ & \\ & \\ & 1 \\ \boldsymbol{\beta_c} \cdot \mathbf{1_{27\times 1}} & \boldsymbol{\beta_r} \cdot \mathbf{1_{27\times 1}} \end{bmatrix}$$

$$F = \begin{bmatrix} 0 & -(1-\rho)\left(r^* + \pi^* - \gamma_\pi \pi^*\right) \\ 0 & 0 \\ -\boldsymbol{I_{27}} & \mathbf{0_{1\times 27}} \\ \mathbf{0_{27\times 27}} & \mathbf{0_{1\times 27}} \\ \mathbf{0_{27\times 27}} & \mathbf{0_{1\times 27}} \\ 0 & -1 \\ \mathbf{0_{27\times 27}} & \mathbf{0_{1\times 27}} \\ \mathbf{0_{27\times 27}} & \mathbf{0_{1\times 27}} \\ 0 & -\rho \\ -0.25 \cdot \boldsymbol{I_{27}} & -(1-\rho)\gamma_\pi \mathbf{w} \\ 0 & -(1-\rho)\gamma_y \mathbf{w} \end{bmatrix}^T$$

$$\boldsymbol{c_\pi} = \begin{bmatrix} (1 - \omega_{b,1} - \omega_{f,1})\,\pi_1^* \\ (1 - \omega_{b,2} - \omega_{f,2})\,\pi_2^* \\ \vdots \\ (1 - \omega_{b,27} - \omega_{f,27})\,\pi_{27}^* \end{bmatrix} \qquad \boldsymbol{c_y} = \begin{bmatrix} \beta_{r,1} r_1^* \\ \beta_{r,2} r_2^* \\ \vdots \\ \beta_{r,27} r_{27}^* \end{bmatrix}$$

$$\boldsymbol{t_y} = 0.25 \begin{bmatrix} \beta_{c,1}\left(\pi_1^* - \pi_{-1}^*\right) \\ \beta_{c,2}\left(\pi_2^* - \pi_{-2}^*\right) \\ \vdots \\ \beta_{c,12}\left(\pi_{27}^* - \pi_{-27}^*\right) \end{bmatrix}$$

$$\boldsymbol{\omega_f} = \begin{bmatrix} \omega_{f,1} & & & \\ & \omega_{f,2} & & \\ & & \ddots & \\ & & & \omega_{f,27} \end{bmatrix} \qquad \boldsymbol{\omega_b} = \begin{bmatrix} \omega_{b,1} & & & \\ & \omega_{b,2} & & \\ & & \ddots & \\ & & & \omega_{b,27} \end{bmatrix}$$

$$\boldsymbol{\beta_f} = \begin{bmatrix} \beta_{f,1} & & & \\ & \beta_{f,2} & & \\ & & \ddots & \\ & & & \beta_{f,27} \end{bmatrix} \qquad \boldsymbol{\beta_b} = \begin{bmatrix} \beta_{b,1} & & & \\ & \beta_{b,2} & & \\ & & \ddots & \\ & & & \beta_{b,27} \end{bmatrix}$$

$$\boldsymbol{\beta_r} = \begin{bmatrix} \beta_{r,1} & & & \\ & \beta_{r,2} & & \\ & & \ddots & \\ & & & \beta_{r,27} \end{bmatrix} \qquad \boldsymbol{\gamma} = \begin{bmatrix} \gamma_1 & & & \\ & \gamma_2 & & \\ & & \ddots & \\ & & & \gamma_{27} \end{bmatrix}$$

$$\boldsymbol{\beta_s} = \begin{bmatrix} 1 & -\beta_{s,1}\frac{w_2}{1-w_1} & \dots & -\beta_{s,1}\frac{w_{12}}{1-w_1} \\ -\beta_{s,2}\frac{w_1}{1-w_2} & 1 & \dots & -\beta_{s,2}\frac{w_{12}}{1-w_2} \\ \vdots & \vdots & \ddots & \vdots \\ -\beta_{s,12}\frac{w_1}{1-w_{12}} & -\beta_{s,12}\frac{w_2}{1-w_{12}} & \dots & 1 \end{bmatrix}$$

$$\boldsymbol{\beta_c} = \begin{bmatrix} \beta_{c,1} & -\beta_{c,1}\frac{w_2}{1-w_1} & \dots & -\beta_{c,1}\frac{w_{27}}{1-w_1} \\ -\beta_{c,2}\frac{w_1}{1-w_2} & \beta_{c,2} & \dots & -\beta_{c,2}\frac{w_{27}}{1-w_2} \\ \vdots & \vdots & \ddots & \vdots \\ -\beta_{c,27}\frac{w_1}{1-w_{27}} & -\beta_{c,27}\frac{w_2}{1-w_{27}} & \dots & \beta_{c,27} \end{bmatrix}$$

$$\mathbf{w} = (1-\alpha)\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_{27} \end{bmatrix} + \alpha \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_{27} \end{bmatrix}$$

In this model, $\boldsymbol{\rho_\pi}$, $\boldsymbol{\rho_y}$ and ρ_i are assumed to be zero matrices.

We use matrix $A = A_0^{-1}(A_1 - BF)$ as input for the algorithm, use Schur decomposition and reject unstable roots (eigenvalues≥ 1). The solution with respect to forward looking variables is obtained as matrices M and C (see Söderlind, 1999) used for simulations.