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The eurozone: what is to be done?

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Abstract

We construct a macro DSGE model of the eurozone and its two main regions, the North and the South, with the aim of matching the macro facts of these economies by indirect inference and using the resulting empirically-based model to assess possible new policy regimes. The model we have found to fit the facts suggests that substantial gains in macro stability and consumer welfare are possible if the fiscal authority in each region is given the freedom to respond to its own economic situation. Further gains could come with the restoration of monetary independence to the two regions, in effect creating a second 'southern euro' bloc.

Keywords: eurozone; macro stability; fiscal policy; monetary independence

JEL Classification: E32, E52, E62, F41

1 Introduction

In this paper we develop a model of the eurozone and use it to examine possible policy rules that could assist it in achieving economic stability across its wide geographic membership.

To understand the tensions within the eurozone, we use the device of a three country model: North and South EU and the Rest of the World. The model is estimated and tested by indirect inference on data for the two aggregated groups, countries of the Northern and of Southern EU, as well as of the aggregate of all other countries, the RoW.

The euro's history since it was founded in 1999 as a virtual currency – with its physical version being issued in 2001 – has fallen into two main segments. The first was an opening 'honeymoon' period up to 2007 when world growth was strong and all parts of the zone were growing well; capital flowed freely and in some profusion from North to South with interest rates equalised by UIP. The second segment was less happy; as the financial crisis spread to the zone, it reduced growth differentially more in the South, creating crises for Southern countries' public finances. With solvency concerns growing, yields on long term public debts rose in the South and capital flows from the North abruptly ceased. The ECB was not allowed at this stage to

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buy government debt; however it lent prolifically to commercial banks in the afflicted Southern countries, encouraging these in turn to buy their governments' debt, so preventing public insolvency from rising yields interacting with worsening finances. Under the Maastricht Treaty's No Bailout clause inter-government help was ruled out. However, to help the governments in difficulties and in collaboration with the IMF, this was soon waived and a new transfer fund instituted across the EU. The resulting transfers were monitored by 'Troika' committees – the three constituent monitors being the Commission, the ECB and the IMF. The conditions for the receipt of help were severe: 'austerity programmes' were enforced so that the transfers should prospectively be paid back.

These events followed fairly closely the playbook of 'asymmetric shocks' about which the creators of the euro had been loudly warned. Clearly, the financial crisis and its effect on the zone was a highly powerful and asymmetric shock that was bound to test the euro's structural responses searchingly. It would have been possible to let Southern countries exit the euro, even if only temporarily, as was suggested (Arghyrou and Tsoukalas, 2010). But such ideas were barely entertained, with opposition to them not just from the North, where there were fears of contamination by breaching the euro's permanence, but also from the South, where fears of political isolation from the EU prevailed.

It would also have been possible for Northern countries to undertake fiscal expansion to alleviate the lack of demand in the South. But this was also rejected by Northern governments, concerned with their own solvency fears. Instead demand stimulus was left as the province of the ECB. It took some time before the ECB moved to stimulative action in the form of QE, as this was opposed by the Bundesbank and German government opinion. Instead, for a long time the ECB conducted limited open market operations to stimulate credit at the Zero Lower Bound. It was simultaneously being forced by commercial bank needs and the public solvency problems in the South to lend freely to these banks as noted above. These loans largely replaced capital outflows to the North and so wound up creating large 'TARGET' balances, whereby under the ECB inter-central-Bank TARGET settlement process, Northern central banks acquired rising deposits at the ECB against rising loans made by Southern central banks. The mechanism was that capital outflows liquidated bank deposits in the South, redepositing them in the North where they were held as bank balances at the ECB; the ECB's extra loans to Southern banks in replacement of their lost deposits wound up as the ECB asset counterpart. In effect the ECB was thereby acting as another source of official transfers from North to South.

At present there is an active debate in EU policy circles about how to develop the eurozone's institutions. One result has been a 'banking union' in which the ECB supervises all eurozone banks to common standards; and takes any necessary action to wind them up, arrange take-overs or otherwise achieve compliance. To some extent this conflicts with the national government responsibilities to regulate their own banking systems under national laws. Nevertheless the ECB's key role in lending to national commercial banks endows it with strong bargaining power in this area.

There has also been discussion about issuing euro bonds backed by all zone governments; this would amount to borrowing by the euro 'state'. However in the absence of such a state, and the fears, particularly in Germany, that this might be used by other countries to force further transfers from Germany *de facto*, the proposal has not got far; the one significant exception has been the Covid Recovery Fund instituted in 2020, which has been financed by an issue of euro-bonds, but will be transferred to EU governments as grants for spending proposals to be tabled with the Commission. Of course if airy talk of 'state-building' were to bear fruit, this could become a precedent for further 'EU state' action in the same vein. Such talk is, however, bedevilled by the same problems currently arising in the context of much less ambitious proposals for cooperation beyond Covid.

Some Southern countries, notably Italy, have proposed national fiscal expansion. However this is prevented by the Stability and Growth Pact, strongly backed today by Germany and other Northern countries such as the Netherlands, which see it as a bulwark against potential Southern insolvency, leading to yet more transfers.

What is striking about this account of events and proposals is that fiscal policy, the only available policy instrument other than money, which is centrally controlled by the ECB, is effectively immobilised by the euro's internal limitations. This has made it difficult to envisage possible policy rules that could assist the euro-zone's capacity to survive; in practice, only monetary policy rules were considered and even these are necessarily limited by inter-governmental concerns.

In the policy discussion of this paper, we assume that the exigencies of endemically poor macroeconomic performance will force greater flexibility in fiscal policy on eurozone governments. Already, only a few years from modest recovery out of the severe eurozone crisis, recession again threatens the zone, with even Germany now growing weakly. QE has been heavily deployed but willingness to push it yet further is now limited. Only fiscal policy is left. If not now, when? With monetary tools failing around the western world the eurozone is not alone in being forced into fiscal action to normalise their economies.

Hence we will pay attention to fiscal policy rules here as well as zone-wide monetary policy rules for the ECB. In a spirit of pure academic enquiry we also investigate a world of independent monetary (as well as fiscal) policy where a Northern euro floats against a Southern euro; this world helps to define a benchmark of what might have been.

In what follows we set out our model of the eurozone, consisting of two subzones, North and South, and the rest of the world. We do not impose the Zero Lower Bound in this model; rather, we treat the corporate bond rate (which never hit the ZLB) as the target variable for monetary policy, whether executed by a Taylor Rule or by QE.

This framework belongs to the area of multi-country modelling, where there is a large literature – exemplified by Chari et al. (2002) and Le et al. (2010). A difference with our approach is that these papers do not focus on modelling and matching the intra-eurozone regional economies' behaviour and interactions. The EU Commission runs a large multi-country model, QUEST (Roeger and Veld, 1997; Ratto et al., 2009; Burgert et al., 2020), which includes each EU country; however, there is no published account of its empirical ability to match the facts of these countries' behaviour, nor of how differing macro policy regimes could stabilise their macro behaviour. This model has mainly been used to examine supply-side reforms across EU countries – as most recently in D'Auria et al. (2009). In our work, although the overall supply-side potential output enters the model, it does so as an exogenous process (and a source of supply shocks) and we do not examine supply-side reforms, only macro policy regime changes. There appears to have been no published work related to what we are trying to do here.

To anticipate our results, firstly, we find that we can match the data behaviour of the EU and its regions with this macro model. Secondly, we find that there is considerable scope for improving macro stability (and consequently welfare) - both regional- and eurozone-wide - by introducing new fiscal policy regimes; most strikingly, we also find that a return to floating and independent monetary and fiscal policies, at least across the two regional blocs, would have the greatest benefits in macro stability. In effect, this resurrects the idea of a 'Southern euro' suggested by Arghyrou and Tsoukalas (2010). Plainly these policy conclusions would be politically controversial within the current EU institutional set-up. However, their economic implications as estimated benchmarks can inform the practical debate.

Our contribution in this paper is twofold. First, it is empirical, to find a model that matches the data according to powerful tests which carries the important implication that its policy evaluation can be taken seriously and treated as approximately accurate. Second, we have examined the effectiveness of various reforming fiscal and monetary policies which are designed to improve the macro stability of the eurozone area. As stability has been weak in recent decades, this remains an important policy issue.

The rest of the paper is organised as follows: in Section 2 we set out the model; in Section 3 we explain our indirect inference methods; in Section 4 we set out the empirical results and how the estimated model behaves and explains past events; in Section 5 we consider policy regime changes and discuss how they affect the stability and welfare of the eurozone and its regions; Section 6 concludes.

2 Model

We use a three-country open-economy model modified from Minford et al. (2021) to account for the broad features of the EU which is split into North and South, and their interactions with their main trading partners which are combined to represent the world economy. The North EU consists of Austria, Belgium, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, Luxembourg, Netherlands and Slovakia. The South EU consists of France, Greece, Italy, Portugal, Spain and Slovenia. The rest of the world consists of China, India, Japan, Norway, Russia, South Korea, Switzerland, Turkey, UK and US. Each of the three country models is a condensed IS-Phillips curve variant of the standard New Keynesian model amending to allow for trade, real exchange rate determination and the balance of payments.

The derivation (which is detailed in Minford et al.) is standard: the IS curve is derived from the household Euler equation, which in turn is substituted into the output market-clearing equation for consumption, yielding a forward-looking output demand equation with terms in net exports and government spending. Net exports are substituted out in terms of their determinants: outputs and relative prices; government spending is embraced by the equation error). A labour-only production function determines output from households' labour supply and exogenous productivity. This gives rise to an exogenous trend output driven by productivity and an output gap reflecting variations in labour input around this trend, with firms' marginal costs rising with the output gap, reflecting lower marginal productivity and rising real wages. The Phillips curve for inflation is then derived under Calvo pricing, as a forward-looking function of expected future inflation and the output gap. Exports are set by other countries' import demands for them and are determined by their output and relative country prices. The real exchange rate is governed by the uncovered interest rate parity (UIP). This is supported by recent evidence for EU data (Burnside, 2019; Minford et al., 2021, 2021b). The balance of payments equation sets each economy's net increase in loans to be equal to that economy's net imports plus interest payments. Monetary policy is set by a Taylor rule, which describes the interest rate setting behaviour of the central bank; the market interest rate fluctuates around the central bank rate, subject to a risk premium. Fiscal policy, which describes government's spending behaviour, is a stable, exogenous process.

The model is listed in full in the Appendix. We present only the key equations, treating the North EU as the home economy, to illustrate the model structure. All variables, except inflation and the nominal interest rate, are measured in natural logarithms. North variables and parameters are marked with $'$; South variables and parameters are marked with $''$; World variables and parameters are asterisked. All shocks in the model, except those to productivity and government spending which are assumed to follow independent AR(1) processes[1].

North IS curve:

$$\begin{aligned} y'_t &= E_t y'_{t+1} - \frac{C'}{Y'}\frac{1}{\sigma'}\Theta'(R'_t - E_t\pi'_{t+1} - \bar{r}') - \frac{X'}{Y'}z'_1\Theta' E_t\Delta y''_{t+1} - \frac{X'}{Y'}z'_2\Theta' E_t\Delta y^*_{t+1} \\ &\quad + \frac{X'}{Y'}z'_3\Theta' E_t\Delta q_{ns,t+1} - \frac{X'}{Y'}z'_4\Theta' E_t\Delta rxr'_{t+1} - \frac{G'}{Y'}\Theta' E_t\Delta g'_{t+1} + \varepsilon'_{IS,t} \end{aligned} \tag{1}$$

where y'_t, y''_t, and y^*_t are the home, South and World outputs, $R'_t - E_t\pi'_{t+1} - \bar{r}'$ is the real interest rate, $q_{ns,t}$ is the home-South real exchange rate (an increase is a South currency depreciation), rxr'_t is the home real *effective* exchange rate (an increase is a home currency depreciation), g'_t is government spending. $\frac{C'}{Y'}$, $\frac{X'}{Y'}$ and $\frac{G'}{Y'}$ are the steady-state ratios of consumption, net exports and government spending to output. Θ', z'_1, z'_2, z'_3 and z'_4 are combinations of the structural parameters (detailed in the Appendix). $\varepsilon'_{IS,t}$ is the demand shock.

North Phillips curve:

$$\begin{aligned} \pi'_t &= -\lambda'_{nw}\left(\beta' E_t\Delta rxr'_{t+1} - \Delta rxr'_t\right) + \lambda'_{ns}\left(\beta'\Delta q_{ns,t+1} - \Delta q_{ns,t}\right) \\ &\quad -\lambda'_{sw}\left(\beta' E_t\Delta rxr''_{t+1} - \Delta rxr''_t\right) + \beta' E_t\pi'_{t+1} + \kappa'_a(y'_t - yf'_t) + \varepsilon'_{PP,t} \end{aligned} \tag{2}$$

where π'_t is CPI inflation, $y'_t - yf'_t$ is the output gap, rxr''_t is the South real effective exchange rate (an increase is a South currency depreciation). β is the discount rate, κ'_a is a combination of the structural parameters including the Calvo probability of price rigidity, λ'_{ns}, λ'_{nw} and λ'_{sw} are functions of the openness of each economy pair. $\varepsilon'_{PP,t}$ is the mark-up shock, which is a supply shock.

North productivity:

$$yf'_t - yf'_{t-1} = \Gamma' + \delta'(yf'_{t-1} - yf'_{t-2}) + \varepsilon'_{yf,t} \tag{3}$$

where yf'_t is assumed to follow a random walk process with drift, Γ', and reflects the permanent impact of the productivity shock, $\varepsilon'_{yf,t}$. δ' is the mean-reverting parameter.

North imports from South (World) is a function of home income and the home-South (home effective) real exchange rate:

$$im'_{s,t} = \mu'_s y'_t + \psi'_s q_{ns,t} \tag{4}$$

$$im'_{w,t} = \mu'_w y'_t - \psi'_w rxr'_t \tag{5}$$

The real exchange rates are determined by UIP, where the home effective rate and the South effective rate adjust, respectively, to ensure that the expected real returns on investment in different markets are equal:

$$rxr'_t - E_t rxr'_{t+1} = \tilde{R}_t - R'_t - (E_t\pi^*_{t+1} - E_t\pi'_{t+1}) \tag{6}$$

[1] See equations (3) and (12).

$$rxr''_t - E_t rxr''_{t+1} = \tilde{R}_t - R''_t - (E_t\pi^*_{t+1} - E_t\pi''_{t+1}) \tag{7}$$

where $\tilde{R}_t$ is the World nominal interest rate, π^*_t is World inflation. The home-South real exchange rate is solved as the (log) difference between the home effective rate and the South effective rate:

$$rxr'_t - rxr''_t = -q_{ns,t} \tag{8}$$

North balance of payments requires the outflow of home money to be equal to the inflow of foreign money (in home currency terms), $BF'_t + IM'_{s,t} + IM'_{w,t} - (\tilde{R}_{t-1} - E_{t-1}\pi^*_t)BF'_{t-1} = (IM''_{n,t} + IM^*_{n,t})/RxR'_t$, which can be log-linearised to be:

$$\begin{aligned}\frac{BF'}{Y'}bf'_t \quad = \quad & \frac{BF'}{Y'}(\tilde{R}_{t-1} - E_{t-1}\pi^*_t - \bar{r}^*) + (1+\bar{r}^*)\frac{BF'}{Y'}bf'_{t-1} \\ & + \frac{1}{RxR'}\frac{IM''_n}{Y'}\left(im''_{n,t} - rxr'_t\right) + \frac{1}{RxR'}\frac{IM^*_n}{Y'}\left(im^*_{n,t} - rxr'_t\right) \\ & - \frac{IM'_s}{Y'}im'_{s,t} - \frac{IM'_w}{Y'}im'_{w,t}\end{aligned} \tag{9}$$

where bf'_t is the home holding of foreign bonds, $\bar{r}^*$ is the steady-state World real interest rate, $im''_{n,t}$ and $im^*_{n,t}$ are the South and World imports from home, respectively. $\frac{BF'}{Y'}$, $\frac{IM'_s}{Y'}$, $\frac{IM'_w}{Y'}$, $\frac{IM''_n}{Y'}$, $\frac{IM^*_n}{Y'}$ and $\frac{1}{RxR'}$ are the steady-state ratios.

The North nominal market interest rate is equal to the ECB rate plus a risk premium shock, $\varepsilon'_{RP,t}$:

$$R'_t = R^{ECB}_t + \varepsilon'_{RP,t} \tag{10}$$

The ECB rate is determined through a Taylor rule:

$$R^{ECB}_t = \rho R^{ECB}_{t-1} + (1-\rho)(\bar{r} + \phi_\pi \Pi_t + \phi_y GAP_t) + \varepsilon^{ECB}_{R,t} \tag{11}$$

where policy responds with inertia to mean inflation and output gap (Π_t and GAP_t, respectively) of the whole EU. $\varepsilon^{ECB}_{R,t}$ is the monetary policy shock.

North fiscal policy is represented by an exogenous, stationary government spending rule:

$$g'_t = \rho'_g g'_{t-1} + \varepsilon'_{g,t} \tag{12}$$

where $\varepsilon'_{g,t}$ is the fiscal policy shock.

Equations (1) - (12) constitute the North EU part of the full model. Since both productivity and home's holding of foreign bonds (yf'_t and bf'_t, solved by (3) and (9), respectively) are unit root processes, to solve the model we follow Fair and Taylor (1983) and Minford et al. (1984, 1986) by using the projection method, whereby rational expectations are solved such that at a terminal date T all of the endogenous variables are at their equilibrium steady-state values, with net foreign assets are not changing (current account balance), inflation at its target value, and the output gap zero. The full model which is detailed in the Appendix is completed by South and World equations, which resemble the North equations, and have similar terminal conditions imposed.

3 Estimation

Another feature of our approach to modelling is our choice of estimation method. Rather than use Bayesian methods, currently the most popular way to estimate DSGE models, or the more traditional maximum likelihood estimator, we use the method of Indirect Inference, in particular, the simulated, quasi-maximum likelihood estimator. This general approach was originally designed by Smith (1993), Gregory and Smith (1991, 1993), Gourieroux et al. (1993) and Gourieroux and Monfort (1996) for estimating a structural model with a complex likelihood function for which 'direct' estimation may be hard to implement. In recent years, this method of inference has been developed substantially by Minford et al. (2008), Meenagh et al. (2009), Le et al. (2011, 2016) and Minford et al. (2019) to provide a formal statistical test of Bayesian-estimated DSGE models, which is not something usually carried out. The DSGE-VAR method (Del Negro and Schorfheide, 2006) provides a way of evaluating model fit, but it is not a statistical test and, therefore, provides no indication whether or not a model should be rejected. Maximum Likelihood methods can be used both to estimate and test DSGE models, but according to Monte Carlo experiments on macro models (Le et al., 2016), the resulting estimates may be highly biased, especially in the small samples commonly used in macro, and the associated likelihood tests generally suffer from insufficient power compared to indirect inference tests.

As our intention is to find a model that matches the data according to rigorous statistical criteria, in order that it can provide a reliable guide to quantitative policy reform, we choose to use Indirect Inference both to estimate and test the model.

3.1 The method of Indirect Inference

The basic idea of Indirect Inference is to use a pure statistical model to describe the data, known as the auxiliary model, and to find the parameter values of the structural (DSGE) model which, when the model is then simulated, gives a set of estimates of the auxiliary model closest to the estimates of the auxiliary model based on actual or observed data. In this way the structural model is matched to the data, but the choice of features to match is broader than just their second moments (variances and correlations) as it includes the dynamic structure of the data. A natural choice of auxiliary model for a DSGE model is a VAR, VARX or VARMA as the solution to a linearised DSGE model is a restricted version of these. The DSGE model with a given set of structural estimates can be tested by comparing the unrestricted estimates of the auxiliary model based on data simulated from the model and observed data; the estimates using the simulated data will reflect the structural restrictions.

We have used the following VARX as our auxiliary model:

$$Y_t = AY_{t-1} + BX_{t-1} + e_t \tag{13}$$

where Y_t is a vector of endogenous variables whose behaviour we aim to match and test against the DSGE model, X_t is a vector of exogenous variables, e_t is a vector of reduced-form errors, A and B are matrices of parameters. Since in this paper we are mostly concerned by the output of the three economies, we set $Y_t \equiv (y'_t, y''_t, y^*_t)'$. We assume that the trends in the data are due, both to a deterministic time trend and to stochastic trends in the productivities (which we measure with the Hodrick-Prescott filter) and set

$X_t \equiv (yf'_t, yf''_t, yf^*_t, t)'$. We denote the estimates of the auxiliary model that are based on simulated data by Φ_T^{Sim} and those using observed data as Φ_T^{Act}.

The simulated data are obtained by bootstrapping the DSGE model and its innovations. For each simulation, auxiliary model estimates are obtained, generating a distribution of the estimates. We then search for parameter values of the DSGE model such that $\overline{\Phi}$, the mean of the vectors $(\Phi_T^{Sim1}, \Phi_T^{Sim2}, ..., \Phi_T^{SimN})$, comes closest to Φ_T^{Act}. In model testing, we ask whether Φ_T^{Act} came from the distribution of Φ_T^{Sim} with a high enough probability such that the DSGE model is not rejected by the sample data.

The distance between the data and the DSGE model, which is both the objective function in estimation and the test statistic in testing, is given by the Wald statistic:

$$Wald = (\Phi_T^{Act} - \overline{\Phi})' \sum\nolimits_{(\Phi\Phi)}^{-1} (\Phi_T^{Act} - \overline{\Phi}) \tag{14}$$

where $\sum_{(\Phi\Phi)}$ is the variance-covariance matrix of the vectors $(\Phi_T^{Sim1}, \Phi_T^{Sim2}, ..., \Phi_T^{SimN})$. The Indirect Inference estimator implements a grid search for the DSGE parameters, θ^{DSGE}, until (14) is minimised[2]. To test whether the DSGE model is rejected by the sample data with these optimal parameters, we set the null hypothesis H_0 that 'the DSGE model is true' and calculate its p-value:

$$p = (100 - WP)/100 \tag{15}$$

where WP is the percentile of the Wald statistic found with the actual data in the distribution of it generated by the simulated samples. The DSGE model would pass/fail the Wald test if the p-value of H_0 is above/below the 1%, 5% or 10% threshold.

3.2 Data, model estimates and fit

The estimation and test results we report in this section are based on 1000 simulated samples, which we generate by bootstrapping the historical DSGE innovations. The data are observed between 2003Q1 and 2019Q4. The observable variables we use for gauging these innovations are output, productivity, inflation, market and policy interest rates, and government spending, of the three economies, together with the North and South effective exchange rates. The data are sourced from Euro-area-statistics, FRED, the IMF and the OECD. We use unfiltered data. The historical innovations are calculated from the DSGE residuals which are assumed to be AR(1) processes with a time trend and a constant. The time series used and the associated adjustments are detailed in the Appendix.

Table 1 reports the Indirect Inference (II) estimates of the DSGE model. They are contrasted with a set of calibrated starting values that are often used in the literature as the prior mean or median values in Bayesian estimation[3]. The steady-state values are fixed and calibrated to be the mean values of the sample data. The time discount factor is fixed at 0.99. The other parameters are estimated by a grid search over the parameter space of values that is permitted by the theoretical model. The II estimates of the shock parameters, and the parameters related to the open economy part of the model, i.e., the degrees of openness ($\alpha's$), inflation's responses to exchange rates ($\lambda's$, which are combinations of $\alpha's$), and the elasticities of

[2]We implement the grid search by using the simulated annealing (SA) algorithm.

[3]However, it is worth pointing that the II estimates – found by a grid search – are not affected by these starting points.

imports ($\mu's$ and $\psi's$) are similar to the calibrated starting values. The key differences are for the elasticities of consumption and labour (inverse of $\sigma's$ and $\varphi's$, respectively) and the Calvo non-adjusting probabilities ($\theta's$), where the estimates are generally lower. This makes the Phillips curves steeper ($\kappa'_\alpha s$). There are further differences in the Taylor rule estimates which imply a more active interest rate response to inflation (ϕ_π) in the EU, but slightly less active in the rest of the world; the interest rate response to the output gap (ϕ_y) is generally higher; and policy inertia (ρ) is much lower in the EU, and higher than the ROW.

Table 1: II estimates and p-value of the DSGE model

Parameter	Definition	Calibrated starting val.			II Estimates		
		North	South	World	North	South	World
β	Time discount factor	0.99	0.99	0.99	Fixed at starting values		
RxR	Steady-state real exchange rate	4.58	5.07	NA	Fixed at starting values		
C/Y	Steady-state consumption ratio	0.49	0.56	0.58	Fixed at starting values		
X/Y	Steady-state net exports ratio	0.43	0.29	0.20	Fixed at starting values		
G/Y	Steady-state government expenditure ratio	0.20	0.21	0.16	Fixed at starting values		
IM_n/Y	Steady-state imports ratio (from North)	NA	0.08	NA	Fixed at starting values		
IM_s/Y	Steady-state imports ratio (from South)	0.07	NA	NA	Fixed at starting values		
IM_w/Y	Steady-state imports ratio (from World)	0.34	0.21	NA	Fixed at starting values		
IM''_n/Y'	South imports from North/North output (SS)	NA	0.06	NA	Fixed at starting values		
IM^*_n/Y'	World imports from North/North output (SS)	NA	NA	0.22	Fixed at starting values		
IM'_s/Y''	North imports from South/South output (SS)	0.09	NA	NA	Fixed at starting values		
IM^*_s/Y''	World imports from South/South output (SS)	NA	NA	0.34	Fixed at starting values		
BF/Y	Hold. of foreign bonds/domestic output (SS)	35.6	-16.0	NA	Fixed at starting values		
σ	Price elasticity of consumption (Inverse of)	1.37	1.37	1.38	2.28	2.91	1.97
φ	Wage elasticity of labour (Inverse of)	2.49	2.49	1.83	2.92	4.21	3.43
θ	Calvo non-adjusting probability	0.91	0.91	0.66	0.76	0.78	0.68
κ_α	Slope of the Phillips curve	0.05	0.05	0.78	0.57	0.64	1.05
α	Degree of openness	0.20	0.20	0.20	0.14	0.17	0.21
λ_{ns}	Inflation response to North-South FX rate	0.50	0.50	0.00	0.28	0.33	-0.02
λ_{nw}	Inflation response to North RxR	0.50	0.00	0.50	0.25	-0.05	0.51
λ_{sw}	Inflation response to South RxR	0.00	0.50	0.50	-0.02	0.38	0.48
μ	Income elasticity of imports	1.00	1.00	1.00	0.76	0.82	0.64
ψ	Exchange rate elasticity of imports	0.80	0.80	0.80	0.86	0.69	0.75
ϕ_π	Monetary policy response to inflation	1.52	1.52	2.50	2.23	2.23	1.99
ϕ_y	Monetary policy response to output gap	0.10	0.10	0.08	0.42	0.42	0.48
ρ	Monetary policy inertia	0.96	0.96	0.60	0.59	0.59	0.76
ρ_g	Fiscal policy inertia	0.90	0.96	0.95	0.90	0.96	0.95
ρ_{IS}	Persistence of demand shock	0.53	0.53	0.60	0.55	0.54	0.61
ρ_{PP}	Persistence of mark-up shock	0.18	0.09	0.15	0.16	0.11	0.14
ρ_{RP}	Persistence of risk-premium shock	0.97	0.97	0.91	0.97	0.97	0.91
ρ_R	Persistence of monetary policy shock	0.85	0.85	0.81	0.89	0.89	0.83
δ_{yf}	Mean reversion of productivity growth	0.94	0.98	0.96	0.94	0.98	0.96
	Model p-value		0			0.117	

H_0: The DSGE model is true.

The p-value of the model is reported at the bottom of Table 1. The model using the starting parameter values is strongly rejected by the Wald test which has a p-value of zero). In marked contrast, the estimated model has a p-value of 11.7% and so very comfortably passes the test at the 5% significance level.

Consequently, we may proceed with our analyses with confidence from both a theoretical and empirical viewpoint.

4 How do the shocks affect the model?

In this section we evaluate the impact of the shocks. The full model of three economies has 17 shocks which interact via trade and capital movements. A variance decomposition will identify the most important shocks. We then evaluate the relevant impulse responses, and review how such shocks affected the data over time. We focus on the following six variables: North output and inflation, South output and inflation, and the EU output and inflation.

4.1 Variance decomposition

Table 2 reports the forecast error-variance decomposition due to shocks for various forecast horizons (To save space we report the combined effect for a few North/South shocks and all Rest of the World shocks which on their own have little effect).

In the short run (1 year ahead), North output is determined by the North demand shock (36%) and the ECB monetary error (35%). North inflation is due mostly to the North mark-up shock (48%), with the ECB error also contributing a significant amount (23%). South variables are affected in a similar way: i.e., output is dominated by the South demand shock (58%), inflation is mainly due to the South mark-up shock (40%), ECB policy has only half as much impact on South output (19%), while the regional risk premium has a non-negligible effect on South inflation (14%). At the EU level, the demand shock explains half of the aggregate output variation, of which 33% is due to South shocks. Average inflation is dominated by the mark-up shock (about 46%), but the North-South contributions are more balanced (26% and 20%, respectively). The ECB continues to play a modest role, contributing to output and inflation, respectively, 27% and 21%.

In the medium run (3-5 years ahead): the North demand shock and the ECB monetary error continue to be the main determinants of North output (but the demand shock is now smaller, accounting for 19-26%). Similarly, South output is determined mainly by South demand shocks and ECB policy shocks, the latter being smaller than before. Mark-up shocks continue to dominate inflation in both North and South, and also do so in the long run. Over time the contribution of demand shocks declines considerably while that of productivity shocks, which by assumption are permanent, become dominant, accounting for over 50% of output variation in North and nearly 60% for South.

These results are consistent with previous evidence on the importance of demand and supply shocks over time. There are, however, a number of new findings. First, there is little spillover between the North and South regions: shocks in one region have little impact on the other region. Second, South demand shocks have a much large effect on South output than North demand shocks have on North output. The South shock is about 66% larger. Moreover, the South demand shock has roughly double the effect on EU output as the North shock, and this difference persists through time. Third, ECB policy shocks have substantial, long-lasting, effect on inflation.

Table 2: Variance decomposition of output and inflation

Quarters ahead	North demand	North mark-up	North product	North others	South demand	South mark-up	South product	South others	ECB policy	RoW combined
4										
y (N)	35.5	4.41	1.01	8.07	4.59	3.07	0.02	1.06	35.3	6.97
y (S)	1.26	4.85	0.01	0.61	57.7	1.18	1.56	8.55	18.9	5.41
y (EU)	17.3	4.67	0.47	4.12	32.8	2.06	0.84	5.03	26.6	6.16
π (N)	6.21	48.3	0.04	10.7	0.43	2.17	0.05	4.39	22.9	4.85
π (S)	0.87	6.74	0.03	5.4	5.63	39.7	0.10	14.5	19.4	7.63
π (EU)	3.38	26.3	0.03	7.9	3.19	22.1	0.07	9.75	21.0	6.32
12										
y (N)	25.9	3.11	11.9	6.6	4.43	2.14	0.33	1.44	38.7	5.45
y (S)	0.97	3.24	0.10	0.51	44.2	0.78	17.6	8.9	19.7	4.02
y (EU)	12.7	3.18	5.63	3.37	25.6	1.42	9.48	5.39	28.6	4.63
π (N)	3.75	45.3	0.46	9.19	0.18	2.93	0.53	4.9	28.4	4.36
π (S)	0.22	5.77	0.29	4.63	6.74	38.5	1.27	11.3	23.6	7.72
π (EU)	1.88	24.4	0.37	6.77	3.66	21.8	0.92	8.27	25.8	6.13
20										
y (N)	19.0	2.28	33.3	4.99	3.28	1.57	1.00	1.25	29.2	4.08
y (S)	0.63	2.12	0.26	0.34	29.1	0.51	44.5	6.64	13.3	2.70
y (EU)	9.25	2.20	15.8	2.52	17.0	1.01	24.0	4.10	20.8	3.31
π (N)	2.55	46.1	1.63	8.81	0.12	2.86	0.85	4.78	28.0	4.30
π (S)	0.12	5.46	0.99	4.37	5.63	39.2	2.53	11.2	22.8	7.67
π (EU)	1.27	24.6	1.29	6.34	3.05	22.1	1.74	8.18	25.2	6.08
40										
y (N)	11.6	1.40	50.9	3.07	2.01	0.96	8.47	0.83	17.9	2.86
y (S)	0.35	1.15	9.41	0.19	15.9	0.28	59.8	3.85	7.23	1.92
y (EU)	5.64	1.27	28.9	1.54	9.35	0.60	35.6	2.43	12.3	2.40
π (N)	2.22	42.2	4.26	8.25	0.07	2.75	4.82	4.52	26.7	4.21
π (S)	0.10	4.95	2.44	3.95	3.97	40.1	6.46	9.71	20.7	7.62
π (EU)	1.10	22.5	3.30	5.97	2.14	22.6	5.69	7.27	23.5	6.02

The 'other' shocks of the North and the South combine the impact of the government spending shock and the risk premium shock; 'RoW combined' combines that of all the World shocks, including the monetary error.

4.2 The key impulse responses

Our results suggest that in the short run to medium run demand shocks are the main determinant of output, and in the medium to long run productivity shocks become increasingly dominant. Throughout the mark-up shocks are key to inflation. Both output and inflation are also strongly affected by the ECB policy shock. In order to gain a fuller understanding of the workings of the transmission mechanism we examine the key impulse responses.

Figure 1 shows the effect of demand shocks. The impulse responses may be interpreted as follows. A rise in North demand (blue) shifts the North IS curve out, which raises North output and causes North inflation to rise via the Phillips curve trade-off. North expansion leads to a positive output gap and inflation at the EU level, which make the ECB raise the policy rate via the Taylor rule, causing both North and South market interest rates to rise. Nevertheless, (with a relatively steep IS curve implying unresponsive output to the interest rate) South output falls only a little, as does South inflation. The EU output and inflation both rise, however, due to the dominating impact of North. A South shock (red) works similarly, but with its impact on South dominating. Domestic demand shocks cause a domestic depreciation.

Figure 1: The effect of a demand shock

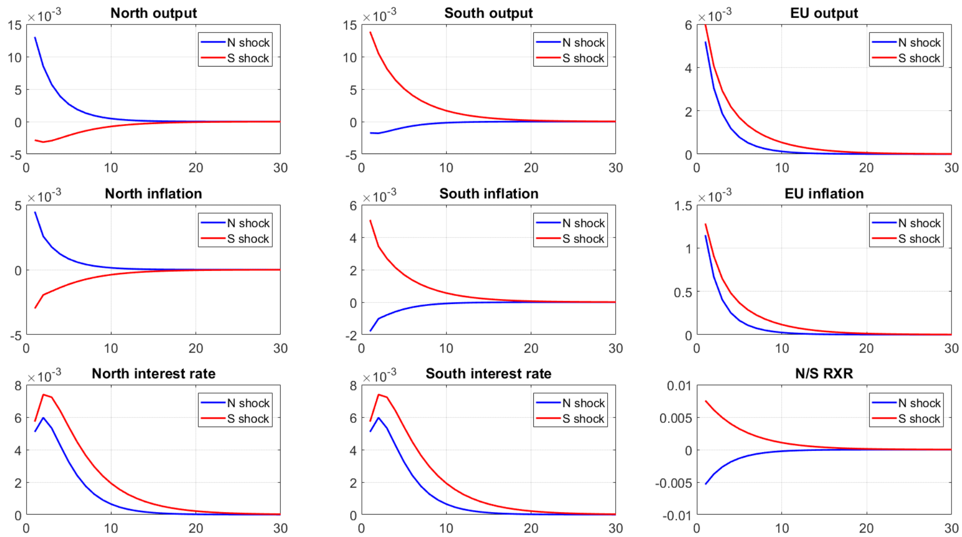
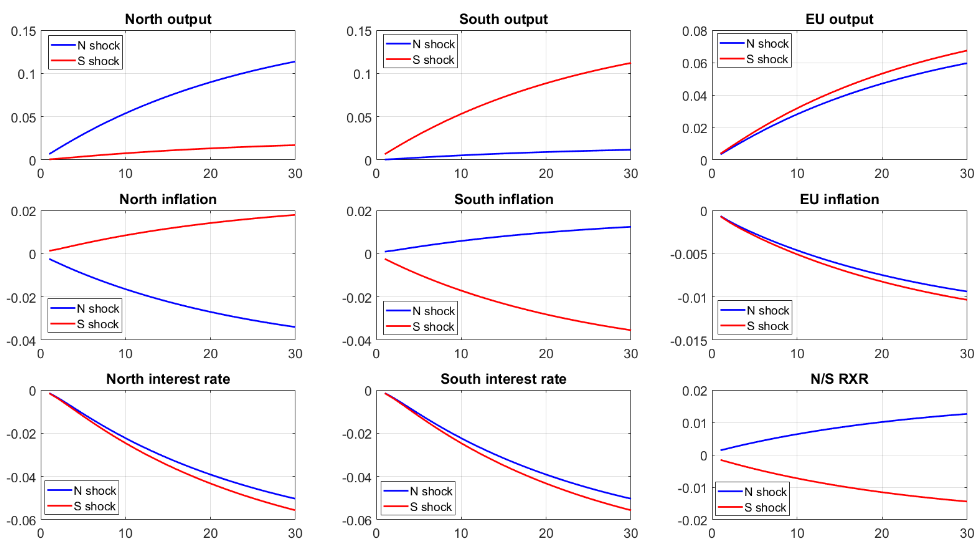


Figure 2: The effect of a productivity shock



The effect of productivity shocks is shown in Figure 2. A rise in North productivity promotes output and reduces inflation in the North in the usual way. South output rises slightly due to higher North imports, which then raises South inflation. At the EU level, output rises while, as the North impact dominates, inflation falls and leads to the ECB reducing interest rates causing market interest rates in both regions to fall. The responses to a South shock develop in a similar way[4]. Domestic productivity shocks cause a domestic depreciation.

[4] It is worth pointing that, because the productivity shock is permanent by assumption (Equation 3), its impact on the

Figure 3: The effect of a mark-up shock

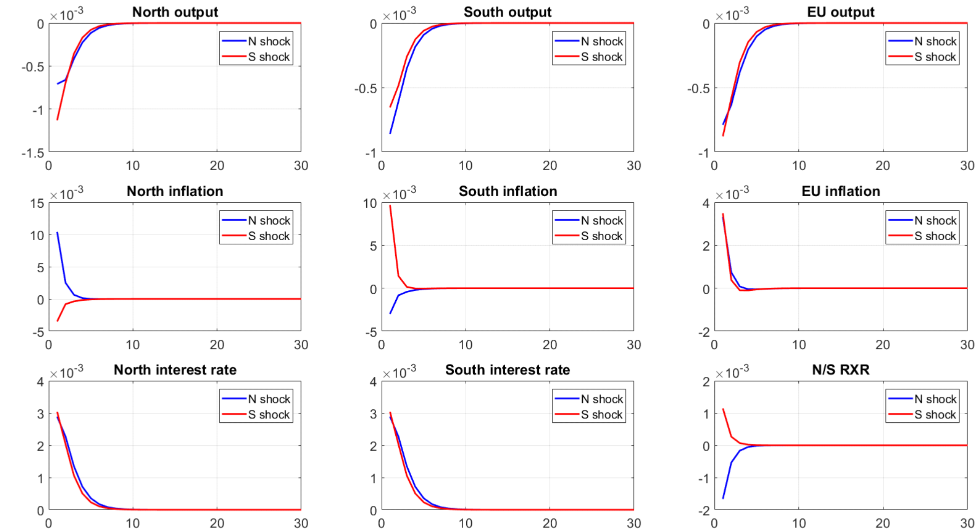
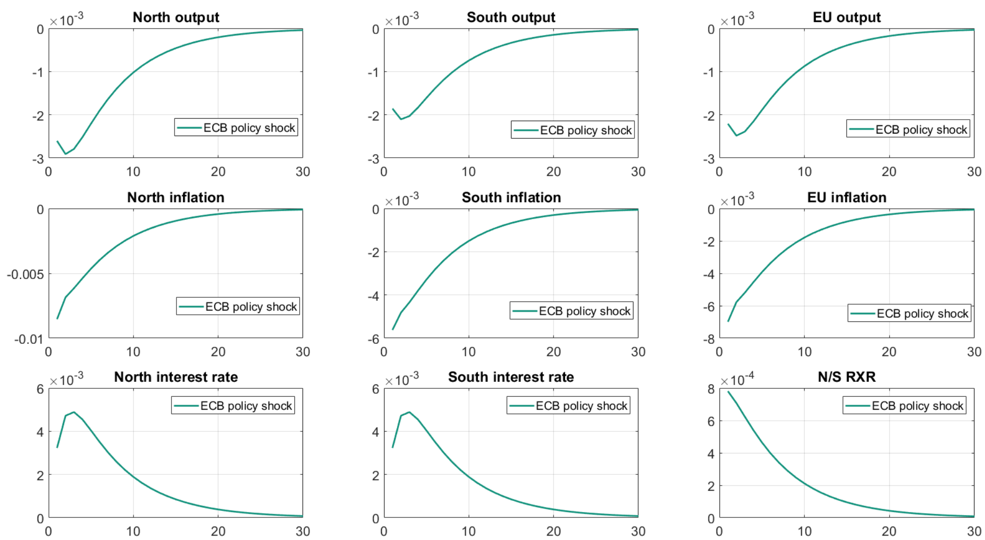


Figure 4: The effect of an ECB policy shock



The mark-up shock (Figure 3) embraces the effects on inflation of exogenous cost factors, including world commodity shocks and labour-market shocks. Again, the responses to a North and South shock are similar. Thus, a positive North shock shifts up the North Phillips curve, raising both regional and EU inflation rates. This causes the ECB to raise the policy rate and hence both North and South outputs to fall in response to higher market rates; the fall in South output also leads to a fall in its inflation. Since output falls in both regions, the Union output falls. EU inflation is the net outcome of the rise in inflation in the North and the fall in the South, in which the North inflation dominates. The effect of a South mark-up shock is analogous.

outputs are also permanent; however it only has a temporary (although still persistent) impact on the inflations, as it do not have a permanent impact on the output *gaps*.

Both regions are affected by ECB policy in the standard way (Figure 4): a tightened policy raises the market interest rate, which reduces demand, causing output and prices to fall. On this occasion we see that – while the interest rate responses are in the same direction in each region. As there is a bigger fall in North prices, North competitiveness rises as a result of a real depreciation.

4.3 Historical decomposition

We can attribute the movements in the main variables to the estimated shocks. The historic shocks are plotted in Figure 5. These are decomposed in Figures 6 (for output) and 7 (for inflation), respectively.

Figure 5: Historical shocks

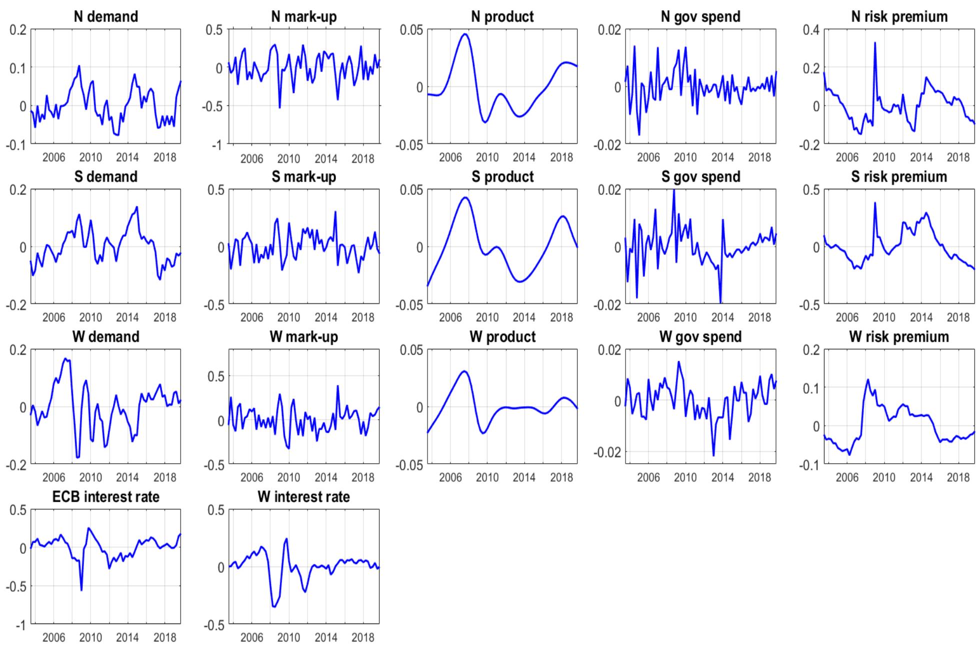
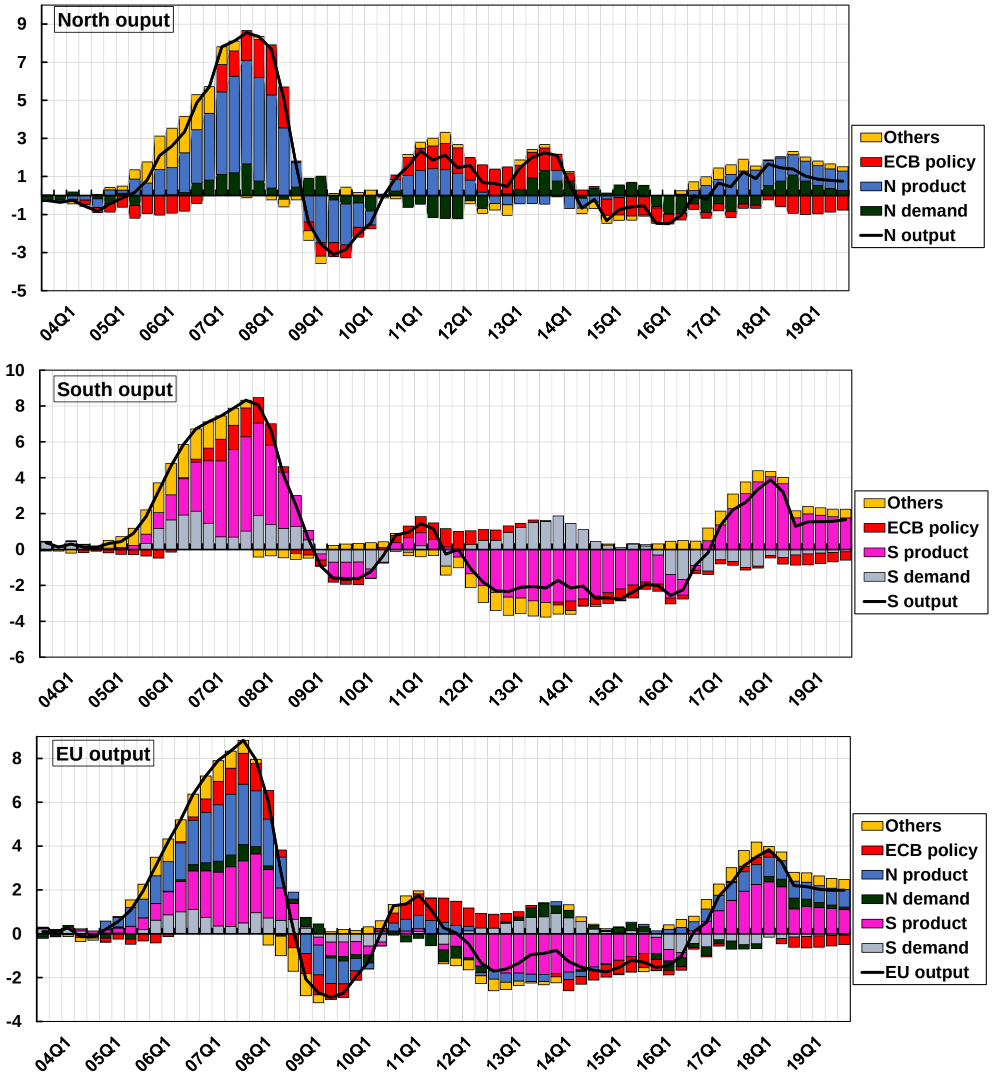


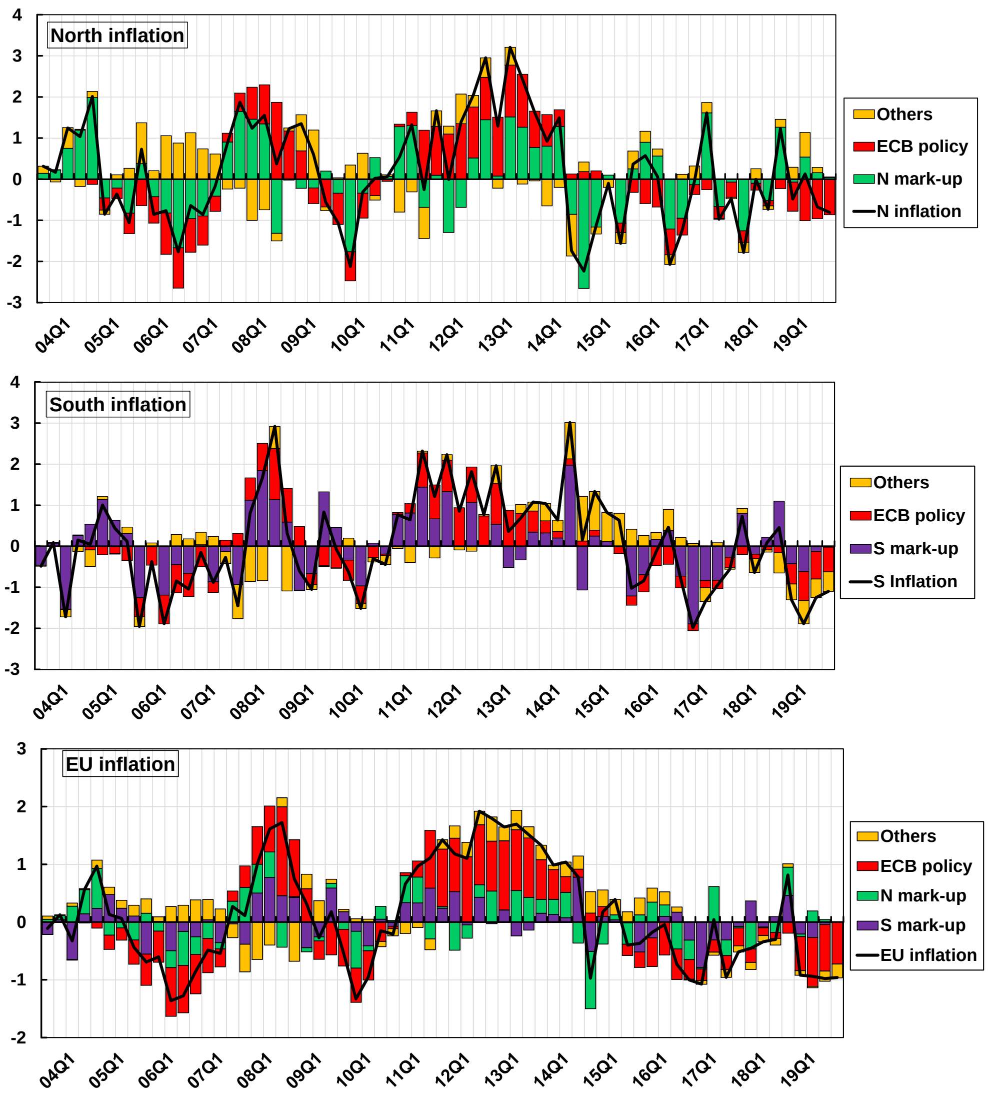
Figure 6 shows that the upswing of North output in the mid- to late- 2000s (before the spread of the global crisis) was a result of a boost of domestic productivity, supported by a modest rise of home demand partly stimulated by the ECB. The peak was reached in the end of 2007, when productivity ceased to rise, and then became negative in 2009 leading to the North recession (See also Figure 5 for the evolution of the shocks). The output then recovered with productivity, aided again by easier monetary environment, from 2010. It then fluctuated within a modest range around the steady-state level from 2014 onwards. There was little cross-border spillover, either from the South or from the World. South output was driven by the same set of 'south' factors and evolved in a similar manner. However with a prolonged episode of productivity wane (2009-16), the South recession (which was almost as deep as the North's) was much more persistent. The output only started to show a sign of recovery when productivity revived from 2017. EU aggregate output was about equally impacted by the two regions before 2009; but since then it had been mainly governed by the South, while the North had been much more stable.

Figure 6: Historical decomposition of output



Movements in inflation, Figure 7, mainly reflect the role of the mark-up shock and ECB policy. Thus, North inflation – which was clearly more volatile between 2006 and 2013 – was fundamentally driven by the domestic mark-up shock, with the ECB disturbances being an important destabiliser (especially during the crisis and post-crisis episodes). North inflation had been below the steady-state level since 2014, as negative mark-up shocks hit, but the ECB did not respond to these shocks actively (See also Figure 5). The South inflation evolved in a similar pattern, but was slightly less volatile and persistent. Like the North, it was dominated by the mark-up shock and the ECB error; but the ECB played a clearly smaller role. The EU inflation – being a weighted average of the two regions' – broadly shared the above features. Nevertheless, since the ECB affected both the regions in the same way, its policy error became the most impactful single factor in the EU perspective.

Figure 7: Historical decomposition of inflation



5 Can new policy regimes improve eurozone stability?

From the previous results it emerges clearly that there is a difficult stabilisation problem. This was originally highlighted in discussions of whether the eurozone was an optimal currency area. The regional demand (IS) shocks create virtually no output spillovers onto the other region; nor do the shocks to the potential output or other supply shocks (to the Phillips curve). The inflation spillovers are bigger but still modest. Hence these shocks have asymmetrical impacts regionally. On the other hand, monetary policy shocks have fairly symmetric effects on both regions. Also the main eurozone policy instrument, the ECB interest rate, responds to asymmetric shocks symmetrically, partly accounting for the asymmetric effects of shocks. For example, a demand expansion in the North will trigger higher EU interest rates, creating recession in the South and offsetting any positive spillover, while a demand contraction in the South will trigger only somewhat lower EU rates, barely counteracting the shock to South output, and setting off a small expansion in the

North – again reducing the spillover. As we show in Table 3, some of these shocks are positively correlated, others negatively correlated or not correlated at all, across the regions of the eurozone. From a cross-regional stability viewpoint, these shocks in total create a 'cocktail' whose effects are generally destabilising to the North, the South and the EU generally.

Table 3: Correlation matrix of the North/South shocks

	ε'_{IS}	ε'_{PP}	ε'_{yf}	ε'_{g}	ε''_{RP}	ε''_{IS}	ε''_{PP}	ε''_{yf}	ε''_{g}	ε''_{RP}
N demand	1									
N mark-up	0.27	1								
N product	0.06	-0.07	1							
N gov spend	0.29	-0.05	-0.03	1						
N risk prem	0.09	-0.18	-0.43	-0.03	1					
S demand	0.61	0.19	-0.22	0.18	0.11	1				
S mark-up	0.08	0.25	-0.28	0.04	-0.03	0.44	1			
S product	0.12	-0.12	0.88	0.07	-0.44	-0.14	-0.31	1		
S gov spend	0.21	0.04	0.19	0.16	-0.18	0.02	0.02	0.33	1	
S risk prem	0.02	-0.01	-0.67	-0.02	0.62	0.44	0.30	-0.75	-0.36	1

Given these findings of policy destabilisation, we examine the implications of the model for policy regimes that might stabilise the eurozone and its regions. We consider seven hypothetical regimes, each of which embodies a potential reform of either fiscal or monetary policy, or both, of the sort widely discussed in policy issues. These are:

Regime 1*) North government spending actively stabilises the EU output – Federal Union.*

Regime 2*) North government spending actively stabilises the South output – Transfer Union.*

Regime 3*) North government spending actively stabilises its own output – Stability and Growth Pact (SGP) abolished, Fiscally Active North.*

Regime 4*) South government spending actively stabilises its own output – SGP abolished, Fiscally Active South.*

Regime 5*) North/South government spending actively stabilises the North/South output respectively – SGP abolished, both regions fiscally active (Regimes 3 & 4 combined).*

Regime 6*) North/South operates independent monetary policy stabilising own output and inflation – Two-euro-zone with active independent ECBs.*

Regime 7*) North/South government spending actively stabilises own output, and North/South operates independent monetary policy stabilising own output and inflation (Regimes 5 & 6 combined) – Two-euro-zone, with both regions fiscally active.*

These regimes involve a degree of federalism, to be compared with the benchmark 'Base case' in which we assume fiscal policy is made inactive by the Stability and Growth Pact, with monetary policy conducted by the ECB as estimated in the model we recall that this Base Case resulted in destabilising policy. Thus Regime 1, 'Federal Union', assumes the North is dominant in an EU union, and uses its own budget actively to stabilise the union economy. Regime 2, 'Transfer Union', goes further and assumes the North engages in transfers to the South. In Regimes 3-5, there is no federalism, but the Pact is abolished and each region is left free to be fiscally active, which it pursues to stabilise its own regional economy; in regime 3 only North does so, in Regime 4 only South, and in Regime 5 both do so. In Regime 6, we allow the North and South each to have its own monetary policy, which in effect splits the ECB into two, and resurrects the idea of a 'Southern euro' (Arghyrou and Tsoukalas, 2010). Regime 7 combines this monetary independence with the general fiscal activism of regime 5.

We simulate the model by bootstrapping the complete set of historical shocks identified earlier in Figure 5[5]. For each regime we generate 1000 samples from which we calculate the average variance of the output gap and inflation, and average social welfare loss and household utility.

Table 4: Average variance of the output gap and inflation

	$Var(y-y^p)$			$Var(\pi)$		
	North	South	EU	North	South	EU
Base case	2.21	2.67	1.94	0.26	0.29	0.11
Regime 1	1.19	2.34	1.08	0.28	0.30	0.12
Regime 2	4.65	2.46	2.05	0.32	0.29	0.12
Regime 3	0.95	2.54	0.98	0.29	0.30	0.11
Regime 4	2.17	0.99	1.06	0.28	0.30	0.11
Regime 5	0.92	0.95	0.75	0.28	0.29	0.11
Regime 6	1.35	1.73	1.23	0.11	0.09	0.09
Regime 7	0.78	0.86	0.54	0.11	0.08	0.08

Table 4 shows that, among all the currently available – i.e., fiscal – regimes, letting both North and South target their own output with a strong response (Regime 5) would provide the maximum output stability both at the regional level and at the EU level. The variance of the EU output gap compared to that of the Base case would be cut by nearly two thirds, from 1.94% to 0.75%. Since the government budget constraint is imposed throughout[6], this would not be at the expense of solvency but it would clearly override the SGP, which is supposed to ensure solvency and zero transfers between regions. According to the model, such an agreement is both unnecessary and damaging because it undermines the fiscal authority's capacity. Letting North stabilise South output – a 'Transfer Union' (Regime 2) – turns out to be the worst choice for both the North and the whole eurozone, while it fails to provide much benefit to South. This is reassuring, as any transfer regime is unlikely to be politically feasible. The other choices (Regimes 1, 3, 4), which all represent active stabilisation by only one region, are less helpful for the whole eurozone and would just marginally benefit the other region.

Turning to monetary reform, the unbundling of policy into a two-euro zone with independent policies – hence, a floating regime (Regime 6) – brings some gains, especially to regional inflation; but it contributes

[5]Thus, Regime 1 replaces the benchmark North government spending equation with $g'_t = \rho'_g g'_{t-1} - GAP_t + \varepsilon'_{g,t}$; Regime 2 replaces the benchmark North government spending equation with $g'_t = \rho'_g g'_{t-1} - (y''_t - yf''_t) + \varepsilon'_{g,t}$; Regime 3 replaces the benchmark government spending equation with $g'_t = \rho'_g g'_{t-1} - (y'_t - yf'_t) + \varepsilon'_{g,t}$; Regime 4 replaces the benchmark South government spending equation with $g''_t = \rho''_g g''_{t-1} - (y''_t - yf''_t) + \varepsilon''_{g,t}$; Regime 6 replaces the ECB Taylor rule with $R^{NCB}_t = \rho R^{NCB}_{t-1} + (1-\rho)[\bar{r} + \phi_\pi \pi'_t + \phi_y(y'_t - yf'_t)] + \varepsilon^{ECB}_{R,t}$ and $R^{SCB}_t = \rho R^{SCB}_{t-1} + (1-\rho)[\bar{r} + \phi_\pi \pi''_t + \phi_y(y''_t - yf''_t)] + \varepsilon^{ECB}_{R,t}$, and sets $R'_t = R^{NCB}_t + \varepsilon'_{RP,t}$, $R''_t = R^{SCB}_t + \varepsilon''_{RP,t}$, and $\phi_\pi = 2.23$, $\phi_y = 0.42$, $\rho = 0.59$ as estimated with the benchmark model.

[6]We do so by imposing, in all these simulations, that, on the terminal date, there is a fiscal shock that is equal to the negative of the previously accumulated fiscal shock times the domestic interest rate.

less extra stability to output than most fiscal regimes. Not surprisingly, if we allow for full independence of both fiscal and monetary policies under regional floating (Regime 7), it promotes the greatest stability of both output and inflation across the continent.

Table 5: Average social welfare loss

$SWL = \frac{1}{2}[\pi^2 + \varpi(y - y^p)^2]$							
$\varpi = 0$	North	South	EU	$\varpi = 0.1$	North	South	EU
Base case	0.13	0.15	0.05	Base case	0.24	0.28	0.15
Regime 1	0.14	0.15	0.06	Regime 1	0.20	0.27	0.11
Regime 2	0.17	0.15	0.06	Regime 2	0.40	0.27	0.16
Regime 3	0.14	0.15	0.06	Regime 3	0.19	0.27	0.11
Regime 4	0.14	0.15	0.05	Regime 4	0.25	0.20	0.11
Regime 5	0.14	0.15	0.05	Regime 5	0.19	0.19	0.09
Regime 6	0.06	0.04	0.04	Regime 6	0.12	0.13	0.10
Regime 7	0.06	0.04	0.04	Regime 7	0.10	0.09	0.07
$\varpi = 0.3$	North	South	EU	$\varpi = 0.5$	North	South	EU
Base case	0.46	0.55	0.34	Base case	0.69	0.81	0.54
Regime 1	0.32	0.50	0.22	Regime 1	0.44	0.74	0.33
Regime 2	0.86	0.51	0.37	Regime 2	1.33	0.76	0.57
Regime 3	0.29	0.53	0.22	Regime 3	0.38	0.78	0.33
Regime 4	0.46	0.30	0.22	Regime 4	0.68	0.40	0.32
Regime 5	0.28	0.29	0.16	Regime 5	0.37	0.39	0.24
Regime 6	0.26	0.30	0.23	Regime 6	0.40	0.48	0.35
Regime 7	0.17	0.17	0.12	Regime 7	0.25	0.26	0.17

Table 6: Average change in equivalent consumption

	North	South	EU
Base case	–	–	–
Regime 1	25.5%	13.2%	15.6%
Regime 2	-1758%	5.61%	-331%
Regime 3	33.3%	-2.17%	4.61%
Regime 4	-5.28%	37.7%	29.5%
Regime 5	35.1%	34.9%	34.9%
Regime 6	21.9%	23.4%	23.1%
Regime 7	49.9%	44.6%	45.6%

The social welfare losses we calculate with various output-inflation weightings (Table 5) confirm that Regime 7 is optimal, but letting each region react flexibly to its own situation with active fiscal responses remains the best choice within the constraint of the existing euro. This ranking is robust if we consider the impact on equivalent household consumption (calculated as household utility change over the effect of a 1% change in permanent consumption): according Table 6, Regime 7 would increase welfare by an equivalent consumption gain in each region of 45-50%, while Regime 5 would give a gain of some 35% – both of which are clearly welfare-superior to the current regime, as well as the other choices.

6 Conclusion

In this paper we have constructed a macro DSGE model of the eurozone and its two main regions, the North and the South, with the aim of fitting the macro facts of these economies and using the resulting empirically-based model to assess possible new policy regimes. The model that we have found to fit the facts finds that there are few spillovers between North and South other than those created by ECB policy. We also found that South demand shocks have double the effect on EU output than North demand shocks. This suggests that Monetary Union provides little or no benefit; in fact, we find it is in the main a source of destabilisation. In contrast, we found that with the restoration of both fiscal and monetary independence to the two regions, in effect creating a second 'southern euro' bloc, there would be substantial gains in macro stability, of both output and inflation, and consequently in consumer welfare. If this is ruled out on political grounds, substantial gains in output stability both at the regional and at the EU levels, with no loss of inflation stability, are still possible if the fiscal authority in each region is given the freedom to respond to its own economic situation.

In the context of the current European policy debate, our work suggests that merely freeing regional economies to pursue fiscal activism subject to their own budget constraints would greatly improve stability and welfare in the eurozone. This merely involves abolishing the Stability and Growth Pact, while avoiding cross-region transfers, so retaining hard public budget constraints at the country level. There is no requirement for federalism in this agenda, contrary to some suggestions that 'more Europe' is needed to create stability in the eurozone. Nor is there any need for the Pact to avoid transfers, as such transfers will not willingly be made even without the Pact. These findings seem highly relevant therefore to EU policy-makers, who, like those in other developed economies, have plainly warmed to fiscal activism during the Covid pandemic.

Not surprisingly we also find that splitting the euro in two and allowing more regional monetary autonomy can add to stability and welfare. This conclusion is not relevant under the current constraints of the eurozone. But in conditions of another major euro-crisis interest in it could resurface.

Overall, the empirical work in this paper suggests that the eurozone can find practical ways to control future macroeconomic shocks and crises.

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Appendix

A Listing of Model

- North EU ($\prime$)

IS curve:

$$\begin{aligned} y'_t \;=\;& E_t y'_{t+1} - \frac{C'}{Y'}\frac{1}{\sigma'}\Theta'(R'_t - E_t\pi'_{t+1} - \bar{r}') - \frac{X'}{Y'}z'_1\Theta' E_t\Delta y''_{t+1} - \frac{X'}{Y'}z'_2\Theta' E_t\Delta y^*_{t+1} \\ &+\frac{X'}{Y'}z'_3\Theta' E_t\Delta q_{ns,t+1} - \frac{X'}{Y'}z'_4\Theta' E_t\Delta rxr'_{t+1} - \frac{G'}{Y'}\Theta' E_t\Delta g'_{t+1} + \varepsilon'_{IS,t} \end{aligned} \tag{A.1}$$

Phillips curve:

$$\begin{aligned} \pi'_t \;=\;& -\lambda'_{nw}\left(\beta' E_t\Delta rxr'_{t+1} - \Delta rxr'_t\right) + \lambda'_{ns}\left(\beta'\Delta q_{ns,t+1} - \Delta q_{ns,t}\right) \\ &-\lambda'_{sw}\left(\beta' E_t\Delta rxr''_{t+1} - \Delta rxr''_t\right) + \beta' E_t\pi'_{t+1} + \kappa'_a(y'_t - yf'_t) + \varepsilon'_{PP,t} \end{aligned} \tag{A.2}$$

Productivity:

$$yf'_t - yf'_{t-1} = \Gamma' + \delta'(yf'_{t-1} - yf'_{t-2}) + \varepsilon'_{yf,t} \tag{A.3}$$

Imports from South EU:

$$im'_{s,t} = \mu'_s y'_t + \psi'_s q_{ns,t} \tag{A.4}$$

Imports from RoW:

$$im'_{w,t} = \mu'_w y'_t - \psi'_w rxr'_t \tag{A.5}$$

Balance of payments:

$$\begin{aligned} \frac{BF'}{Y'}bf'_t \;=\;& \frac{BF'}{Y'}(\tilde{R}_{t-1} - E_{t-1}\pi^*_t - \bar{r}^*) + (1+\bar{r}^*)\frac{BF'}{Y'}bf'_{t-1} \\ &+\frac{1}{RxR'}\frac{IM''_n}{Y'}\left(im''_{n,t} - rxr'_t\right) + \frac{1}{RxR'}\frac{IM^*_n}{Y'}\left(im^*_{n,t} - rxr'_t\right) \\ &-\frac{IM'_s}{Y'}im'_{s,t} - \frac{IM'_w}{Y'}im'_{w,t} \end{aligned} \tag{A.6}$$

Risk premium:

$$R'_t = R^{ECB}_t + \varepsilon'_{RP,t} \tag{A.7}$$

Fiscal policy:

$$g'_t = \rho'_g g'_{t-1} + \varepsilon'_{g,t} \tag{A.8}$$

- South EU (″)

IS curve:

$$\begin{aligned} y''_t \quad = \quad & E_t y''_{t+1} - \frac{C''}{Y''}\frac{1}{\sigma''}\Theta''(R''_t - E_t\pi''_{t+1} - \bar{r}'') - \frac{X''}{Y''}z''_1\Theta'' E_t\Delta y'_{t+1} - \frac{X''}{Y''}z''_2\Theta'' E_t\Delta y^*_{t+1} \\ & -\frac{X''}{Y''}z''_3\Theta'' E_t\Delta q_{ns,t+1} - \frac{X''}{Y''}z''_4\Theta'' E_t\Delta rxr''_{t+1} - \frac{G''}{Y''}\Theta'' E_t\Delta g''_{t+1} + \varepsilon''_{IS,t} \end{aligned} \tag{A.9}$$

Phillips curve:

$$\begin{aligned} \pi''_t \quad = \quad & -\lambda''_{ns}\left(\beta''\Delta q_{ns,t+1} - \Delta q_{ns,t}\right) - \lambda''_{sw}\left(\beta'' E_t\Delta rxr''_{t+1} - \Delta rxr''_t\right) \\ & +\lambda''_{nw}\left(\beta'' E_t\Delta rxr'_{t+1} - \Delta rxr'_t\right) + \beta'' E_t\pi''_{t+1} + \kappa''_a(y''_t - yf''_t) + \varepsilon''_{PP,t} \end{aligned} \tag{A.10}$$

Productivity:

$$yf''_t - yf''_{t-1} = \Gamma'' + \delta''(yf''_{t-1} - yf''_{t-2}) + \varepsilon''_{yf,t} \tag{A.11}$$

Imports from North EU:

$$im''_{n,t} = \mu''_n y''_t - \psi''_n q_{ns,t} \tag{A.12}$$

Imports from RoW:

$$im''_{w,t} = \mu''_w y''_t - \psi''_w rxr''_t \tag{A.13}$$

Balance of payments:

$$\begin{aligned} \frac{BF''}{Y''}bf''_t \quad = \quad & \frac{BF''}{Y''}(\tilde{R}_{t-1} - E_{t-1}\pi^*_t - \bar{r}^*) + (1+\bar{r}^*)\frac{BF''}{Y''}bf''_{t-1} \\ & +\frac{1}{RxR''}\frac{IM'_s}{Y''}\left(im'_{s,t} - rxr''_t\right) + \frac{1}{RxR''}\frac{IM^*_s}{Y''}\left(im^*_{s,t} - rxr''_t\right) \\ & -\frac{IM''_n}{Y''}im''_{n,t} - \frac{IM''_w}{Y''}im''_{w,t} \end{aligned} \tag{A.14}$$

Risk premium:

$$R''_t = R^{ECB}_t + \varepsilon''_{RP,t} \tag{A.15}$$

Fiscal policy:

$$g''_t = \rho''_g g''_{t-1} + \varepsilon''_{g,t} \tag{A.16}$$

ECB Taylor rule:

$$R_t^{ECB} = \rho R_{t-1}^{ECB} + (1-\rho)(\bar{r} + \phi_\pi \Pi_t + \phi_y GAP_t) + \varepsilon_{R,t}^{ECB} \tag{A.17}$$

Average EU inflation:

$$\Pi_t = \frac{\exp(y_t')}{\exp(y_t') + \exp(y_t'')}\pi_t' + \frac{\exp(y_t'')}{\exp(y_t') + \exp(y_t'')}\pi_t'' \tag{A.18}$$

Average EU output gap:

$$GAP_t = \frac{\exp(y_t')}{\exp(y_t') + \exp(y_t'')}\left(y_t' - yf_t'\right) + \frac{\exp(y_t'')}{\exp(y_t'') + \exp(y_t'')}\left(y_t'' - yf_t''\right) \tag{A.19}$$

- RoW ($*$)

IS curve:

$$\begin{aligned} y_t^* \quad = \quad & E_t y_{t+1}^* - \frac{C^*}{Y^*}\frac{1}{\sigma^*}\Theta^*(\tilde{R}_t - E_t\pi_{t+1}^* - \bar{r}^*) - \frac{X^*}{Y^*}z_1^*\Theta^* E_t\Delta y_{t+1}' - \frac{X^*}{Y^*}z_2^*\Theta^* E_t\Delta y_{t+1}'' \\ & + \frac{X^*}{Y^*}z_3^*\Theta^* E_t\Delta rxr_{t+1}' + \frac{X^*}{Y^*}z_4^*\Theta^* E_t\Delta rxr_{t+1}'' - \frac{G^*}{Y^*}\Theta^* E_t\Delta g_{t+1}^* + \varepsilon_{IS,t}^* \end{aligned} \tag{A.20}$$

Phillips curve:

$$\begin{aligned} \pi_t^* \quad = \quad & \lambda_{nw}^*\left(\beta^* E_t\Delta rxr_{t+1}' - \Delta rxr_t'\right) + \lambda_{sw}^*\left(\beta^* E_t\Delta rxr_{t+1}'' - \Delta rxr_t''\right) \\ & + \lambda_{ns}^*\left(\beta^*\Delta q_{ns,t+1} - \Delta q_{ns,t}\right) + \beta^* E_t\pi_{t+1}^* + \kappa_a^*(y_t^* - yf_t^*) + \varepsilon_{PP,t}^* \end{aligned} \tag{A.21}$$

Productivity:

$$yf_t^* - yf_{t-1}^* = \Gamma^* + \delta^*(yf_{t-1}^* - yf_{t-2}^*) + \varepsilon_{yf,t}^* \tag{A.22}$$

Taylor rule:

$$R_t^* = \rho^* R_{t-1}^* + (1-\rho^*)[\bar{r}^* + \phi_\pi^*\pi_t^* + \phi_y^*(y_t^* - yf_t^*)] + \varepsilon_{R,t}^* \tag{A.23}$$

Imports from North EU:

$$im_{n,t}^* = \mu_n^* y_t^* + \psi_n^* rxr_t' \tag{A.24}$$

Imports from South EU:

$$im_{s,t}^* = \mu_s^* y_t^* + \psi_s^* rxr_t'' \tag{A.25}$$

Risk premium:

$$\tilde{R}_t = R_t^* + \varepsilon_{RP,t}^* \tag{A.26}$$

Fiscal policy:

$$g_t^* = \rho_g^* g_{t-1}^* + \varepsilon_{g,t}^* \tag{A.27}$$

- Real exchange rate determination:
  - North UIP against RoW:

$$rxr_t' - E_t rxr_{t+1}' = \tilde{R}_t - R_t' - (E_t \pi_{t+1}^* - E_t \pi_{t+1}') \tag{A.28}$$

- – South UIP against RoW:

$$rxr_t'' - E_t rxr_{t+1}'' = \tilde{R}_t - R_t'' - (E_t \pi_{t+1}^* - E_t \pi_{t+1}'') \tag{A.29}$$

- – North-South bilateral exchange rate:

$$rxr_t' - rxr_t'' = -q_{ns,t} \tag{A.30}$$

- Shock processes: for $i = \prime, \prime\prime$, or $*$, $\varepsilon_{IS,t}^i$, $\varepsilon_{PP,t}^i$, $\varepsilon_{RP,t}^i$, $\varepsilon_{R,t}^{ECB}$ and $\varepsilon_{R,t}^*$ follow an AR(1) process; $\varepsilon_{yf,t}^i$ and $\varepsilon_{g,t}^i$ are iid.
- Terminal conditions: for $i = \prime, \prime\prime$, or $*$, $\pi_T^i = R_T^i - \bar{r}^i$, $y_T^i = yf_T^i$, $bf_T^i = bf_{T-1}^i$ and $g_T^i = g_{T-1}^i$ on the terminal date T.
- Note on the combined parameters:
  - $z_1' = \frac{M_s'}{Y'}\mu_n''$, $z_2' = \frac{M_w'}{Y'}\mu_n^*$, $z_3' = \frac{M_s'}{Y'}\psi_n'' + \frac{N_s'}{Y'}\psi_s'$, $z_4' = \frac{M_w'}{Y'}\psi_n^* + \frac{N_w'}{Y'}\psi_w'$, $\Theta' = [1 + \frac{X'}{Y'}(\frac{N_s'}{Y'}\mu_s' + \frac{N_w'}{Y'}\mu_w')]^{-1}$;
  - $z_1'' = \frac{M_n''}{Y''}\mu_s'$, $z_2'' = \frac{M_w''}{Y''}\mu_s^*$, $z_3'' = \frac{M_n''}{Y''}\psi_s' + \frac{N_n''}{Y''}\psi_n''$, $z_4'' = \frac{M_w''}{Y''}\psi_s^* + \frac{N_w''}{Y''}\psi_w''$, $\Theta'' = [1 + \frac{X''}{Y''}(\frac{N_n''}{Y''}\mu_n'' + \frac{N_w''}{Y''}\mu_w'')]^{-1}$;
  - $z_1^* = \frac{M_n^*}{Y^*}\mu_w'$, $z_2^* = \frac{M_s^*}{Y^*}\mu_w''$, $z_3^* = \frac{M_n^*}{Y^*}\psi_w' + \frac{N_n^*}{Y^*}\psi_n^*$, $z_4^* = \frac{M_s^*}{Y^*}\psi_w'' + \frac{N_s^*}{Y^*}\psi_s^*$, $\Theta^* = [1 + \frac{X^*}{Y^*}(\frac{N_n^*}{Y^*}\mu_n^* + \frac{N_s^*}{Y^*}\mu_s^*)]^{-1}$;
  - $\frac{C}{Y}$'s, $\frac{G}{Y}$'s, $\frac{M}{Y}$'s, $\frac{N}{Y}$'s, $\frac{X}{Y}$'s are the steady-state ratios of consumption, government spending, exports, imports and net exports relative to output.

B Measurement, sources and adjustments of the raw data

The data are observed between 2003Q1 and 2019Q4. The observable variables are output, productivity, inflation, market and policy interest rates, and government spending, of the three economies, and the North and South effective exchange rates. The North consists of Austria, Belgium, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, Luxembourg, Netherlands and Slovakia. The South consists of France, Greece, Italy, Portugal, Spain and Slovenia. The rest of the world consists of China, India, Japan, Norway, Russia, South Korea, Switzerland, Turkey, UK and US. The data are sourced from Euro-area-statistics, FRED, the IMF and the OECD.

Output, productivity and government spending are normalised by CPI and the working-age population; inflation is defined as the quarter-on-quarter growth of CPI; market and policy interest rates are quoted as the quarterly rate; effective exchange rates are adjusted by inflation. All time series, where applicable, are seasonally adjusted. The time series collected, their sources, and the relevant adjustments are summarised in Table B.1.

Table B.1: Measurement, sources & adjustments of the raw data

Observable variables	Time series collected	Source[a]	Divided by CPI?	Divided by pop.?	Seasonally adjusted ?
Output	GDP	OECD	$\surd$	$\surd$	$\surd$
Productivity	HP trend of GDP	–	$\surd$	$\surd$	$\surd$
Government spending	Government spending	OECD	$\surd$	$\surd$	$\surd$
Inflation	CPI (Quarter-on-quarter growth)	OECD	N.A.	N.A.	$\surd$
Market interest rate	Prime lending rate	EAS, IMF	N.A.	N.A.	N.A.
Policy interest rate	Discount rate	IMF	N.A.	N.A.	N.A.
Effective exchange rate	Broad EER for the EU area	FRED	N.A.	N.A.	$\surd$

a: EAS (Euro-area-statistics) ; FRED (Federal Reserve Economic Data); IMF (International Monetary Fund); OECD (Organisation for Economic Co-operation and Development).