Journal of Financial Stability 63 (2022) 101064

Contents lists available at ScienceDirect

Journal of Financial Stability

journal homepage: www.elsevier.com/locate/jfstabil

The eurozone: What is to be done to maintain macro and financial stability?☆

Patrick Minford [a], Zhirong Ou [b,*], Michael Wickens [c], Zheyi Zhu [d]

[a] Cardiff University and CEPR
[b] Cardiff University
[c] Cardiff University, University of York, CEPR and CESifo
[d] Cardiff Metropolitan University

ARTICLE INFO

JEL classification:
E32
E52
E62
F41

Keywords:
Eurozone
Macro stability
Fiscal policy
Monetary independence

ABSTRACT

The financial stability of the eurozone depends on its macroeconomic stability and vice versa. 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 that could maintain financial stability. The model we have found to fit the facts suggests that substantial gains in 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. Enhanced fiscal flexibility increases fluctuations in debt and deficit ratios to GDP while keeping average ratios stable, maintaining solvency. A reformed Stability and Growth Pact could be limited to monitoring solvency.

1. Introduction

The financial stability of the eurozone depends on its macroeconomic stability and vice versa. In this paper we develop a model of the eurozone and use it to examine possible policy rules that could assist it in achieving macroeconomic and financial stability across its wide geographic membership. We interpret the threats to this stability as coming from the asymmetric regional effects of shocks across the eurozone, notably in the South. The threats are twofold. First, when the South is forced into a bad recession such as in the global financial crisis, fears are created that a Southern country might be forced out of the euro; these fears trigger concerns in financial markets for the future of the zone and the ECB, and so for the government debts of countries in the zone, which the ECB has supported through its balance sheet. Secondly, the banks in Southern countries come under pressure, as credit demands and bankruptcies rise sharply; as these banks hold large amounts of their governments' debts, these pressures in turn provoke fears in financial markets over these government debts and in turn over the banks' soundness - in a 'doom loop'. Our work here focuses on how, in the model we estimate, policy regimes can be put in place to minimise these threats. We also note that these threats already provoked countering responses in the zone, one economic in the ECB's decision enunciated by Mr. Draghi to do 'whatever it takes' to preserve the euro from such threats, and secondly political in the emergence of domestic campaigns against the euro – exit for fear of its leading to EU exit – as illustrated by the Greek government's decision not to follow up on its threatened departure. These countermeasures were effective in stopping these threats from forcing up risk-premia unsustainably. However, we search in this paper for fiscal and monetary mechanisms that can stop them developing at all. In it we will treat financial instability and instability of output and inflation ('macro' instability) as closely connected. In our model shocks impact directly on the economy – notably GDP and inflation, and on financial variables such as real interest rates and real exchange rates, before triggering indirect effects through the model's channels in both directions; thus real interest fluctuations affect demand, while GDP and inflation affect real interest rates and real exchange rates. The model is considerably simpler than the complex reality sketched out above. But we find that it does well in matching the behaviour of the data, and so should give us a good guide to the effects of different policy regimes on economic stability. We focus in particular on

☆ We are grateful to the editor and referees for their insightful comments which have helped improve the paper substantially. Any remaining errors will be ours.
* Correspondence to: Aberconway building, Colum Drive, Cardiff CF10 3EU, UK.
E-mail address: ouz@cardiff.ac.uk (Z. Ou).

https://doi.org/10.1016/j.jfs.2022.101064

Available online 9 August 2022

monetary and fiscal policy in this paper; micro policy on regulation and prudential intervention is outside the scope of our work here.

To understand the tensions within the eurozone, we use the device of a three country New Keynesian open economy 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. In what follows we discuss the recent history of the eurozone as viewed through the lens of this model, as an introduction to the formal empirical analysis of this history that we will lay out in the rest of the paper.

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 Uncovered Interest Parity (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 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 Quantitative Easing (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 spasmodic talks of 'state-building' were to bear fruit, they could become a precedent for further 'EU state' actions in the same vein. Such talks are, 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 (SGP), 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 eurozone'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, recovery from the Covid pandemic is threatened by further headwinds from the new waves of Covid. 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 its economy.

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, as an illustration, we allow a Northern euro to float 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 market lending rate (the Other Depository Corporations rate reported by the IMF, which never hit the ZLB) as the target variable for monetary policy, whether executed by a Taylor Rule or by QE. Thus the ECB uses variations in its holdings of short term loans (via Repos) and long term debt (via QE) to influence both short and long term lending rates in the market.

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/financial stability (and consequently welfare) – both region- 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/financial 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 stability of the euro area. As stability has been weak in recent decades, this remains an important policy issue. To anticipate our policy findings, we suggest that much more active national fiscal policy, carried out under the normal disciplines of the intertemporal government budget constraint, with the SGP suspended in favour of some centralised solvency monitoring scheme, would massively reduce the instability in the eurozone.

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.[1] 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 the appendix) 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). 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), which 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 spending is financed by domestic bonds and tax revenue, which we model explicitly.

To save space we present only the country model here for the North EU, treating it 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, are assumed to follow independent AR(1) processes.[2] The full model, which is complemented by the counterpart equations of the South EU and the rest of the world, is listed in full in the appendix.

North IS curve:

$$\begin{aligned} y_t^{'} = \; & E_t y_{t+1}^{'} - \frac{C^{'}}{Y^{'}}\frac{1}{\sigma^{'}}\Theta^{'}\left(R_t^{'} - E_t\pi_{t+1}^{'} - \overline{r}^{'}\right) - \frac{X^{'}}{Y^{'}}z_1^{'}\Theta^{'}E_t\Delta y_{t+1}^{''} \\ & -\frac{X^{'}}{Y^{'}}z_2^{'}\Theta^{'}E_t\Delta y_{t+1}^{*} + \frac{X^{'}}{Y^{'}}z_3^{'}\Theta^{'}E_t\Delta q_{ns,t+1} - \frac{X^{'}}{Y^{'}}z_4^{'}\Theta^{'}E_t\Delta rxr_{t+1}^{'} \\ & -\frac{G^{'}}{Y^{'}}\Theta^{'}E_t\Delta g_{t+1}^{'} + \varepsilon_{IS,t}^{'} \end{aligned} \tag{1}$$

where $y_t^{'}, y_t^{''}$, and y_t^{*} are the North, South and World outputs, $R_t^{'} - E_t\pi_{t+1}^{'}$ is the real interest rate (the steady-state value being $\overline{r}^{'}$), $q_{ns,t}$ is the North-South real exchange rate (an increase is a North currency appreciation), $rxr_t^{'}$ is the North real effective exchange rate (an increase is a North depreciation against the World), $g_t^{'}$ 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. $\Theta^{'}, z_1^{'}, z_2^{'}, z_3^{'}$ and $z_4^{'}$ are combinations of the structural parameters (detailed in Appendix A). $\sigma^{'}$ is the inverse of the price elasticity of consumption. $\varepsilon_{IS,t}^{'}$ is the demand shock.

North Phillips curve:

$$\begin{aligned} \pi_t^{'} = \; & -\lambda_{nw}^{'}\left(\beta^{'}E_t\Delta rxr_{t+1}^{'} - \Delta rxr_t^{'}\right) + \lambda_{ns}^{'}\left(\beta^{'}\Delta q_{ns,t+1} - \Delta q_{ns,t}\right) \\ & -\lambda_{sw}^{'}\left(\beta^{'}E_t\Delta rxr_{t+1}^{''} - \Delta rxr_t^{''}\right) + \beta^{'}E_t\pi_{t+1}^{'} + \kappa_a^{'}\left(y_t^{'} - yf_t^{'}\right) + \varepsilon_{PP,t}^{'} \end{aligned} \tag{2}$$

where $\pi_t^{'}$ is CPI inflation, $y_t^{'} - yf_t^{'}$ is the output gap, $rxr_t^{''}$ is the South real effective exchange rate (where an increase in $rxr_t^{''}$ is a South depreciation). β is the discount rate, $\kappa_a^{'}$ is a combination of the structural pa-

[1] We put France in the Southern group. While geographically part of France is in the North, with a border on the North Sea, in most other respects it resembles a southern EU country. It has a large immigrant community from its ex-colonies in North Africa; but in terms of economic behaviour a key factor is its distorted labour market due to a high minimum wage combined with its large unskilled immigrant population, which gives it a high natural rate of unemployment in common with the majority of Southern countries. On policy matters it accordingly aligns itself on the side of more transfers and a weaker SGP; its debt ratio has been more similar to that of the Southern countries, especially since the financial crisis; and it has been one of the strongest advocates of greater centralisation and 'more Europe'.

[2] See Eqs. (3) and (12).

rameters including the Calvo probability of price rigidity, $\lambda_{nw}^{'}, \lambda_{ns}^{'}$ and $\lambda_{sw}^{'}$ are functions of the openness of each economy pair. $\varepsilon_{PP,t}^{'}$ is the mark-up shock, which is a supply shock.

North productivity:

$$yf_t^{'} - yf_{t-1}^{'} = \Gamma^{'} + \delta^{'}\left(yf_{t-1}^{'} - yf_{t-2}^{'}\right) - \varpi^{'}\left(\tau_t^{'} - \tau_{t-1}^{'}\right) + \varepsilon_{yf,t}^{'} \tag{3}$$

where $yf_t^{'}$ is assumed to follow a random walk process with drift, $\Gamma^{'}$, and reflects the permanent impact of the productivity shock, $\varepsilon_{yf,t}^{'}.\delta^{'}$ is the mean-reverting parameter. $\varpi^{'}$ is the impact of the average tax rate (modelled in Eq. 15 below) on productivity.

North imports from South and World are functions of the North income and the North-South or North 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 effective real exchange rates are determined by UIP, where both the North and South rates adjust to ensure that the expected real returns on investment in the domestic and world markets are equal:

$$rxr_t^{'} - E_t rxr_{t+1}^{'} = R_t^{*} - R_t^{'} - \left(E_t\pi_{t+1}^{*} - E_t\pi_{t+1}^{'}\right) \tag{6}$$

$$rxr_t^{''} - E_t rxr_{t+1}^{''} = R_t^{*} - R_t^{''} - \left(E_t\pi_{t+1}^{*} - E_t\pi_{t+1}^{''}\right) \tag{7}$$

where R_t^{*} is the World nominal interest rate, π_t^{*} is World inflation. The North-South bilateral exchange rate is solved as the (log) difference between the North and South effective rates:

$$rxr_t^{'} - rxr_t^{''} = -q_{ns,t} \tag{8}$$

North balance of payments requires the outflow of North money to be equal to the inflow of foreign money (in North currency terms), $BF_t^{'} + IM_{s,t}^{'} + IM_{w,t}^{'} - \left(1 + R_{t-1}^{*} - E_{t-1}\pi_t^{*}\right)BF_{t-1}^{'} = .$ $\left(IM_{n,t}^{''} + IM_{n,t}^{*}\right)/RxR_t^{'}$, which can be log-linearised to be:

$$\begin{aligned}\frac{BF^{'}}{Y^{'}}bf_t^{'} = {} & \frac{BF^{'}}{Y^{'}}\left(R_{t-1}^{*} - E_{t-1}\pi_t^{*} - \bar{r}^{*}\right) + \left(1 + \bar{r}^{*}\right)\frac{BF^{'}}{Y^{'}}bf_{t-1}^{'} \\ & + \frac{1}{RxR^{'}}\frac{IM_n^{''}}{Y^{'}}\left(im_{n,t}^{''} - rxr_t^{'}\right) + \frac{1}{RxR^{'}}\frac{IM_n^{*}}{Y^{'}}\left(im_{n,t}^{*} - rxr_t^{'}\right) \\ & - \frac{IM_s^{'}}{Y^{'}}im_{s,t}^{'} - \frac{IM_w^{'}}{Y^{'}}im_{w,t}^{'}\end{aligned} \tag{9}$$

where $bf_t^{'}$ is the North 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 North, 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, $\varepsilon_{RP,t}^{'}$:

$$R_t^{'} = R_t^{ECB} + \varepsilon_{RP,t}^{'} \tag{10}$$

The ECB rate is determined through a Taylor rule:

$$R_t^{ECB} = \rho R_{t-1}^{ECB} + (1-\rho)\left(\bar{r} + \phi_\pi \Pi_t + \phi_y GAP_t\right) + \varepsilon_{R,t}^{ECB} \tag{11}$$

where policy responds with inertia to mean inflation and output gap (Π_t and GAP_t, respectively) of the whole EU. $\bar{r}$ is the Wicksellian rate of interest. $\varepsilon_{R,t}^{ECB}$ 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 government spending shock. The government budget constraint is given by $G_t^{'} - T_t^{'} = \Delta B_t^{'} - r_{t-1}^{'} B_{t-1}^{'}$, which can be log-linearised to be:

$$\frac{G^{'}}{Y^{'}}g_t^{'} - \frac{T^{'}}{Y^{'}}t_t^{'} = \frac{B^{'}}{Y^{'}}b_t^{'} - \frac{B^{'}}{Y^{'}}\left(R_{t-1}^{'} - E_{t-1}\pi_t^{'}\right) - (1+\bar{r}^{'})\frac{B^{'}}{Y^{'}}b_{t-1}^{'} \tag{13}$$

where $t_t^{'}$ is the tax revenue, $b_t^{'}$ is the level of domestic bonds; $\frac{T^{'}}{Y^{'}}$ and $\frac{B^{'}}{Y^{'}}$ are the steady-state revenue and debt ratios.

Tax revenue is given by $T_t^{'} = \tau_t^{'} Y_t^{'}$, whose log-linearised form is:

$$t_t^{'} = \ln \tau_t^{'} + y_t^{'} \tag{14}$$

where $\tau_t^{'}$, which is the average tax rate, is governed by $\left(1+\tau_t^{'}\right) = \left(1+\bar{\tau}^{'}\right)\left(\frac{B_t^{'}}{Y_t^{'}}/\frac{B^{'}}{Y^{'}}\right)^{\phi_\tau^{'}}\Sigma_{\tau,t}^{'}$ where the tax rate responds positively $\left(\phi_\tau^{'}\right)$ to the debt ratio, subject to a shock $\left(\Sigma_{\tau,t}^{'}\right)$. The linearised tax policy (dropping the constants) is:

$$\tau_t^{'} = \phi_\tau^{'}\left(b_t^{'} - y_t^{'}\right) + \varepsilon_{\tau,t}^{'} \tag{15}$$

The primary deficit is given by $D_t^{'} = G_t^{'} - T_t^{'}$, which can be log-linearised to be:

$$\frac{D^{'}}{Y^{'}}d_t^{'} = \frac{G^{'}}{Y^{'}}g_t^{'} - \frac{T^{'}}{Y^{'}}t_t^{'} \tag{16}$$

where $d_t^{'}$ and $\frac{D^{'}}{Y^{'}}$ are deficit and the steady-state deficit ratio, respectively.

Eqs. (1) - (16) constitute the North EU part of the full model. Since both productivity and 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 not changing (current account balance), inflation at its target value, the output gap zero, and the primary surplus equal to the cost of servicing domestic bonds outstanding. The full model detailed in the appendix is completed by the South and World equations, which resemble the North's, and are imposed with similar terminal conditions.

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 for, and subsequently to re-estimate, 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.

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		
G/Y	Steady-state government expenditure ratio	0.20	0.21	0.16	Fixed at starting values		
T/Y	Steady-state tax revenue ratio	0.18	0.17	0.13	Fixed at starting values		
D/Y	Steady-state deficit ratio	0.02	0.04	0.03	Fixed at starting values		
B/Y	Steady-state debt ratio (domestic bonds)	0.68	0.90	0.82	Fixed at starting values		
BF/Y	Steady-state ratio of foreign bonds	35.6	-16.0	NA	Fixed at starting values		
X/Y	Steady-state net exports ratio	0.43	0.29	0.20	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		
$IM_n^{\prime\prime}/Y^{\prime}$	South imports from North/North output (SS)	NA	0.06	NA	Fixed at starting values		
$IM_n^{*}/Y^{\prime}$	World imports from North/North output (SS)	NA	NA	0.22	Fixed at starting values		
$IM_s^{\prime}/Y^{\prime\prime}$	North imports from South/South output (SS)	0.09	NA	NA	Fixed at starting values		
$IM_s^{*}/Y^{\prime\prime}$	World imports from South/South output (SS)	NA	NA	0.34	Fixed at starting values		
σ	Price elasticity of consumption (Inverse of)	1.37	1.37	1.38	1.98	2.63	2.17
φ	Wage elasticity of labour (Inverse of)	2.49	2.49	1.83	2.46	3.92	2.93
θ	Calvo non-adjusting probability	0.91	0.91	0.66	0.68	0.69	0.64
r_α	Slope of the Phillips curve	0.05	0.05	0.78	1.09	1.21	1.35
α	Degree of openness	0.20	0.20	0.20	0.15	0.18	0.19
λ_{ns}	Inflation response to North-South FX rate	0.50	0.50	0.00	0.29	0.42	-0.03
λ_{nw}	Inflation response to North RxR	0.50	0.00	0.50	0.31	-0.02	0.40
λ_{sw}	Inflation response to South RxR	0.00	0.50	0.50	-0.01	0.44	0.37
δ	Mean reversion of productivity growth	0.95	0.95	0.95	0.94	0.96	0.96
ω	Impact of taxes on productivity growth	0	0	0	0.07	0.07	0.12
μ	Income elasticity of imports	1.00	1.00	1.00	0.81	0.84	0.71
ψ	Exchange rate elasticity of imports	0.80	0.80	0.80	0.74	0.71	0.68
ϕ_π	Monetary policy response to inflation	1.52	1.52	2.50	1.93	1.93	2.23
ϕ_y	Monetary policy response to output gap	0.10	0.10	0.08	0.21	0.21	0.33
ρ	Monetary policy inertia	0.96	0.96	0.60	0.72	0.72	0.66
ρ_g	Fiscal policy inertia	0.90	0.96	0.95	0.90	0.96	0.95
ϕ_τ	Tax response to the debt ratio	0.40	0.40	0.40	0.79	0.92	0.63
ρ_{IS}	Persistence of the demand shock	0.53	0.53	0.60	0.73	0.82	0.61
ρ_{PP}	Persistence of the mark-up shock	0.18	0.18	0.15	0.16	0.21	0.14
ρ_{RP}	Persistence of the risk-premium shock	0.97	0.97	0.91	0.97	0.97	0.91
ρ_R	Persistence of the monetary policy shock	0.56	0.56	0.81	0.70	0.70	0.78
ρ_τ	Persistence of the tax policy shock	0.70	0.70	0.70	0.77	0.79	0.85
Model p-value		0			0.083		

H_0: The DSGE model is true.

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:

$$Y_t = AY_{t-1} + BX_{t-1} + e_t \tag{17}$$

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 $Y_t \equiv \left(y_t^{'}, y_t^{'\prime}, y_t^{*}\right)^{'}$. 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 $X_t \equiv \left(yf_t^{'}, yf_t^{'\prime}, yf_t^{*}, t\right)^{'}$. We denote the estimates of the auxiliary model that are based on simulated data by Φ_T^{Sim} and those based on observed data by Φ_T^{Act}; the estimates we consider are the coefficients of the lagged variables and the variances of the VARX residuals.

The simulated data are obtained by bootstrapping the innovations of the DSGE model. 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 $\left(\Phi_T^{Sim1}, \Phi_T^{Sim}2, \ldots, \Phi_T^{SimN}\right)$, 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:

Table 2
Variance decomposition of output and inflation.

Quarters ahead	North demand	North mark-up	North product	North premium	South demand	South mark-up	South product	South premium	ECB policy	All others
4										
y(N)	53.2	3.59	0.27	4.43	7.04	3.19	0.00	0.63	20.3	7.34
y(S)	1.49	1.10	0.01	0.26	72.2	2.83	0.42	2.23	13.8	5.73
y(EU)	25.8	2.27	0.13	2.22	41.6	3.00	0.22	1.48	16.8	6.48
π(N)	16.5	35.1	0.02	15.8	4.62	3.61	0.00	5.91	13.3	5.19
π(S)	4.18	2.41	0.00	8.30	17.4	33.9	0.02	12.6	12.2	9.04
π(EU)	12.2	22.4	0.01	1.48	14.0	24.1	0.01	1.91	15.0	8.96
12										
y(N)	40.3	3.17	10.6	8.43	5.94	2.50	0.44	1.56	19.0	8.08
y(S)	1.46	0.95	0.35	0.78	56.5	2.69	10.1	3.45	15.7	7.95
y(EU)	19.7	1.99	5.16	4.37	32.8	2.60	5.57	2.56	17.3	8.01
π(N)	13.8	31.4	0.24	15.7	3.58	3.39	0.03	8.68	17.8	5.32
π(S)	3.82	1.90	0.02	7.44	16.0	31.9	0.22	12.5	16.9	9.30
π(EU)	10.4	19.7	0.15	1.63	12.7	23.1	0.16	1.28	21.6	9.26
20										
y(N)	27.3	1.59	30.0	6.41	4.77	0.49	2.99	1.79	17.7	6.96
y(S)	1.06	0.79	1.41	1.16	46.7	2.13	22.7	4.43	14.1	5.63
y(EU)	13.4	1.17	14.8	3.63	27.0	1.36	13.4	3.19	15.8	6.25
π(N)	11.5	26.3	0.88	19.3	3.55	4.21	0.06	11.8	17.4	5.07
π(S)	3.46	1.82	0.04	9.16	14.7	29.0	0.77	17.0	15.6	8.32
π(EU)	9.67	17.9	0.58	2.27	12.7	23.3	0.58	1.88	22.1	9.09
40										
y(N)	12.7	0.76	51.9	3.71	1.31	0.23	13.9	1.69	10.3	3.42
y(S)	0.69	0.54	8.97	0.40	14.5	0.55	60.8	2.05	9.60	1.95
y(EU)	6.33	0.65	29.1	1.95	7.76	0.91	38.8	1.88	9.94	2.64
π(N)	10.8	28.9	5.62	18.3	1.50	2.90	1.16	9.44	16.7	4.60
π(S)	1.42	0.67	0.13	10.3	15.3	25.4	5.29	18.0	13.1	10.4
π(EU)	7.77	18.5	3.60	1.68	11.7	19.8	4.46	2.71	19.6	10.2

The ‘all others’ column combines the North/South government spending shocks and all RoW shocks.

$$Wald = \left(\Phi_T^{Act} - \overline{\Phi}\right)' \sum_{\Phi\Phi}^{-1} \left(\Phi_T^{Act} - \overline{\Phi}\right) \tag{18}$$

where $\sum_{\Phi\Phi}$ is the variance-covariance matrix of the vectors $\left(\Phi_T^{Sim1}, \Phi_T^{Sim2}, \ldots, \Phi_T^{SimN}\right)$. The Indirect Inference estimator implements a grid search for the DSGE parameters, θ^{DSGE}, until (18) is minimised.[3] To test whether the DSGE model is rejected by the sample data with these optimal parameters, we set the null hypothesis H_O that 'the DSGE model is true' and calculate its p-value:

$$p = (100 - WP)/100 \tag{19}$$

where WP is the percentile of the Wald statistic found with the observed 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. Unfiltered data are used. 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 Appendix B.

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.[4] 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 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 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 $\left(\kappa_\alpha' s\right)$. 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 RoW; the interest rate response to the output gap $\left(\phi_y\right)$ is generally higher; and policy inertia (ρ) in the EU is lower.

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 8.3% and so passes the test at the 5% significance level comfortably. 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 20 shocks which interact via trade and capital

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

[4] However, it is worth pointing that the II estimates - found by a grid search - are not affected by these starting values. Table 1: II estimates and p-value of the DSGE model

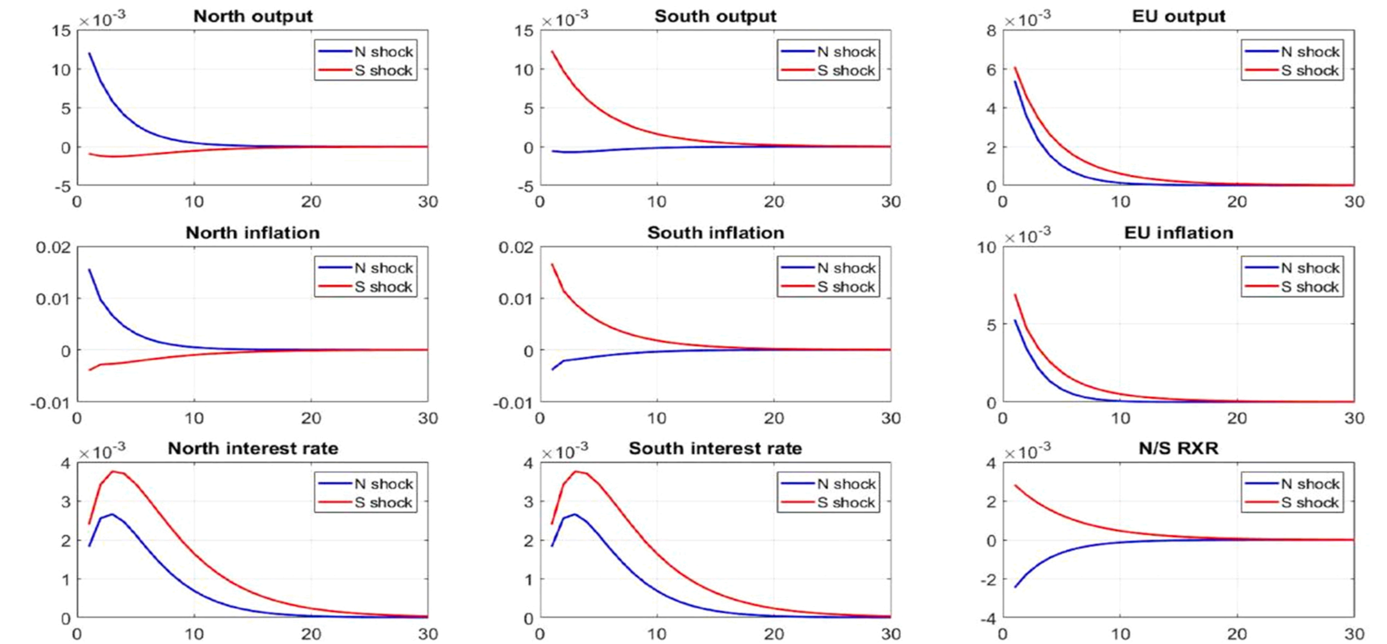

Fig. 1. The effect of a demand shock.

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 impact of both the North/South government spending shocks and all the RoW shocks which on their own have little effect).

In the short run (1 year ahead), North output is mostly determined by the North demand shock (53%), with the ECB monetary error contributing a significant proportion (20%). North inflation is dominated by the North mark-up shock (35%), while both the North demand shock, the North risk premium shock and the ECB error are non-negligible (each contributing 13–17%). South variables are affected in a similar way: i.e., output is dominated by the South demand shock (72%), inflation is mainly due to the South mark-up shock (34%) and the South demand shock (17%), the ECB error has somewhat lower impact on South output (14%) but is about as impactful to South inflation (12%), the South risk premium shock also contributes somewhat less to South inflation (13%). At the EU level, the demand shock explains more than two thirds of the aggregate output variation, of which 42% is due to South shocks. Average inflation is dominated by the mark-up shock (about 47%), but the North-South contributions are more balanced (22% and 24%, respectively). The ECB continues to play a modest role, contributing 17% and 15% to output and inflation, respectively.

In the medium run (3–5 years ahead): the North demand shock and the ECB error continue to be the main determinants of North output (but the demand shock is now smaller, accounting for 27–40%). Similarly, South output is determined mainly by South demand shocks and ECB errors, the latter being somewhat bigger than before. Mark-up shocks continue to be the most important single determinant of inflation in both regions; and there are some modest cross-region risk premium spillovers (about 7–12%). Over time (10 years ahead), the contribution of demand shocks declines considerably while that of productivity shocks, which by assumption are permanent, become dominant, accounting for 52% of output variation in North and 61% in South; however, there is no substantial North-South spillovers (9–14%).

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, by and large, there is not much spillover between North and South: shocks in one region have only limited impact on the other region. Second, in the short run, South demand shocks have a much larger effect (39% larger) on South output than North demand shocks have on North output. Moreover, the South demand shock generally has a much stronger (61% stronger) impact on EU output than the North shock. This rises to over double the impact in the medium run. Third, North and South markup shocks have roughly the same impact on EU inflation at all horizons, around 20%. The impact of ECB policy shocks is less obvious in the short run but over time it becomes about the same as the markup shocks. For comparison, Smets and Wouters (2003) found that '*In the medium to long run, monetary policy shocks also account for about 20 to* 40% *of the inflation variance*'.

4.2. The key impulse responses

The above suggests that in the short to medium run demand shocks are the main determinant of output, and in the medium to long run productivity shocks become increasingly dominant. On the other hand mark-up shocks are key to inflation throughout. Both output and inflation are also moderately affected by ECB errors. In order to gain a fuller understanding of the workings of the transmission mechanism we examine the key impulse responses.

Fig. 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 makes 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.

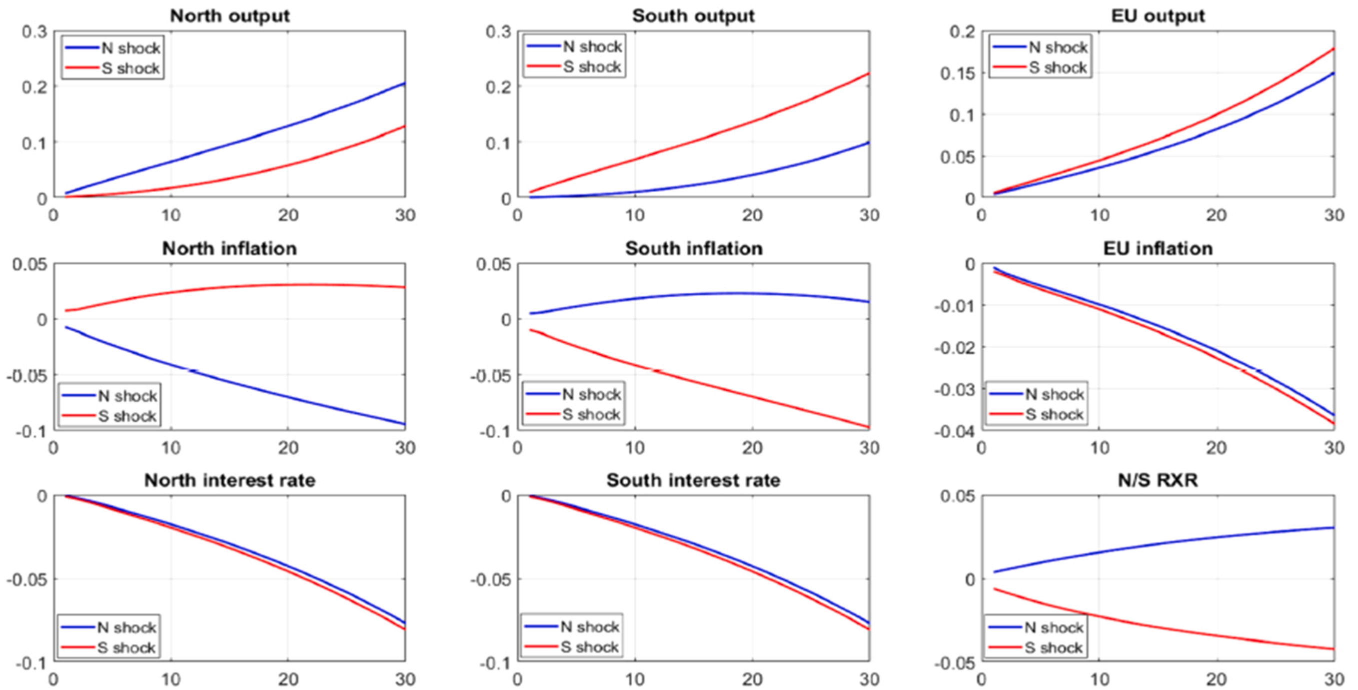

Fig. 2. The effect of a productivity shock.

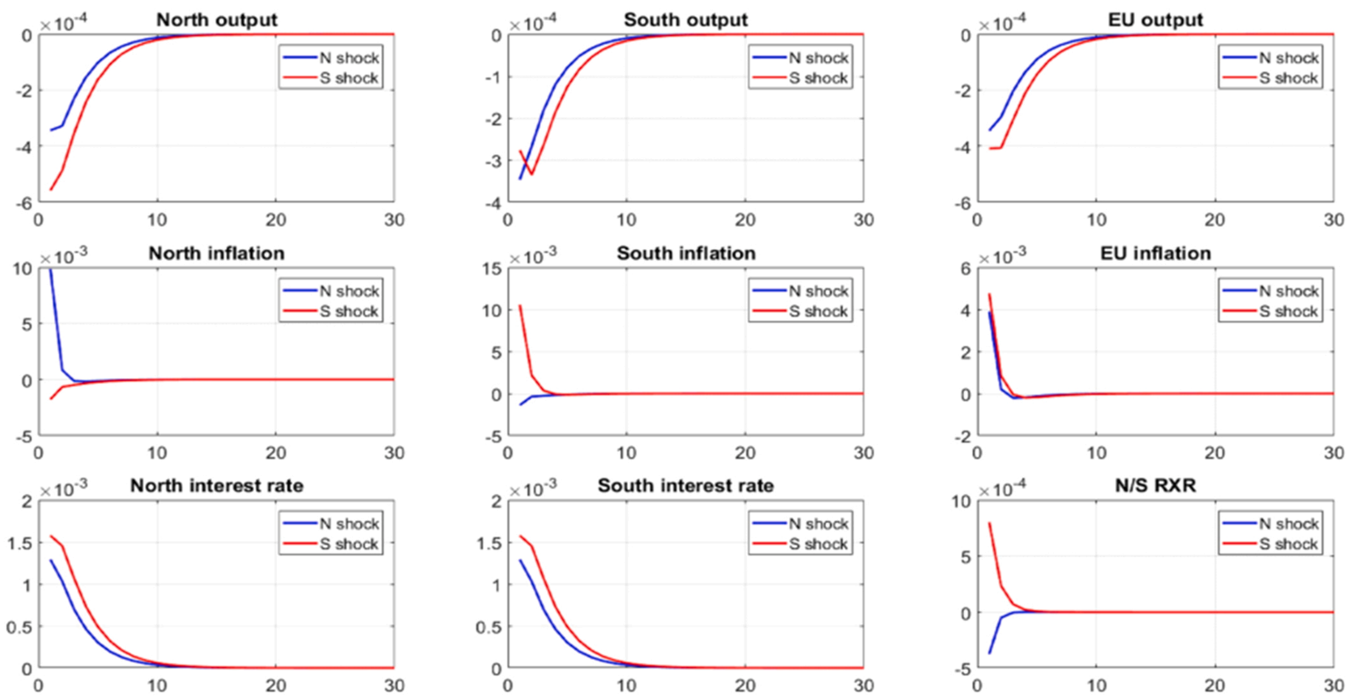

Fig. 3. The effect of a mark-up shock.

The effect of productivity shocks is shown in Fig. 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.[5] Domestic productivity shocks cause a domestic depreciation.

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

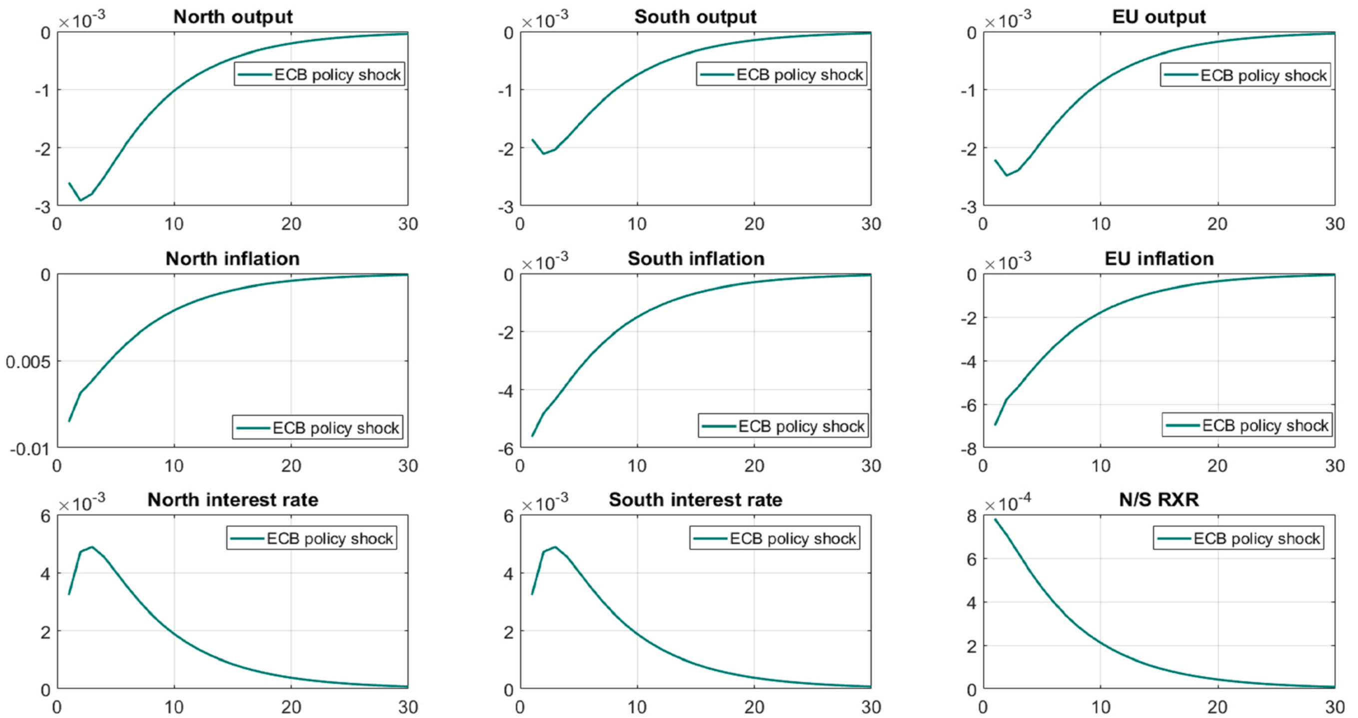

Fig. 4. The effect of an ECB policy shock.

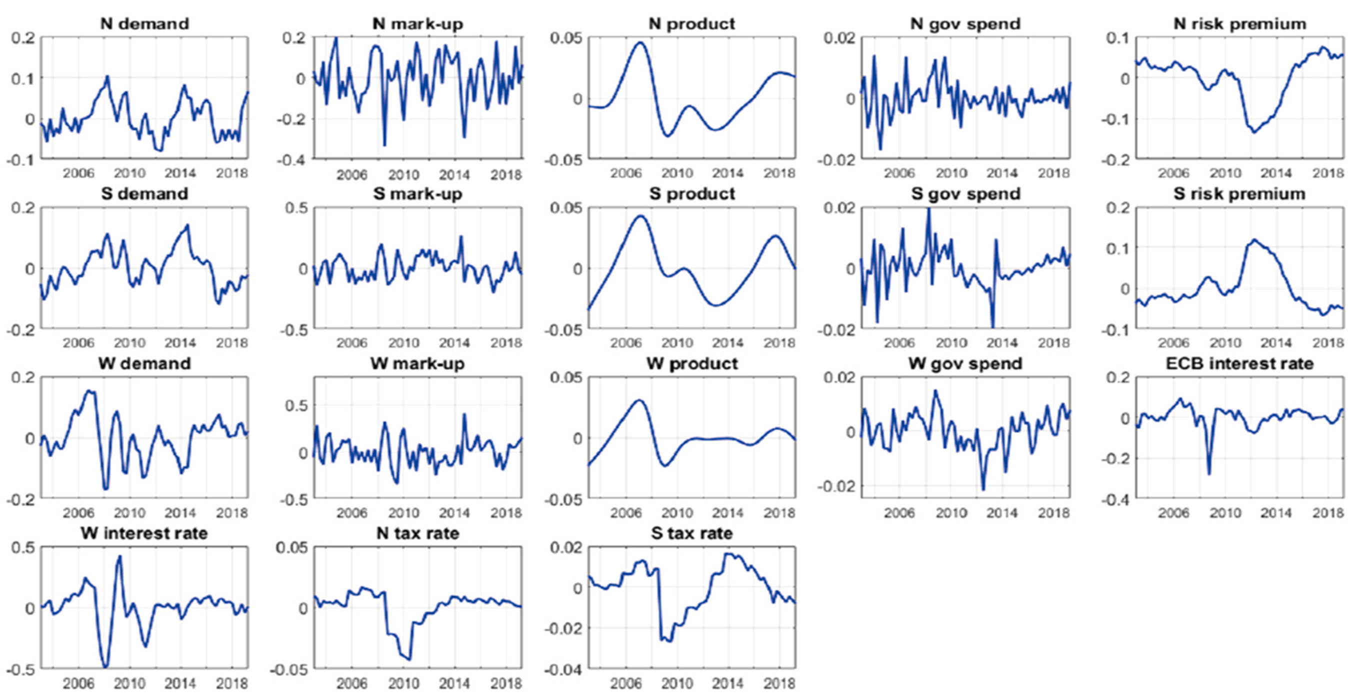

Fig. 5. Historical shocks.

The mark-up shock (Fig. 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.

Both regions are affected by ECB policy in the standard way (Fig. 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.

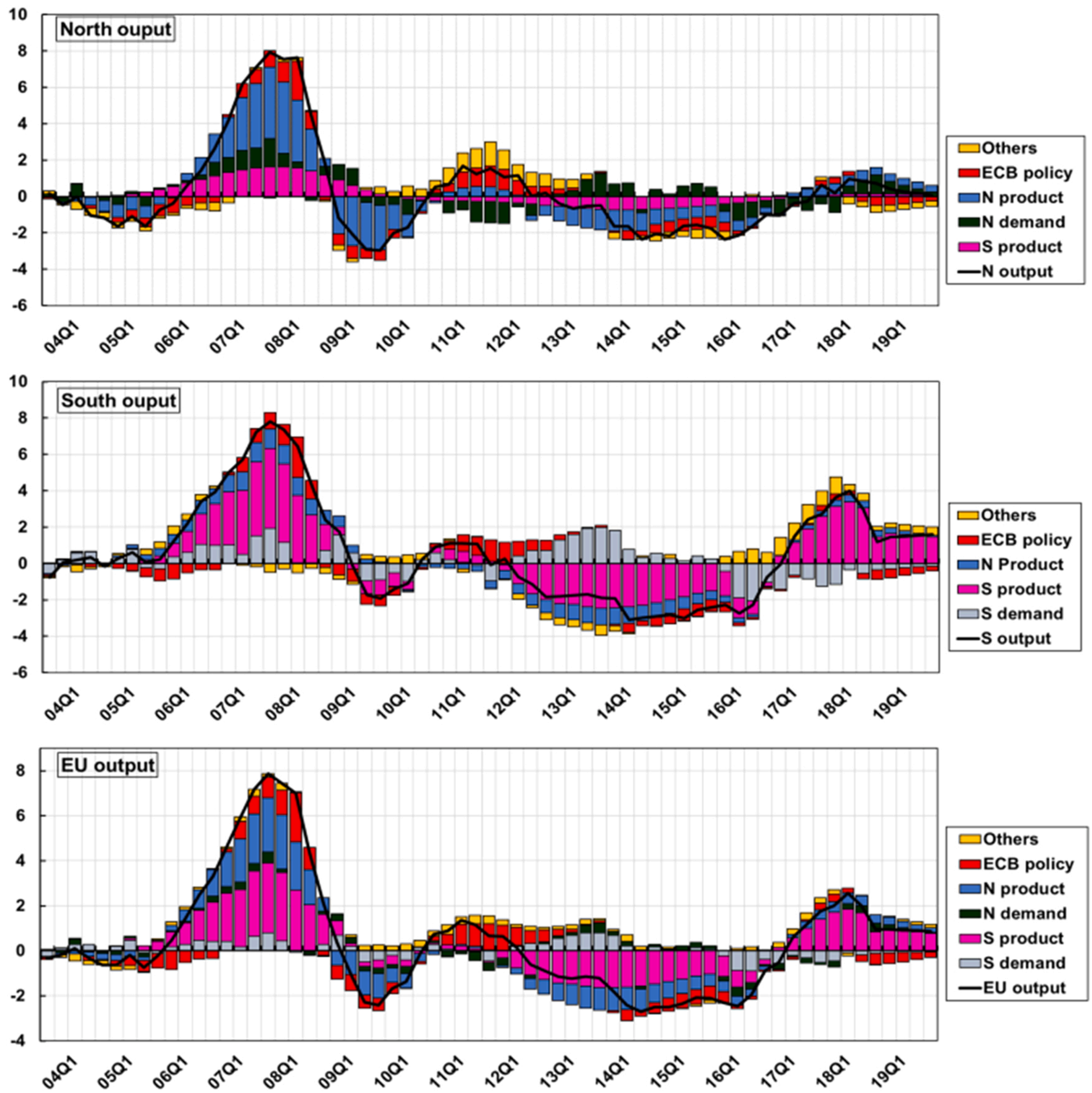

Fig. 6. Historical decomposition of output.

4.3. Historical decomposition

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

Fig. 6 shows that the upswing of North output in the mid- to late-2000 s (before the spread of the global crisis) was a result of a boost of home productivity, aided by a modest rise of home demand partly stimulated by the ECB, and a small portion of South productivity spillovers. The peak was reached in the end of 2007, when productivity in both regions ceased to rise, and then became negative in 2009 leading to the North recession (See also Fig. 5 for the evolution of the shocks). A short-lived recovery was then triggered, due to a temporary home productivity improvement and an easier monetary environment. But from 2012 onwards, it fluctuated around the steady-state level within a modest range, with long cycles nevertheless. Overall, there were rather limited cross-border spillovers from South and RoW. South output was driven by the same set of home and foreign factors, and evolved in a similar manner. However, North-to-South productivity spillovers were even weaker in this case; and South output was clearly more persistent and destabilised since the crisis. EU aggregate output was about equally impacted by the two regions before 2009; but since then it has been dominated by South shocks, while the North became much more stable.

Movements in inflation, Fig. 7, mainly reflect the role of the mark-up shock, the risk premium shock, and ECB policy. Thus, North inflation - which was clearly more destabilised between 2006 and 2013 - was constantly driven by domestic mark-up shocks, and risk premiums (including those from South) and ECB errors are key destabilisers (The risk premium shocks loomed large mainly in the post-crisis episode). North inflation had been below the steady-state level for most of the time since 2014, as negative mark-up shocks hit and North risk premiums surged, but the ECB did not respond to these shocks actively (See also Fig. 5). South inflation evolved in a similar pattern, but was more stabilised. EU inflation – being a weighted average of the two regions' – broadly shared the above features. Nevertheless, since the ECB affected both regions in the same way, it appeared to be more impactful in the EU perspective.

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

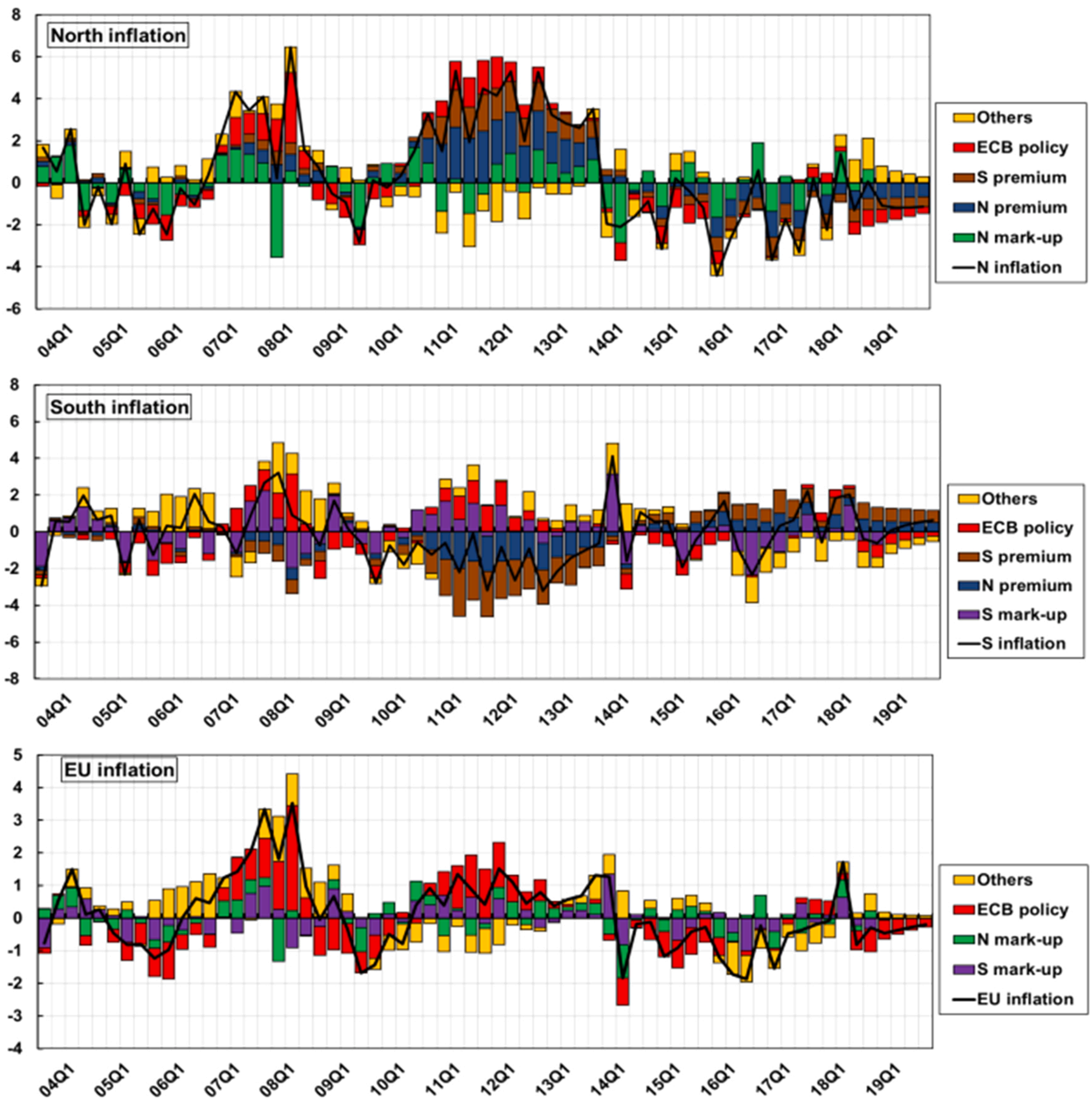

Fig. 7. Historical decomposition of inflation.

Table 3
Correlation matrix of the North/South shocks.

ε'_{IS}	ε'_{PP}	ε'_{yf}	ε'_{g}	ε'_{RP}	$\varepsilon'_{\tau,t}$	ε''_{IS}	ε''_{PP}	ε''_{yf}	ε''_{g}	ε''_{RP}	$\varepsilon''_{\tau,t}$	$\varepsilon'_{\tau,t}$
N demand	1											
N mark-up	0.24	1										
N product	0.08	-0.06	1									
N gov spend	0.30	-0.05	-0.03	1								
N risk prem	0.06	-0.10	0.63	0.00	1							
N tax rate	0.25	-0.01	0.53	-0.18	0.13	1						
S demand	0.61	0.15	-0.21	0.18	-0.47	0.11	1					
S mark-up	0.11	0.03	-0.27	0.10	-0.34	-0.06	0.49	1				
S product	0.14	-0.10	0.88	0.07	0.60	0.25	-0.14	-0.27	1			
S gov spend	0.21	0.04	0.19	0.16	0.32	-0.09	0.02	0.06	0.33	1		
S risk prem	-0.06	0.10	-0.63	-0.01	-1.00	-0.13	0.48	0.34	-0.61	-0.33	1	
S tax rate	0.15	-0.02	0.33	-0.15	-0.03	0.84	0.34	0.01	0.06	-0.22	0.03	1

region; the shocks to productivity (the potential output) are the only supply shock that can create some. 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

Table 4
Average variance of the output gap, inflation and the real interest rate.

	$Var(y-yf)$			$Var(\pi)$			$Var(R-\pi)$		
	North	South	EU	North	South	EU	North	South	EU
Base Case	1.95	2.13	1.29	0.32	0.35	0.16	1.05	0.78	0.68
Regime 1	1.47	2.21	1.12	0.33	0.36	0.17	1.06	0.76	0.67
Regime 2	4.45	2.27	2.34	0.48	0.36	0.22	1.49	0.86	0.84
Regime 3	0.61	2.19	0.77	0.30	0.35	0.13	0.94	0.70	0.54
Regime 4	1.89	0.71	0.56	0.32	0.31	0.14	0.99	0.72	0.58
Regime 5	0.63	0.69	0.41	0.31	0.31	0.14	0.92	0.60	0.52
Regime 6	2.02	2.26	1.31	0.15	0.16	0.09	0.61	0.71	0.53
Regime 7	0.65	0.67	0.42	0.15	0.15	0.09	0.48	0.57	0.43

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.

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 EU output – Federal Union.*

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

***Regime 3**) North government spending actively stabilises North output – SGP abolished, Fiscally Active North.*

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

***Regime 5**) North/South government spending actively stabilises 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 that 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 that North engages in transfers to 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 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 Fig. 5. For each regime we generate 1000 samples from which we calculate the average variance of the output gap, inflation and the (realised) real interest rate, and the average social welfare loss and household utility.[6]

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 EU output gap compared to that of the Base Case would be cut by 68%, from 1.3% to 0.4%. Since the government budget constraint is imposed throughout, 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 regions, especially for North; North stability is substantially hurt in this case, while South stability is not improved either presumably due to cross-region spillovers. This is reassuring, as any transfer regime is unlikely to be politically feasible. The other choices (Regimes 1, 3, 4), which all

[6] 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 $R_t^{NCB} = \rho R_{t-1}^{NCB} + (1-\rho)\left[\bar{r} + \phi_\pi \pi_t' + \phi_y (y_t' - yf_t')\right] + \varepsilon_{R,t}^{ECB}$ and $R_t^{SCB} = \rho R_{t-1}^{SCB} + (1-\rho)\left[\bar{r} + \phi_\pi \pi_t'' + \phi_y (y_t'' - yf_t'')\right] + \varepsilon_{R,t}^{ECB}$, and sets $R_t' = R_t^{NCB} + \varepsilon_{RP,t}'$, $R_t'' = R_t^{SCB} + \varepsilon_{RP,t}''$, and $\phi_\pi = 2.23, \phi_y = 0.42, \rho = 0.59$ as estimated with the benchmark model.In this model active fiscal policy changes the tax rate in response to debt and so affects productivity (the 'potential output',). Our measure of output stability is the output gap which excludes this effect on yf, so potentially biasing our output variance downwards. So we examined measures of output stability that includes this effect, such as the gap between output and the 'baseline yf' (where there is no active fiscal policy); we find that this hardly changed the variances, confirming that they are dominated by demand shocks and that the effect of tax changes on productivity contributes little to output variance.

Table 5
Average social welfare loss.

$SWL = \frac{1}{2}\left[\pi^2 + \varpi(y - yf)^2\right]$

$\varpi = 0$	North	South	EU	$\varpi = 0.1$	North	South	EU
Base Case	0.16	0.18	0.08	Base Case	0.26	0.28	0.14
Regime 1	0.17	0.18	0.09	Regime 1	0.24	0.29	0.14
Regime 2	0.24	0.18	0.11	Regime 2	0.46	0.29	0.23
Regime 3	0.15	0.18	0.07	Regime 3	0.18	0.28	0.10
Regime 4	0.16	0.16	0.07	Regime 4	0.25	0.19	0.10
Regime 5	0.16	0.16	0.07	Regime 5	0.19	0.19	0.09
Regime 6	0.08	0.07	0.05	Regime 6	0.18	0.19	0.11
Regime 7	0.08	0.07	0.05	Regime 7	0.11	0.11	0.07
$\varpi = 0.3$	North	South	EU	$\varpi = 0.5$	North	South	EU
Base Case	0.45	0.49	0.27	Base Case	0.65	0.71	0.40
Regime 1	0.39	0.51	0.25	Regime 1	0.53	0.73	0.37
Regime 2	0.91	0.52	0.46	Regime 2	1.35	0.75	0.70
Regime 3	0.24	0.50	0.18	Regime 3	0.30	0.72	0.26
Regime 4	0.48	0.26	0.15	Regime 4	0.63	0.33	0.21
Regime 5	0.25	0.26	0.13	Regime 5	0.31	0.33	0.17
Regime 6	0.38	0.42	0.24	Regime 6	0.58	0.65	0.37
Regime 7	0.17	0.18	0.11	Regime 7	0.24	0.24	0.15

Table 6
Average change in equivalent consumption.

	North	South	EU
Base Case	–	–	–
Regime 1	7.83%	9.33%	8.63%
Regime 2	-65.5%	-3.16%	-36.5%
Regime 3	26.3%	1.13%	14.2%
Regime 4	2.24%	40.6%	19.7%
Regime 5	21.4%	37.4%	28.7%
Regime 6	3.13%	6.16%	4.23%
Regime 7	32.2%	53.3%	39.2%

represent active stabilisation by only one region, are less helpful for the whole eurozone and would not or 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 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.

Plainly, given the close connection between macro and financial variables – as we elaborated at the beginning of this paper, a policy regime that improves macro stability should also improve financial stability, and vice versa. This is precisely what we find here about the variance of the real interest rate; thus, the regimes that reduce macro instability also reduce financial instability.

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 the change in household utility over the effect of a 1% change in permanent consumption assuming $\left(U = \sum_{t=0}^{\infty}\beta^t C_t^{1-\sigma}(1-\sigma)^{-1}\right)$: according to Table 6, Regime 7 would increase welfare by an equivalent consumption gain in each region of 32 – 53%, while Regime 5 would give a gain of 21–37% – both of which are clearly welfare-superior to the current regime, as well as the other choices. We may note that the ranking of regimes in terms of consumer welfare mirrors exactly that in terms of financial stability; this comes about because instability of real returns increases instability of consumption which in turn causes household disutility.

5.1. Implications for government debts and deficits

The Stability and Growth Pact focuses tightly on rules restraining country governments' debt and deficits. However, the fiscal rules we have examined above all assume the SGP is eliminated. Many politicians and commentators, particularly in Northern countries, tend to argue that any such abandonment of the SGP will lead in practice to transfers from North to South because of pressure from the South to liquidate their poor fiscal position. It is assumed in this discussion that higher debts and deficits will trigger this pressure. Plainly this may not be correct. But we look in this section at the question of whether the policy regimes we have examined do in fact create such debt and deficit pressures, given that we impose the normal government budget constraints at the country level.

Table 7 shows that the debt/GDP and the deficit/GDP ratios fluctuate much more widely than in the Base Case when the SGP is withdrawn. With Regime 5, which maximises welfare if the single-euro-zone set-up is kept, the range for the debt ratio rises to 26–135% from 27% to 108% in the Base Case; and for the deficit ratio to 1.3–3.2% from 0.9% to 3.9%. For the South the increases are still larger, to 45 –264% from 34% to 169%, and to 1.9 –6.6% from 1.0% to 5.4%, respectively.

Yet under Regime 5 all countries have in place domestic tax regimes that ensure solvency. Also, average debt and deficit ratios are about the same with Regime 5 as in the Base Case, demonstrating that the budget discipline is working to keep finances in order over the long term. What the fiscal policies in Regime 5 are doing is showing short term flexibility,

Table 7
Average debt and deficit ratios.

	Debt/GDP			Deficit/GDP		
	North	South	EU	North	South	EU
Base Case	55.5	94.8	63.2	1.44	3.01	1.77
[Min, Max]	[15.5,93.1]	[34.2169]	[27.4108]	[0.45,2.96]	[0.98,5.35]	[0.85,3.85]
Regime 1	59.3	101	71.4	1.64	3.23	2.27
[Min, Max]	[13.5188]	[51.2204]	[32.6152]	[0.65,4.24]	[1.18,5.30]	[0.98,3.76]
Regime 2	66.2	104	68.2	1.97	2.98	1.85
[Min, Max]	[11.8324]	[46.8207]	[24.8194]	[0.58,5.51]	[1.21,4.97]	[1.09,4.51]
Regime 3	50.8	93.5	58.8	1.41	3.10	1.83
[Min, Max]	[10.7128]	[41.7156]	[24.6135]	[0.63,5.58]	[0.99,5.19]	[0.91,2.79]
Regime 4	55.8	117	66.4	1.47	3.50	1.99
[Min, Max]	[17.3141]	[46.7245]	[26.3170]	[0.58,3.87]	[1.82,6.91]	[1.20,2.91]
Regime 5	48.4	120	60.4	1.37	3.09	1.92
[Min, Max]	[10.5120]	[45.2264]	[25.8135]	[0.71,5.36]	[1.89,6.64]	[1.26,3.17]
Regime 6	56.1	95.3	64.8	1.66	3.02	1.79
[Min, Max]	[14.9102]	[34.5158]	[27.3108]	[0.43,2.64]	[0.90,5.42]	[0.83,2.85]
Regime 7	49.8	118	60.8	1.39	3.32	1.85
[Min, Max]	[10.9126]	[42.5239]	[27.6131]	[0.69,4.91]	[1.52,6.53]	[1.19,3.03]

fluctuating in response to shocks. As we have seen, the whole-EU gain in welfare from this regime over the Base Case is a 29% equivalent rise in permanent consumption. This is being achieved without any pooling of fiscal sovereignty, and also with no cross-country guarantee or transfer mechanism.

It would seem to us that the logical 'pact' to put in place of the existing SGP would be one that monitors solvency, rather than preventing this welfare-enhancing flexibility. Of course the experience of dealing with Covid has clearly illustrated that advanced countries are capable of sharp fluctuations in debt and deficits without endangering solvency.

5.2. Potential pitfalls of our regime analysis

We have seen from our analysis that permitting regions to pursue active fiscal policies, subject only to their own solvency constraint, would greatly reduce macro and financial instability and in so doing substantially raise household welfare. In an illustration of the disadvantages of having a single currency, we found that a two-euro zone with independent regional monetary policies would improve matters even further. The method we have used satisfies Lucas' critique (Lucas, 1976) in that we have varied the policy regimes while keeping the model's structural parameters constant; thus the IRFs under the changing regimes, including the new spillover effects, should be accurately calculated. What concerns might be entertained for our results?

One concern could be that the environment we have assumed changes with the regimes in some way, perhaps in response to the changing volatility. Thus lending frictions or risk-premia might change. For example in the two-euro case the South might well be rated as a more risky region, and its risk-premium might therefore rise. Or lending rates could fall with the less volatile environment in both regions. These shifts will no doubt occur and will change constant elements in the model, shifting the IS curve and altering the average variable values in the different regimes. But our model results do not involve the mean outcomes, the first moments, under the changing regimes; they only involve the variances, second moments, which are unaffected by the constants. Provided the structural DSGE model parameters are unaffected, as they should be, the variance results will be unchanged.

Another concern could be with the behaviour of the ECB or its successors in the two-euro set-up, particularly in its response to active fiscal policies. Perhaps there would be political pressure for the central bank to finance government deficits directly through QE; in this case the changing fiscal regime would also alter the monetary regime. We clearly cannot rule out this possibility. However, it lies outside the scope of our paper to assess the political feasibility of our regime combinations. We have simply examined potential regime combinations on the assumption that they are politically feasible, in order to determine their potential benefits were they to be followed; this is intended as a contribution to the political debate on policy we hope will occur in the future. As part of this we have assumed fiscal activism is accompanied by the existing monetary regimes in which the central bank targets the lending rate in response to economic conditions, using its balance sheet, both short and long, as its instruments (presumably using more long bond QE in the mix the closer rates on short term repo loans get to the lower bound). Hence, conditional on the state of the economy, the ECB would not buy extra government bonds in response to higher fiscal deficits; it will maintain its balance sheet policy to hit its targets. Of course this also implies that it will respond, as per these targets, to any effects on the economy of fiscal policy; but that is in line with our assumptions about the policy regimes being followed.

Because we do not explicitly model the use of the ECB's balance sheet in its implementation monetary policy – we assume instead that its choice of interest rate fully implements its monetary policy – we do not need to include it in the model.[7] The explicit modelling of the use of its balance sheet lies outside the scope of our paper. We note that the monetary target rule is entirely orthogonal to fiscal policies as these must be financed by market borrowing and the resulting debt must obey each government's intertemporal budget constraint, which are embedded in the model. We also note that the ECB pursues average eurozone-wide and not individual country welfare. This is reflected in the ECB's monetary target rule we use for the single euro set-up in the model. In our two euro scenario we create two target rules, again without going into the their exact implementation strategies. A more detailed examination of the ECB's use of its balance sheet is a very suitable subject for further research. But it would need to match the data at least as well as our present model to justify the considerable extra complications it would create.

Of course, this paper is in the end but modelling and subject to model uncertainty. Our results come from a model that fits the facts but errors cannot be ruled out. The point of our analysis is to show that there are huge potential reductions in financial and macro instability from the introduction of greater fiscal and monetary flexibility, according to a reasonably accurate model of the eurozone economy. Since the eurozone stability status quo is prone to high instability, we simply suggest that our results imply it is worth trying this new approach.

6. Conclusion

In this paper we have constructed a macro DSGE model of the eurozone and its two main regions, North and 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 productivity, risk premium and ECB policy, which are, however, modest. 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 and financial stability and consequently in consumer welfare. If this is ruled out on political grounds, substantial gains in output both at the regional and at the EU levels 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. If a pact is to be retained, it could be transformed into a monitoring mechanism of country solvency – purportedly to ensure that no transfer crisis arises. 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.

As an illustration of the effects of having a single currency, 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

[7] This was a concern expressed by one of our referees.

resurface.

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

Appendix

A listing of model

- North EU (')

IS curve:

$$\begin{aligned} y_t' = \; & E_t y_{t+1}' - \frac{C'}{Y'}\frac{1}{\sigma'}\Theta'\left(R_t' - E_t\pi_{t+1}' - \overline{r}'\right) - \frac{X'}{Y'}z_1'\Theta' E_t\Delta y_{t+1}'' - \frac{X'}{Y'}z_2'\Theta' E_t\Delta y_{t+1}^{*} \\ & + \frac{X'}{Y'}z_3'\Theta' E_t\Delta q_{ns,t+1} - \frac{X'}{Y'}z_4'\Theta' E_t\Delta rxr_{t+1}' - \frac{G'}{Y'}\Theta' E_t\Delta g_{t+1}' + \varepsilon_{IS,t}' \end{aligned} \tag{A.1}$$

Phillips curve:

$$\begin{aligned} \pi_t' = \; & -\lambda_{nw}'\left(\beta' E_t\Delta rxr_{t+1}' - \Delta rxr_t'\right) + \lambda_{ns}'\left(\beta'\Delta q_{ns,t+1} - \Delta q_{ns,t}\right) \\ & -\lambda_{sw}'\left(\beta' E_t\Delta rxr_{t+1}'' - \Delta rxr_t''\right) + \beta' E_t\pi_{t+1}' + \kappa_a'\left(y_t' - yf_t'\right) + \varepsilon_{PP,t}' \end{aligned} \tag{A.2}$$

Productivity:

$$yf_t' - yf_{t-1}' = \Gamma' + \delta'\left(yf_{t-1}' - yf_{t-2}'\right) - \varpi'\left(\tau_t' - \tau_{t-1}'\right) + \varepsilon_{yf,t}' \tag{A.3}$$

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:

$$\begin{aligned} \frac{BF'}{Y'}bf_t' = \; & \frac{BF'}{Y'}\left(R_{t-1}^{*} - E_{t-1}\pi_t^{*} - \overline{r}^{*}\right) + \left(1 + \overline{r}^{*}\right)\frac{BF'}{Y'}bf_{t-1}' \\ & + \frac{1}{RxR'}\frac{IM_n''}{Y'}\left(im_{n,t}'' - rxr_t'\right) + \frac{1}{RxR'}\frac{IM_n^{*}}{Y'}\left(im_{n,t}^{*} - rxr_t'\right) \\ & - \frac{IM_s'}{Y'}im_{s,t}' - \frac{IM_w'}{Y'}im_{w,t}' \end{aligned} \tag{A.6}$$

Risk premium:

$$R_t' = R_t^{ECB} + \varepsilon_{RP,t}' \tag{A.7}$$

Fiscal policy:

$$g_t' = \rho_g' g_{t-1}' + \varepsilon_{g,t}' \tag{A.8}$$

Government budget constraint:

$$\frac{G'}{Y'}g_t' - \frac{T'}{Y'}t_t' = \frac{B'}{Y'}b_t' - \frac{B'}{Y'}\left(R_{t-1}' - E_{t-1}\pi_t'\right) - \left(1 + \overline{r}'\right)\frac{B'}{Y'}b_{t-1}' \tag{A.9}$$

Tax revenue:

$$t_t' = \ln\tau_t' + y_t' \tag{A.10}$$

Tax policy:

$$\tau_t' = \phi_\tau'\left(b_t' - y_t'\right) + \varepsilon_{\tau,t}'$$

Primary deficit:

$$\frac{D^{'}}{Y^{'}}d^{'}_t = \frac{G^{'}}{Y^{'}}g^{'}_t - \frac{T^{'}}{Y^{'}}t^{'}_t \quad (A.11)$$

- South EU ('')

IS curve:

$$\begin{aligned} y^{''}_t = \; & E_t y^{''}_{t+1} - \frac{C^{''}}{Y^{''}}\frac{1}{\sigma^{''}}\Theta^{''}\left(R^{''}_t - E_t\pi^{''}_{t+1} - \overline{r}^{''}\right) - \frac{X^{''}}{Y^{''}}z^{''}_1\Theta^{''}E_t\Delta y^{'}_{t+1} - \frac{X^{''}}{Y^{''}}z^{''}_2\Theta^{''}E_t\Delta y^{*}_{t+1} \\ & - \frac{X^{''}}{Y^{''}}z^{''}_3\Theta^{''}E_t\Delta q_{ns,t+1} - \frac{X^{''}}{Y^{''}}z^{''}_4\Theta^{''}E_t\Delta rxr^{''}_{t+1} - \frac{G^{''}}{Y^{''}}\Theta^{''}E_t\Delta g^{''}_{t+1} + \varepsilon^{''}_{IS,t} \end{aligned} \quad (A.12)$$

Phillips curve:

$$\begin{aligned} \pi^{''}_t = \; & -\lambda^{''}_{ns}\left(\beta^{''}\Delta q_{ns,t+1} - \Delta q_{ns,t}\right) - \lambda^{''}_{sw}\left(\beta^{''}E_t\Delta rxr^{''}_{t+1} - \Delta rxr^{''}_t\right) \\ & + \lambda^{''}_{nw}\left(\beta^{''}E_t\Delta rxr^{'}_{t+1} - \Delta rxr^{'}_t\right) + \beta^{''}E_t\pi^{''}_{t+1} + \kappa^{''}_a\left(y^{''}_t - yf^{''}_t\right) + \varepsilon^{''}_{PP,t} \end{aligned} \quad (A.13)$$

Productivity:

$$yf^{''}_t - yf^{''}_{t-1} = \Gamma^{''} + \delta^{''}\left(yf^{''}_{t-1} - yf^{''}_{t-2}\right) - \varpi^{''}\left(\tau^{''}_t - \tau^{''}_{t-1}\right) + \varepsilon^{''}_{yf,t} \quad (A.14)$$

Imports from North EU:

$$im^{''}_{n,t} = \mu^{''}_n y^{''}_t - \psi^{''}_n q_{ns,t} \quad (A.15)$$

Imports from RoW:

$$im^{''}_{w,t} = \mu^{''}_w y^{''}_t - \psi^{''}_w rxr^{''}_t \quad (A.16)$$

Balance of payments:

$$\begin{aligned} \frac{BF^{''}}{Y^{''}}bf^{''}_t = \; & \frac{BF^{''}}{Y^{''}}\left(R^{*}_{t-1} - E_{t-1}\pi^{*}_t - \overline{r}^{*}\right) + (1+\overline{r}^{*})\frac{BF^{''}}{Y^{''}}bf^{''}_{t-1} \\ & + \frac{1}{RxR^{'}}\frac{IM^{'}_s}{Y^{''}}\left(im^{'}_{s,t} - rxr^{'}_t\right) + \frac{1}{RxR^{''}}\frac{IM^{*}_s}{Y^{''}}\left(im^{*}_{s,t} - rxr^{''}_t\right) \\ & - \frac{IM^{''}_n}{Y^{''}}im^{''}_{n,t} - \frac{IM^{''}_w}{Y^{''}}im^{''}_{w,t} \end{aligned} \quad (A.17)$$

Risk premium:

$$R^{''}_t = R^{ECB}_t + \varepsilon^{''}_{RP,t} \quad (A.18)$$

Fiscal policy:

$$g^{''}_t = \rho^{''}_g g^{''}_{t-1} + \varepsilon^{''}_{g,t} \quad (A.19)$$

Government budget constraint:

$$\frac{G^{''}}{Y^{''}}g^{''}_t - \frac{T^{''}}{Y^{''}}t^{''}_t = \frac{B^{''}}{Y^{''}}b^{''}_t - \frac{B^{''}}{Y^{''}}\left(R^{''}_{t-1} - E_{t-1}\pi^{''}_t\right) - (1+\overline{r}^{''})\frac{B^{''}}{Y^{''}}b^{''}_{t-1} \quad (A.20)$$

Tax revenue:

$$t^{''}_t = \ln\tau^{''}_t + y^{''}_t \quad (A.21)$$

Tax policy:

$$\tau^{''}_t = \phi^{''}_\tau\left(b^{''}_t - y^{''}_t\right) + \varepsilon^{''}_{\tau,t}$$

Primary deficit:

$$\frac{D^{''}}{Y^{''}}d^{''}_t = \frac{G^{''}}{Y^{''}}g^{''}_t - \frac{T^{''}}{Y^{''}}t^{''}_t \quad (A.22)$$

ECB Taylor rule:

$$R^{ECB}_t = \rho R^{ECB}_{t-1} + (1-\rho)\left(\overline{r} + \phi_\pi\Pi_t + \phi_y GAP_t\right) + \varepsilon^{ECB}_{R,t} \quad (A.23)$$

Average EU inflation:

$$\Pi_t = \frac{\exp\left(y^{'}_t\right)}{\exp\left(y^{'}_t\right) + \exp\left(y^{''}_t\right)}\pi^{'}_t + \frac{\exp\left(y^{''}_t\right)}{\exp\left(y^{'}_t\right) + \exp\left(y^{''}_t\right)}\pi^{''}_t \quad (A.24)$$

Average EU output gap:

$$GAP_t = \frac{\exp(y_t^{'})}{\exp(y_t^{'}) + \exp(y_t^{''})}(y_t^{'} - yf_t^{'}) + \frac{\exp(y_t^{''})}{\exp(y_t^{''}) + \exp(y_t^{'})}(y_t^{''} - yf_t^{''}) \tag{A.25}$$

- RoW($*$)

IS curve:

$$\begin{aligned} y_t^* = \quad & E_t y_{t+1}^* - \frac{C^*}{Y^*}\frac{1}{\sigma^*}\Theta^*(R_t^* - E_t\pi_{t+1}^* - \bar{r}^*) - \frac{X^*}{Y^*}z_1^*\Theta^* E_t \Delta y_{t+1}^{'} - \frac{X^*}{Y^*}z_2^*\Theta^* E_t \Delta y_{t+1}^{''} \\ & + \frac{X^*}{Y^*}z_3^*\Theta^* E_t \Delta rxr_{t+1}^{'} + \frac{X^*}{Y^*}z_4^*\Theta^* E_t \Delta rxr_{t+1}^{''} - \frac{G^*}{Y^*}\Theta^* E_t \Delta g_{t+1}^* + \varepsilon_{IS,t}^* \end{aligned} \tag{A.26}$$

Phillips curve:

$$\begin{aligned} \pi_t^* = \quad & \lambda_{nw}^*(\beta^* E_t \Delta rxr_{t+1}^{'} - \Delta rxr_t^{'}) + \lambda_{sw}^*(\beta^* E_t \Delta rxr_{t+1}^{''} - \Delta rxr_t^{''}) \\ & + \lambda_{ns}^*(\beta^* \Delta q_{ns,t+1} - \Delta q_{ns,t}) + \beta^* E_t \pi_{t+1}^* + \kappa_a^*(y_t^* - yf_t^*) + \varepsilon_{PP,t}^* \end{aligned} \tag{A.27}$$

Productivity:

$$yf_t^* - yf_{t-1}^* = \Gamma^* + \delta^*(yf_{t-1}^* - yf_{t-2}^*) - \varpi^*(\tau_t^* - \tau_{t-1}^*) + \varepsilon_{yf,t}^* \tag{A.28}$$

Taylor rule:

$$R_t^* = \rho^* R_{t-1}^* + (1-\rho^*)\left[\bar{r}^* + \phi_\pi^* \pi_t^* + \phi_y^*(y_t^* - yf_t^*)\right] + \varepsilon_{R,t}^* \tag{A.29}$$

Imports from North EU:

$$im_{n,t}^* = \mu_n^* y_t^* + \psi_n^* rxr_t^{'} \tag{A.30}$$

Imports from South EU:

$$im_{s,t}^* = \mu_s^* y_t^* + \psi_s^* rxr_t^{''} \tag{A.31}$$

Fiscal policy:

$$g_t^* = \rho_g^* g_{t-1}^* + \varepsilon_{g,t}^* \tag{A.32}$$

Government budget constraint:

$$\frac{G^*}{Y^*}g_t^* - \frac{T^*}{Y^*}t_t^* = \frac{B^*}{Y^*}b_t^* - \frac{B^*}{Y^*}(R_{t-1}^* - E_{t-1}\pi_t^*) - (1+\bar{r}^*)\frac{B^*}{Y^*}b_{t-1}^* \tag{A.33}$$

Tax revenue:

$$t_t^* = \ln \tau_t^* + y_t^* \tag{A.34}$$

Tax policy:

$$\tau_t^* = \phi_\tau^*(b_t^* - y_t^*) + \varepsilon_{\tau,t}^*$$

Primary deficit:

$$\frac{D^*}{Y^*}d_t^* = \frac{G^*}{Y^*}g_t^* - \frac{T^*}{Y^*}t_t^* \tag{A.35}$$

- Real exchange rate determination:

1. North UIP against RoW:

$$rxr_t^{'} - E_t rxr_{t+1}^{'} = R_t^* - R_t^{'} - (E_t\pi_{t+1}^* - E_t\pi_{t+1}^{'}) \tag{A.36}$$

2. South UIP against RoW:

$$rxr_t^{''} - E_t rxr_{t+1}^{''} = R_t^* - R_t^{''} - (E_t\pi_{t+1}^* - E_t\pi_{t+1}^{''}) \tag{A.37}$$

3. North-South bilateral exchange rate:

$$rxr_t^{'} - rxr_t^{''} = -q_{ns,t} \tag{A.38}$$

- Shock processes: for $i = {'}, {''}$ or $*$, $\varepsilon_{IS,t}^i$, $\varepsilon_{PP,t}^i$, $\varepsilon_{RP,t}^i$, $\varepsilon_{\tau,t}^i$, $\varepsilon_{R,t}^{ECB}$ and $\varepsilon_{R,t}^*$ are independent AR(1) processes; $\varepsilon_{yf,t}^i$ and $\varepsilon_{g,t}^i$ are iid.
- Terminal conditions: for $i = 1, {''}$, or $*$, $\pi_T^i = R_T^i - \bar{r}^i, y_T^i = yf_T^i, bf_T^i = bf_{T-1}^i, g_T^i = g_{T-1}^i, b_T^i = \frac{1}{\bar{r}^i}\left(\frac{B^i}{Y^i}\right)^{-1}\left[\frac{T^i}{Y^i}t_T^i - \frac{G^i}{Y^i}g_T^i - \frac{B^i}{Y^i}(R_T^i - \pi_T^i)\right]$ on the terminal date T.

- Note on the combined parameters:

$$z_1' = \frac{EX_s'}{Y_s'}\mu_n'', z_2' = \frac{EX_w'}{Y'}\mu_n^*, z_3' = \frac{EX_s'}{Y'}\psi_n'' + \frac{IM_s'}{Y'}\psi_s', z_4' = \frac{EX_w'}{Y'}\psi_n^* + \frac{IM_w'}{Y'}\psi_w', \Theta' = \left[1 + \frac{X'}{Y'}\left(\frac{IM_s'}{Y'}\mu_s' + \right)\right]\left(\quad \frac{IM_w'}{Y'}\mu_w'\right)\Big]^{-1};.$$
$$z_1'' = \frac{EX_n''}{Y''}\mu_s', z_2'' = \frac{EX_w''}{Y''}\mu_s^*, z_3'' = \frac{EX_n''}{Y''}\psi_s' + \frac{IM_n''}{Y''}\psi_n'', z_4'' = \frac{EX_w''}{Y''}\psi_s^* + \frac{IM_w''}{Y''}\psi_w'', \Theta'' = [1 + \quad \frac{X''}{Y''}\left(\frac{IM_n''}{Y''}\mu_n'' + \frac{IM_w''}{Y''}\mu_w''\right)\Big]^{-1};.$$
$$z_1^* = \frac{EX_n^*}{Y^*}\mu_w', z_2^* = \frac{EX_s^*}{Y^*}\mu_w'', z_3^* = \frac{EX_n^*}{Y^*}\psi_w' + \frac{IM_n^*}{Y^*}\psi_n^*, z_4^* = \frac{EX_s^*}{Y^*}\psi_w'' + \frac{IM_s^*}{Y^*}\psi_s^*, \Theta^* = \left[1 + \frac{X^*}{Y^*}\left(\frac{IM_n^*}{Y^*}\mu_n^* + \right)\right]\left(\quad \frac{IM_s^*}{Y^*}\mu_s^*\right)\Big]^{-1};.$$

$\frac{C}{Y}$'s, $\frac{G}{Y}$'s, $\frac{T}{Y}$'s, $\frac{D}{Y}$'s, $\frac{B}{Y}$'s, $\frac{BF}{Y}$'s, $\frac{EX}{Y}$'s, $\frac{IM}{Y}$'s, $\frac{X}{Y}$'s are the steady-state ratios of consumption, government spending, tax revenue, deficits, domestic bonds, foreign bonds, exports, imports and net exports relative to output.

A.1 Derivation of the IS and phillips curves (North example)

The derivation of the IS and Phillips curves of the linear model is standard. To derive the former, note that under the standard assumption of CRRA utility, the consumption Euler equation is:

$$c_t' = E_t c_{t+1}' - \frac{1}{\sigma'}\left(R_t' - E_t\pi_{t+1}' - \overline{r}' + E_t \ln \epsilon_{t+1}' - \ln \epsilon_t'\right) \tag{A.39}$$

where ϵ_t' is the time preference shock. Let the aggregate demand be $Y_t' = C_t' + G_t' + NX_t'$, such that:

$$y_t' = \frac{C'}{Y'}c_t' + \frac{G'}{Y'}g_t' + \frac{X'}{Y'}nx_t' \tag{A.40}$$

and for simplicity, let $nx_t' = \left(\mu_n''y_t'' - \psi_n''q_{ns,t}\right) + \left(\mu_n''y_t'' - \psi_n''q_{ns,t}\right) - \left(\mu_s'y_t' + \psi_s'q_{ns,t}\right) - \left(\mu_w'y_t' - \psi_w'rxr_t'\right) + \eta_t'$, where η_t' is a residual. The IS curve (A.1) can be obtained by substituting (A.40) into (A.39) for c_t'.

To derive the Phillips curve, note that the North CPI is defined as:

$$p_t' = \left[(1-2\alpha)p_{N,t} + \alpha p_{S,t} + \alpha p_{W,t}\right] \tag{A.41}$$

where $p_{N,t}, p_{S,t}$ and $p_{W,t}$ are the prices of domestic goods in North, South and RoW, respectively, and a is North's openness. The foreign prices can be substituted out with the real exchange rates such that:

$$p_t' = p_{N,t} + \lambda_{nw}' rxr_t' + \lambda_{sw}' rxr_t'' + \lambda_{ns}' q_{ns,t} \tag{A.42}$$

where$\lambda_{nw}' = a\left(\Gamma_1^{NW} + \Gamma_1^{NS}\right), \lambda_{sw}' = a\left(\Gamma_2^{NW} - \Gamma_2^{NS}\right), \lambda_{ns}' = -a\left(\Gamma_3^{NW} + \Gamma_3^{NS}\right); \Gamma_1^{NW} = \frac{(a\Xi_2 - bc)\Xi_3 + (c\Xi_3 - ab)b}{\zeta}$, $\Gamma_2^{NW} = \frac{(c\Xi_3 - ab)a}{\zeta}, \Gamma_3^{NW} = \frac{(a\Xi_2 - bc)}{\zeta}, \Gamma_1^{NS} = \frac{(a\Xi_2 - bc)b}{\zeta_2}, \Gamma_2^{NS} = \frac{(b\Xi_1 - ac)b}{\zeta_2}, \Gamma_3^{NS} = \frac{(b\Xi_1 - ac)\Xi_2 + (a\Xi_2 - bc)c}{\zeta_2}$; $\Xi_1 = (1 - \alpha - c)$, $\Xi_2 = (1 - b - c)$, $\Xi_3 = (1 - \alpha - b)$, where b and c are the openness of South and RoW; $\zeta = \left(\Xi_1\Xi_3 - a^2\right)(a\Xi_2 - bc) - (ab - c\Xi_3)(\Xi_1 b - ac)$, $\zeta_2 = \left[\left(\Xi_2\Xi_3 - b^2\right)(c\Xi_1 - ac - (bc - a\Xi_2)(c\Xi_3 - ba)).\right]$.

Writing equation (A.42) in first-difference form implies:

$$\pi_t' = \pi_{N,t} + \lambda_{nw}'\Delta rxr_t' + \lambda_{sw}'\Delta rxr_t'' + \lambda_{ns}'\Delta q_{ns,t} \tag{A.43}$$

where $\pi_{N,t}$ is North's domestic goods price inflation. Since under Calvo pricing $\pi_{N,t}$ is given by:

$$\pi_{N,t} = \beta' E_t \pi_{N,t+1} + \kappa_a'\left(y_t' - yf_t'\right) \tag{A.44}$$

where $\kappa_a' = \frac{(1-\beta'\theta')(1-\theta')}{\theta'}\left(\sigma'\frac{Y'}{C'}\frac{1}{\Theta'} + \varphi'\right)$, θ' is the Calvo-non-adjusting probability, and φ' is the inverse of the wage elasticity of labour, the Phillips curve (A.2) can be obtained by substituting (A.44) into (A.43) for $\pi_{N,t}$.

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.

See Table B1.

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	√	√	√
Productivity	HP trend of GDP	–	√	√	√
Government spending	Government spending	OECD	√	√	√
Inflation	Quarter-on-quarter CPI inflation	OECD	N.A.	N.A.	√
Market interest rate	Market lending rate (the ODCs rate)	EAS, IMF	N.A.	N.A.	N.A.
Policy interest rate	ECB: average of N/S market rates	–	N.A.	N.A.	N.A.
	RoW CB: set to equal the market rate	–	N.A.	N.A.	N.A.
Effective exchange rate	Broad EER for the EU area	FRED	N.A.	N.A.	√

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

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