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Abstract

We analyse the likely effects of changes in the monetary and financial regimes of EMU countries on the dynamics of output and inflation. In particular, we evaluate the impact of the regime shift on the forecasting performance of reduced-form models. Data for both the pre-EMU and the EMU regimes are generated by a relatively standard open-economy-DSGE model with sticky prices and wages, and restricted access to financial markets for some individuals. We find that the effects of the shift in the monetary regime on the processes followed by macroeconomic variables depend on the nature of the shocks impacting the economy. For plausible shock distributions the reduction in the accuracy of VAR-based inflation forecasts is relatively large and significant. The effect of the regime shift on output forecasts seems rather more modest and statistically insignificant. The impact on ouput forecasting accuracy would be comparatively much larger if the new monetary union regime were accompanied by a moderate relaxation of constraints affecting financial market access.

JEL codes: E17, E32, E37

Keywords: Forecasting, General equilibrium models, Monetary Union, Inflation and Output dynamics.

1. Introduction

In the last few years, central banks and other policy institutions have shown an increasing interest in Neo-Keynesian DSGE models (see e.g. Woodford's 2003 textbook) as a promising framework to conduct forecasting and policy analysis. This interest should come as no surprise. These models are micro-founded and, as they assume sticky prices, allow nominal variables to play a relevant role. Moreover, equilibrium conditions can be approximated by a set of explicit economic relations that resemble those of traditional macro-models -albeit with fully endogenous expectational terms- in which parameters are deep in the sense of being related to structural features of the economy. Last but not least, by exploiting optimising conditions of a representative agent, this framework provides a useful device to discuss optimal policy choices.

The new models seem, in practice, quite suitable for analysing euro zone economies[1]. As countries participating in EMU have experienced a sharp change in the rules governing interest rate decisions with respect to the previous regime, the presumption is that forecasts and policy simulations based on non-structural models will be heavily flawed as a consequence of their substantive exposure to the Lucas critique (Lucas, 1976). Only with a large number of observations in the new monetary union regime would those models be able to recover the forecasting ability they may have had in the previous regime. By contrast, DSGE models need much less information to accommodate changes in the monetary regime by modifying the structural parameters which have been affected by the regime shift.

However, the new-generation DSGE models are currently subject to intensive scrutiny by the profession. So far, their forecasting ability does not seem generally superior to more traditional macro models[2]. This explains why, despite their many theoretical shortcomings, many institutions continue using standard reduced-form

[1] The Eurosystem has already shown a keen interest in exploring the capabilities of new DSGE models.To our knowledge, at least the ECB and the National Central Banks of Germany, France, Italy, Finland and Spain already have or are currently developing DSGE models.

[2] There have recently been some interesting attempts to build a bridge between VAR and DSGE models using Bayesian techniques (see del Negro and Schorfeide, 2004 and 2005 and del Negro et al., 2005). This approach has already delivered some promising forecasting results by combining the in-sample fit of VARs with the more robust and parsimonious parametrisation of DSGE models.

models in their forecasting exercises. Along the same lines, some central banks (see Bank of England, 2005) have already constructed hybrid models with a core micro-founded part and a number of more ad-hoc components that help to improve the forecasting performance.

Arguably, this suboptimal forecasting performance of DSGE models is partly due to the lack of empirical relevance of some of their theoretical advantages. Most researchers would agree that major changes in the so-called deep or structural parameters in an economy might have significant effects on the dynamics of output and inflation. But it is also true that these kinds of developments are unusual, and that policy changes of a more limited scope are likely to have a meagre, hardly noticeable, effect. Along these lines Taylor (1989, 1999), Estrella and Fuhrer (1998) and Rudebusch, (2005), among others, have argued that plausible variations in monetary policy rules do not change actual macroeconomic dynamics in a statistically and/or economically significant manner[3]. These authors have focused their analysis on the effects of changes in the estimated rules followed by the Fed in the last third of the previous century on the stability of standard VAR models.

The issue remains open, however as to whether the negative results on the relevance of the Lucas critique found for the US apply also to a deeper regime shift such as the creation of a monetary union in Europe. This implies a potentially large transformation as a result of the elimination of exchange rate fluctuations across member countries and the adoption of a brand-new common monetary policy for all of them.

An additional element to be taken into account is that, in conjunction with EMU membership, most euro-zone economies have experienced other major structural transformations that are only partially linked to euro adoption. In particular, households' balance sheets have changed markedly in several countries as a consequence of the consolidation of an environment of macroeconomic stability, lower financing costs, and increased flexibility and competition in the financial sector. Those developments are also likely to influence the monetary transmission mechanism and, therefore, the dynamics of macroeconomic variables in a relevant

[3]See Lindé (2001) as an example of the opposite view.

manner[4].

In this paper we provide an analysis of the likely effects of changes in the policy regime caused by EMU on the dynamics of output and inflation as represented by reduced-form models. We take as a reference for the analysis an economy whose central bank conducted a policy of a partial exchange rate peg before joining a Monetary Union (MU). As in other papers we generate artificial data for both regimes using a relatively standard two-country DSGE model with sticky prices and wages. However, unlike previous studies for the US -such as Rudebusch (2005) or Lubik and Surico (2006)- we do not rely on the statistical significance of the structural change of reduced-form parameters as the metric to evaluate the relevance of the policy change. We rather assess the forecasting performance in the MU regime of reduced-form models estimated with data belonging to the previous regime.

In order to take into account the effects of a paralell process of financial liberalisation we consider that -as our economy enters MU- the proportion of individuals with access to financial markets increases. This allows us to compare also the effects on macroeconomic dynamics and the forecasting performance of reduced-form models of the change in the monetary regime with that of financial development.

The structure of the rest of the paper is as follows. Section 2 outlines the theoretical model and derives impulse-response functions of output and inflation under both the pre-MU and MU regimes. Section 3 presents our metric to assess relative forecasting performance and applies it to VAR models estimated with data generated by our artificial economy under both regimes. In order to provide a comparison with previous literature on the topic, we also apply that metric to a change in the parameters of the rule followed by monetary policy in the pre-EMU regime. Section 4 analyses the case of financial liberalisation. Section 5 concludes.

2. The model

We model a world with two countries. Households in both countries trade in domestic and foreign one-period bonds. The central bank in each country exe-

[4] A case in point is Spain. In this country, the household debt/Gross Disposable Income ratio has increased more than twofold since the mid- nineties. Moreover, according to available micro-information, the proportion of indebted households, which was around 30% in 1995, is now approaching 50%. See Malo de Molina and Restoy (2005) for an analysis of the macroeconomic implications of these developments in the Spanish economy.

cutes monetary policy according to a standard interest rate rule that includes the exchange rate as one of its arguments:

$$R_t = R_{t-1}^{\rho_R} \left(\frac{\pi_t}{\pi}\right)^{(1\text{-}\rho_R)\rho_\pi} \left(\frac{y_t}{y}\right)^{(1\text{-}\rho_R)\rho_y} \left(\frac{s_t}{s}\right)^{-(1\text{-}\rho_R)\rho_s} \upsilon_t^{(1\text{-}\rho_R)} \tag{2.1}$$

where R_t is the gross nominal interest rate, π_t is the inflation rate and s_t represents the exchange rate. Variables without the t subscript represent the corresponding steady-state values and υ_t is an unanticipated monetary shock. This partial peg captures a key feature of many European countries in the run-up to the euro.

Except for their size, and a few other features to be mentioned below, the domestic and foreign economies are symmetric. Thus, for simplicity, we describe the domestic economy in detail and make explicit where it differs from the foreign one.

2.1. Households

2.1.1. Consumption and saving

There are two types of households. A proportion Γ are 'rule of thumb' consumers (RoT hereafter) who decide on optimal consumption ($c_{r,t}$) and labour ($n_{r,t}$), without access to the financial market (Galí, López-Salido and Vallés, 2004). Given the amount of hours worked (to be defined later), these households consume all their (labour) income and hence consumption is given by

$$c_{r,t} = \frac{W_t}{P_t} n_{r,t} \tag{2.2}$$

where $\frac{W_t}{P_t}$ represents the real wage.

Unconstrained (intertemporal optimising) households have access to perfect capital markets and maximise the following separable utility function defined in terms of consumption ($c_{o,t}$) and leisure (1-$n_{o,t}$),

$$U_t(i){=}E_t \sum_{t=0}^{\infty} \beta^t a_t \left[\frac{1}{1\text{-}\sigma} \left(\frac{c_{o,t}(i)}{c_{o,t-1}^{\gamma}(i)} \right)^{(1\text{-}\sigma)} \text{-} \frac{(n_{o,t}(i))^{(1+\varphi)}}{1{+}\varphi} \right] \tag{2.3}$$

subject to

$$B_{H,t}(i){+}\frac{B_{F,t}(i)}{s_t}{+}P_t c_{o,t}(i) \leq R_{t-1} B_{H,t-1}(i){+}\frac{R_{t-1}^{*} B_{F,t\text{-}1}(i)}{\Psi\left(b_{F,t-1}\right) s_t}{+}W_t n_{o,t}(i){+}\int_0^1 \omega_t(j) dj \tag{2.4}$$

where β is the discount factor, a_t is a preference shock, σ is the (inverse of the) intertemporal elasticity of substitution of consumption, and φ is the inverse of the elasticity of labour when holding the marginal utility of consumption constant. We also assume some degree of habit formation in consumption indexed by γ ($\gamma \in [0,1]$). Optimising households earn labour income as well as capital income stemming from the ownership of domestic firms ($\int_0^1 \omega(j)dj$) and from domestic (B_H) and foreign bond (B_F) holdings (the latter denominated in foreign currency). There is no capital and the price of foreign bonds is augmented by a premium (Ψ) that varies with the total amount of foreign bonds held by domestic residents (Benigno, 2001). In particular, we assume that the premium depends on the ratio of foreign asset holdings as a proportion of nominal value added, $b_{F,t-1}$ $\left(\text{equal to } \frac{B_{F,t-1}}{s_{t-1}P_{t-1}Y_{t-1}}\right)$, such that if $b_{F,t-1}>0$, the return on asset holdings is reduced, whereas the cost of servicing the debt is higher if country H is a borrower ($b_{F,t-1}<0$)[5]. Under this assumption $B_{F,t}$ tends to its steady state value (which we assume to be zero without loss of generality) rendering the model stationary in the presence of transitory shocks[6]. As an additional simplification we assume zero aggregate net supply of both countries' bonds and also that domestic H bonds can only be held by domestic residents, so that the following aggregate (financial) market clearing conditions hold at any t:

$$B^*_{H,t} = 0 \tag{2.5}$$

$$B_{H,t} = 0 \tag{2.6}$$

$$B_{F,t} + B^*_{F,t} = 0 \tag{2.7}$$

The aggregate first-order conditions of this optimisation problem are:

$$\lambda_t = \begin{matrix} a_t \left[\frac{c_{o,t}}{(c_{o,t-1})^\gamma}\right]^{-\sigma} \frac{1}{(c_{o,t-1})^\gamma} \\ -\beta\gamma E_t a_{t+1} \left[\frac{c_{o,t+1}}{(c_{o,t})^\gamma}\right]^{-\sigma} c_{o,t+1} \frac{(c_{o,t})^{\gamma-1}}{(c_{o,t})^{2\gamma}} \end{matrix} \tag{2.8}$$

$$\lambda_t = \beta E_t \frac{R_t \lambda_{t+1}}{\pi_{t+1}} \tag{2.9}$$

[5] This cost function is such that $\Psi(0)$=1.An example of this function would be: $\Psi(b_{F,t-1}) = e^{-\Psi b_{F,t-1}}$

[6] Schmitt-Grohé and Uribe (2003) explore alternative ways to remove non-stationarity in open-economy models with incomplete markets, stemming from the accumulation of foreign assets, and find that all produce similar conditional and unconditional correlations.

$$\lambda_t = \beta E_t \frac{R_t^* \lambda_{t+1}}{\Psi(b_{F,t})\pi_{t+1}} \left(\frac{s_t}{s_{t+1}}\right) \tag{2.10}$$

where λ_t is the Lagrange multiplier associated with the budget constraint of optimising households. Substituting (2.10) into (2.9) we obtain the uncovered interest rate parity condition:

$$E_t \frac{R_t^* \lambda_{t+1}}{\Psi(b_{F,t})\pi_{t+1}} \left(\frac{s_t}{s_{t+1}}\right) = E_t \frac{R_t \lambda_{t+1}}{\pi_{t+1}} \tag{2.11}$$

2.1.2. Wages and employment

The labour market does not clear. Workers set nominal wages and employment is decided by firms. Each household supplies a different type of labour and thus has some monopoly power in the labour market. A labour aggregator combines labour services from all households and sells a bundle of such services to firms according to a CES aggregation technology:

$$n_t = \left[\int_0^1 n_t(i)^{\frac{\varepsilon_W - 1}{\varepsilon_W}} di\right]^{\frac{\varepsilon_W}{\varepsilon_W - 1}} \tag{2.12}$$

where n_t is aggregate per capita hours and ε_W is the elasticity of substitution among labour varieties. Since firms do not discriminate between unconstrained and RoT households, the following holds:

$$n_{r,t} = n_{o,t} = n_t$$

The aggregator minimises the cost of producing a given amount of aggregate labour, taking $W_t(i)$ as given. Household i's labour demand is thus given by:

$$n_t(i) = \left(\frac{W_t(i)}{W_t}\right)^{-\varepsilon_W} n_t \tag{2.13}$$

From the zero profit condition of the labour aggregator we obtain the aggregate nominal wage $W_t = \left(\int_0^1 W_t(i)^{1-\varepsilon_W} \, di\right)^{\frac{1}{1-\varepsilon_W}}$.

Households are wage-setters in the labour market. Following Erceg, Henderson and Levin (2000), each period only a fraction $1-\theta_w$ of workers reset their nominal wage to maximise utility. Let $\widetilde{W}_t$ (for simplicity we drop the index i) denote the newly set wage at time t. Until the next reoptimisation, the nominal wage is adjusted automatically each period according to the indexation rule: $W_t = W_{t-1}d_t^{\xi^W}$, where d_t is the (gross) nominal wage indexation rate, which we assume to be a function of aggregate variables observed at time $t-1$. There is partial indexation, measured by ξ^W.

Solving for the optimal wage $\widetilde{W}_t$ and aggregating across symmetric individuals we have.

$$\widetilde{W}_t = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k n_{t,t+k} U_{c,t,t+k} MRS_{t,t+k}}{E_t \sum_{k=0}^{\infty} (\beta\theta_w)^k n_{t,t+k} U_{c,t,t+k} \frac{\prod_{i=1}^{k} d_{t+i}^{\xi^W}}{PC_{t+k}}}$$

where variables $x_{t,t+k}$ refer to the realisation at $t+k$ of variables chosen by households that set wages at t. Given that we assume complete domestic markets, we have it that $\lambda_{t,t+k} = \lambda_{t+k}$ and using the firm's optimal labour demand we can relate the individual marginal rate of substitution to the average in the following way

$$MRS_{t,t+k} = MRS_{t+k} \left(\frac{n_{t,t+k}}{n_{t+k}} \right)^{\varphi} = MRS_{t+k} \left[\left(\frac{\widetilde{W}_t}{W_t} \right) \prod_{i=1}^{k} d_{t+i}^{\xi^W} \right]^{-\varphi\varepsilon_w} \tag{2.14}$$

$$MRS_{t+k} = \frac{a_t \left(n_{t+k} \right)^{\varphi}}{\lambda_{t+k}} \tag{2.15}$$

Finally, given the aggregate wage index defined above, the law of motion of aggregate wages is:

$$W_t = \left[(1-\theta_w) \left(\widetilde{W}_t \right)^{1-\varepsilon_w} + \theta_w \left(W_{t-1} d_t^{\xi^W} \right)^{1-\varepsilon_w} \right]^{\frac{1}{1-\varepsilon_w}} \tag{2.16}$$

2.2. Firms

2.2.1. Final goods producing firms (final goods aggregators)

Production takes place at different stages. There is a continuum of firms producing different varieties of goods using capital and labour; these firms exploit their (limited) monopoly power to set prices as a mark-up over marginal costs. At a second stage, intermediate aggregators combine those varieties in order to generate bundles that are sold to the final aggregators of consumption and investment goods. The final goods aggregators combine these bundles of goods into the different baskets of goods demanded by households. All aggregators are competitive and obtain zero profits.

We assume that all goods are traded. Consumption c_t is a composite of goods produced at home, $c_{H,t}$, and imported from abroad, $c_{F,t}$:

$$c_t = \left[(\omega_H)^{\frac{1}{\rho}} (c_{H,t})^{\frac{\rho-1}{\rho}} + (\omega_F)^{\frac{1}{\rho}} (c_{F,t})^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \tag{2.17}$$

where ρ is the elasticity of substitution. The relative value of parameters ω_H and ω_F captures the bias towards domestic goods in consumption. The relative demand for imported goods is given by:

$$\frac{c_{F,t}}{c_{H,t}} = \frac{\omega_F}{\omega_H} \left(\frac{s_t^{-1} P_{F,t}}{P_{H,t}} \right)^{-\rho} \tag{2.18}$$

where $s_t^{-1} P_{F,t}$ is the price of imported goods denominated in domestic currency and $P_{H,t}$ is the price of domestic consumption goods. Thus, we are assuming complete and immediate pass-through. The CPI consistent with the zero profit condition of final goods aggregators may be expressed as:

$$P_t = \left[\omega_H (P_{H,t})^{1-\rho} + \omega_F \left(s_t^{-1} P_{F,t} \right)^{1-\rho} \right]^{\frac{1}{1-\rho}} \tag{2.19}$$

2.2.2. Intermediate aggregators and price-setting.

Intermediate aggregators combine the different varieties of goods produced by the different sectors of production and aggregate them into a composite good. Thus, $c_{H,t}(j)$ varieties are aggregated in a bundle $c_{H,t}$, sold at $P_{H,t}$; these varieties are imperfect substitutes with elasticity of substitution ϕ:

$$c_{H,t} = \int_0^1 \left(c_{H,t}(j)^{\frac{\phi-1}{\phi}} dj \right)^{\frac{\phi}{\phi-1}}$$

where

$$c_{H,t}(j) = c_{H,t} \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\phi} \tag{2.20}$$

and

$$P_{H,t} = \int_0^1 \left(P_{H,t}(j)^{1-\phi} dj \right)^{\frac{1}{1-\phi}} \tag{2.21}$$

As in Calvo (1983) firms set nominal prices on a staggered basis. Each firm resets its price with probability 1-θ each period, irrespective of the time elapsed since the last adjustment. Each period a proportion 1-θ of producers reset their prices, while θ^k is the probability that the price set at time t will still hold at time t+k (thus, flexible prices require θ=0). Furthermore, the fraction θ of firms that cannot reset their prices optimally adjust their price according to steady-state inflation (π_H): $P_{H,t}(j) = P_{H,t-1}(j)\pi_H$.[7]

Firms are symmetric in equilibrium and the newly set price at each t ($\widetilde{P}_{H,t}$) is given by:

$$\widetilde{P}_{H,t} = \left(\frac{\phi}{\phi - 1}\right) \frac{E_t \sum_{k=0}^{\infty} (\beta\theta)^k \zeta_{t+k} P_{H,t+k} mc_{t,t+k} y_{t+k}}{E_t \sum_{k=0}^{\infty} (\beta\theta)^k \zeta_{t+k} \prod_{i=1}^{k} \left(\pi_{H,t+i-1}\right)^{\xi^P} y_{t+k}} \tag{2.22}$$

where $U_{c,t+k}$ is the marginal utility of consumption at t+k and ζ_{t+k}=$\left(\frac{U_{c,t+k}}{U_{c,t}}\right)$. This equation can be interpreted as a dynamic markup equation, so firms set prices using the expected future changes in demand and marginal costs. We assume $mc_{t,t+k}(j) = mc_{t+k}$:

$$mc_{t+k} = \frac{1}{(1-\alpha)} \left(\frac{W_{t+k}}{P_{t+k}}\right) \left(\frac{n_{t+k}}{y_{t+k}}\right) \tag{2.23}$$

Only a fraction 1-ω of those firms that are actually allowed to optimally set prices at t actually do so through this optimising process. The remaining fraction, ω, chooses its price ($P_{H^B,t}$) according to a simple backward-looking rule

$$P_{H^B,t} = P_{H,t-1}\pi_{H,t-1} \tag{2.24}$$

where $P_{H,t-1}$ is the average price at t-1. Finally, since the different varieties of goods aggregate to a composite good through an Armington aggregator, the corresponding aggregate price will be given by:

$$P_{H,t} = \left[\theta \left(P_{H,t-1}\pi_H\right)^{1-\phi} + (1\text{-}\theta)(1\text{-}\omega)\widetilde{P}_{H,t}^{(1-\phi)} + (1\text{-}\theta)\omega P_{H^B,t}^{(1-\phi)}\right]^{\frac{1}{1-\phi}} \tag{2.25}$$

Once demand and prices of the different varieties of goods in each sector are set, firms determine their factor demands by minimising costs taking the prices of inputs as given and subject to the following technological constraint:

$$y_t(j) = (z_t n_t(j))^{1-\alpha} \tag{2.26}$$

[7] Smets and Wouters (2003) introduce inflation inertia through an alternative assumption about indexation. Firms that cannot reset their prices optimally adjust prices according to a simple indexation rule, so as to catch up with lagged inflation: $P_{H,t+i}(j) = P_{H,t+i-1}(j)\left(\pi_{H,t+i-1}\right)^{\xi^P}$ where ξ^P is a parameter that indicates the degree of non-optimisers' price adjustment whose extreme values reflect no indexation ($\xi^P = 0$) or full indexation ($\xi^P = 1$).

Labour demand is given by,

$$mc_t(j)\frac{\partial y_t(j)}{\partial n_t(j)} = \frac{W_t}{P_{H,t}(j)} \tag{2.27}$$

2.3. Calibration

We obtain a numerical solution for the log-linear system. Although we do not have a specific euro area economy in mind, we set in our benchmark calibration relatively conventional parameter values for a medium-sized and fairly open economy. We would then conduct sensitivity analysis in order to check the robustness of our results to different parameter values including those governing the size and the degree of openness. Table 2.1 summarises the values of the calibrated baseline parameters. The relative risk aversion coefficient (σ) is 2, the quarterly discount factor (β) is $0.98^{0.25}$ and the habits, γ, parameter is set to 0.75.[8]

The elasticity of output with respect to efficient labour (1-α) is 0.6, as in Cooley and Prescott (1995). The standard deviations (σ_a, σ_z) of the shocks are set to reproduce a 1% standard deviation of domestic output, whereas the first-order autocorrelation coefficients ρ_a and ρ_z are 0.9. Foreign and domestic shocks are symmetric unless stated otherwise[9].

The probability of price adjustment in a given period (1-θ) is 0.25, in line with some of the values of this parameter estimated for the euro area by Galí, Gertler and López-Salido (2001), and we have assumed a similar frequency in wage adjustment (1-θ_W=0.25). Finally, inflation inertia (ω) is set to a moderate 0.5.

The proportion of RoT consumers varies across countries in the baseline. We assume that the smallest economy also displays a higher proportion of constrained consumers ($\Gamma = 0.6$) than the larger one ($\Gamma^* = 0.3$) before EMU. In section 4 we will explore the case in which the proportion of RoT consumers in the small country converges on that of the large country. This is meant to represent the process of financial liberalisation that some countries may have experienced along with economic integration in Europe.

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[8] Andrés, Lopez-Salido and Vallés (2006) estimate even larger values of this parameter for the euro area.

[9] To facilitate interpretation, impulse response functions are obtained with different shock variances. These are chosen in order to obtain a response of GDP with respect to the steady state of 1%. Given the simplicity of the model we do not aim to replicate the second moments of GDP; however, our calibration yields volatilities of output close to those reported by Agresti and Mojon (2001) for the euro area.

We assume trade balance in the steady state. The share of imports of the domestic economy is 0.4, while the larger economy is much less open $(0.4\left(\frac{C}{C^*}\right)$ where $\left(\frac{C}{C^*}\right)$=0.1 is the relative size). The elasticity of substitution between domestic and imported consumption goods (ρ) is 1.5 (see Chari, Kehoe and McGrattan, 2002). The weights in aggregators (ω_H, ω_H^*, ω_F and ω_F^*) that define the home bias are consistent in the steady state with the calibrated values of ρ, $\frac{C}{C^*}$, $\frac{C_H}{C}$, $\frac{C_H^*}{C}$, $\frac{C_F}{C^*}$ and $\frac{C_F^*}{C^*}$ discussed above.

The last set of parameters refers to the interest rate rule. In the baseline model, we set the autocorrelation coefficient of the interest rate (ρ_r) equal to 0.5 and the response to inflation deviations from target (ρ_π) equal to 1.5. These values are consistent with the original Taylor rule, although they imply a slightly quicker and more aggressive response of the interest rate to inflation than that usually estimated for EMU countries. The steady-state level of gross inflation (π) is set at $1.02^{0.25}$, i.e. the target level of the ECB. Finally, in the pre-MU years the domestic interest rate is allowed to react to deviations of the exchange rate from target (the foreign policy rate does not accommodate exchange rate variations). This reaction does not imply fixed exchange rates in the benchmark case, but a gradual upward (downward) adjustment in the nominal rate to prevent large depreciations (appreciations): ρ_s=0.5.

2.4. The effects of a currency union on impulse-responses

We now take a first look at the change in macroeconomic dynamics that occurs when both countries form a monetary union, comparing impulse-response functions of output and inflation following different types of shocks under both regimes. In all cases we take as a benchmark for comparison the model with a Taylor-type policy rule that includes a partial exchange rate peg,and an inertial component with calibrated parameters as in Table 1. The foreign central bank has in all cases the same Taylor reaction function (except that there is no peg to the exchange rate ($\rho_s^* = 0$)). The shocks considered are: i) an idiosyncratic demand shock, implemented as a shock to the domestic rate of time preference, a_t; ii) a common demand shock affecting a_t and a_t^*; iii) an idiosyncratic technology shock implemented as a shock to domestic total factor productivity z_t; and iv) a common technology shock that entails changes in z_t and z_t^*.

In the monetary union regime, the common interest rate is set according to a Taylor rule based on area-wide variables weighted according to conventional parameters (ρ_y=0.5, ρ_π=1.5, ρ_R=0.5). Graph 2.1 presents impulse-response functions corresponding to the four shocks considered under the benchmark (pre-MU) and the alternative (MU) regimes.

After a domestic demand shock, the absence of compensating exchange rate appreciation makes inflation increase initially by more under MU than under a partial peg. This higher inflation rate also induces a greater downward response of the real rate (despite the reaction of the nominal rate) and leads to a stronger output response. Thus the moderate reaction of CPI inflation under a partial peg is the consequence of less demand pressure, lower GDP inflation, and the appreciation of the currency. This pattern is reversed after some quarters; the stronger response of domestic inflation under MU exacerbates the loss of competitiveness and makes output decrease more sharply than under the pre-MU regime.

As for idiosyncratic technology shocks, inflation initially falls on impact in both regimes, although the effect is less pronounced in the pre-MU regime as an exchange rate depreciation mitigates disinflation. Price and wage stickiness and the presence of a high proportion of RoT households also make output fall temporarily in both regimes. As wages and prices gradually adjust to the productivity shock, output resumes an expansionary path. Under the pre-MU regime, interest rate hikes moderate output growth which therefore becomes less pronounced than in the partial-peg regime. Since the expected increase of output is lower than under MU, lower expected marginal costs generate, beyond the very short term, lower inflation in the pre-MU regime.

Not surprisingly, common shocks -whether demand or technological- do generate similar output and inflation responses under a partial or a full-peg regime. Since, under common shocks, the exchange rate moves little and home and foreign economies are fairly symmetric, monetary policy actions under both regimes become virtually identical.

3. The empirical relevance of the monetary regime shift

As we have seen in the previous section, output and inflation dynamics are affected when the economy enters a monetary union. The issue we explore now is whether the structural change prompted by the regime shift significantly affects the validity of reduced-form models estimated with pre-MU data to make inference on the MU regime.

3.1. The metric

Since the most common use of reduced-form models is to conduct macroeconomic forecasts, we analyse the extent to which these models -estimated with data belonging to the pre-MU regime- fail to provide accurate forecasts when the economy is under the MU regime. In our setting we will consider that the regime shift does matter empirically only if reduced-form models that ignore that shift significantly underperform similar reduced-form models estimated using data belonging to the new regime. Our metric makes our analysis different from that followed in previous literature on the empirical relevance of the Lucas critique. Most papers have usually relied on tests of stability of parameters in reduced VAR models following a change in the policy regime. While in statistical terms both approaches can hardly offer substantially different results, our metric allows us to derive a more direct and economically meaningful measurement of the performance of VAR models after a monetary regime shift.

We will proceed as follows. We will first generate sets of data, each equivalent to 25 years of quarterly data of output, inflation, interest rates and the exchange rate, for both (pre-MU and MU) regimes using the two-country DSGE model as outlined in section 2.[10] We will then estimate VAR models for each set of data and compare the out-of-sample relative forecasting accuracy in the new (monetary union) regime of the VARs estimated with old (pre-MU) and new (MU) data.

In order to generate data we assume that the economy is subject to the four types of shocks considered in Section 2: namely, an idiosyncratic demand shock, an idiosyncratic supply shock, a common demand shock and a common supply shock. All shocks are independently distributed and follow a univariate AR process. In the initial calibration we have assumed that the variance of the demand shocks is three times larger than that of the supply shocks. This is inspired by the relative ability of both shocks to explain by themselves the variance of output. Moreover, the idiosyncratic shocks are assumed to have the same variance as the common shocks[11]. We will in any case explore the sensitivity of the results to changes in those assumptions.

Relative forecasting accuracy will be measured by means of ratios of mean-squared errors (RMSE) and by the Diebold-Mariano (1995) test of equal forecasts

[10] Actually, we generate 150 observations and discard the first 50 to minimise the dependendence from the initial conditions.

[11] According to Giannone and Reichlin (2006), the relative contribution of common and country-specific shocks to output variability varies markedly across euro-area countries . However, the average contribution of each type of shock is roughly 50% (see Table 4 in that paper).

for a four-quarter horizon. All statistics will be computed using, for each parameterisation of the DSGE model, 5000 simulations of data and the corresponding number of estimated VAR models.

Before we report the results for the regime shift caused by the creation of a currency union, we will check, by way of illustration, what our new metric would say about the empirical relevance of shifts in the parameters of the monetary policy regimes as regards reduced-form models' accuracy. This has so far been the standard experiment conducted in previous papers that dealt with the practical implications of shifts in monetary policy rules. It is, therefore, a natural starting point.

3.2. Changes in monetary policy rules

We consider first our benchmark model under two monetary rules: a very tight monetary policy rule ($\rho_\pi = 3, \rho_y = 0$) and a loose rule ($\rho_\pi = 1.1, \rho_y = .5$). Table 3.1 presents the results of the exercise. Namely, the RMSE for both output and inflation of the VAR model estimated under the old (*tight monetary policy*) regime respect to that of the VAR model estimated with data generated by the new (*loose monetary policy*) regime. To allow comparisons with previous work, the first row reports results for a fairly closed economy ($\frac{C_H}{C} = .95$). The RMSE statistic is fairly small in the case of output and higher in the case of inflation. However, the Diebold-Mariano test does not permit rejection of the hypothesis of equal forecasting errors. These results are consistent with those of Rudebusch (2005) using tests of VAR parameter stability: while, as a consequence of the Lucas critique, the performance of a VAR model estimated under the old regime is expected to be inferior to VAR models estimated under the new regime, it is hard to detect the difference using standard statistical tests. In the second row, we report the same statistics for the case of an open economy ($\frac{C_H}{C} = .6$). As in the case of a closed economy, there is no significant difference in output and inflation forecasts, although RMSEs are larger in the open economy case. This can be seen as an extension -based on a different metric- of Rudebusch's results on the empirical relevance of the Lucas critique to an open economy setting.

In the last four rows of the table we investigate the robustness of the results found for the open economy for different shock structures. Simulations using all shocks are informative but may also hide significant differences in forecasts conditional upon specific shocks. To cope with that we also compute RMSE and Diebold-Mariano statistics for economies subject to each specific shock at a time.

Interestingly, for all four shocks, inflation forecasts are now significantly different across VARs. Moreover, under an idiosyncratic supply shock, the hypothesis that output forecasts are equal can also be rejected. This should not come as a surprise as supply shocks are those which generate the trade-off between inflation and output. Therefore, in a context in which only that type of shock matters, attitudes by central banks towards inflation and output stabilisation would make a clearer difference to output and inflation dynamics. This result suggests that tests of the empirical relevance of the Lucas critique are dependent on the distribution of shocks in DSGE models and therefore on the least structural component of the modelled economy, and one that is difficult to isolate from observed data.

3.3. Forecasts under a currency union

We will now proceed to check the impact of the currency union on the forecasting ability of reduced-form models estimated with data corresponding to the previous partial-peg regime. For the pre-MU regime, the VARs are composed of four variables, namely output, inflation, interest rate and the exchange rate, while in the MU regime the exchange rate is dropped from the VARs. We will start with the benchmark model as outlined in Section 2 using the variance ratios of structural shocks presented above. We will then conduct some sensitivity exercises.

Table 3.2 presents RMSEs and Diebold-Mariano tests of equal forecasts for output and inflation of VAR models estimated with data belonging to the pre-MU or the MU regime. The first row reports results for the benchmark parametrisation. The first striking result is that there is no statistically significant difference in the four-quarter-ahead output forecasts of the pre-MU and the MU VARs. We find however quite different results for inflation forecasts. The pre-MU VAR predicts inflation in the monetary union regime much worse than the MU VAR. Mean squared errors are 30% larger in the pre-MU VAR and the difference is highly significant. This suggests that, as occurred in the case of changes in the parameters of the domestic Taylor rule, variations in the interest rate response to domestic developments do not easily influence output dynamics in a statistically significant manner. However, it seems that the elimination of exchange rate variability does make a difference as regards the CPI inflation process, regardless of the shock structure in the model.

In order to check the robustness of the results, we assume -as we did before- that the economy is subject to only one of the shocks considered. Results are reported in lines 2 to 5 in Table 3.2. These experiments show a remarkable degree of similarity with the benchmark case in which all structural shocks are active. In all four cases, RMSEs of output are relatively small and forecast differences are insignificant. Moreover, in three cases we can reject the hypothesis that inflation forecasts are equal. Only in the case of a common demand shock is the difference not statistically significant, although the RMSE is still quite large (1.34).

In rows 6 to 10 we perform additional sensitivity analysis. In particular, we allow for a smaller elasticity of intertemporal substitution (from $\sigma = 2$ to $\sigma = 4$), in order to increase the sensitivity of consumption to the interest rates (row 6), increase the share of domestic goods (from 60% to 80%) in the consumption basket (row 7), and increase the relative size (from 10% to 50%) of the home economy in relation to the MU total (row 8). We finally allow for full flexibility of prices (row 9) and wages (row 10). As can be seen, within a reasonable range of parameter values, the results for the benchmark exercise hold also for economies which show more aversion to intertemporal substitution of consumption, or are noticeably larger or more closed. Not surprisingly, though, when we allow for flexible prices and/or wages, the statistically significant difference in inflation forecasts disappears. Differences in the monetary regime are only important insofar as monetary policy matters, as is the case in an economy with non-negligible nominal rigidities.

4. The impact of financial development

The process of nominal convergence and integration into a monetary union has entailed structural transformations which may have affected the functioning of the economy in a significant manner. Therefore, by concentrating exclusively on the effects of changes in the monetary regime, the analysis in the previous section may fall short of identifying how EMU has actually changed output and inflation dynamics.

By way of illustration, we assess in this section the impact of a relaxation of the financial constraints faced by the economy. In particular, we assume that when the home country joins the currency union it also converges to the degree of financial development enjoyed by the foreign country. In our simple model - without endogenous financial frictions- this can be approximated by lowering the proportion of consumers who do not have access to financial markets. Thus, the MU regime implies not only a common monetary policy but also an equal weight of constrained consumers in both economies (30%).

As seen in Graph 4.1, the shape of responses to a demand shock is very similar to the case in which we ignore changes in the number of RoT consumers. However, differences in output and, to a lesser extent, inflation responses are larger. As there is now a higher proportion of agents that can borrow against future income, output can respond more to the persistent expansionary demand shock. This also translates into higher inflation vis-à-vis the benchmark case.

The effect of reducing the proportion of RoT consumers becomes more evident when the economy faces an idiosyncratic technology shock. Output in the new MU regime grows persistently more (or falls less) than in the regime of partial peg with a higher number of RoT consumers. Supply shocks tend to reduce hours worked on impact in models with nominal price rigidities (Gali, 1999). This is so despite the fact that current consumption of Ricardian consumers increases along with their permanent (future) income. On the contrary, RoT households must reduce their consumption since their current labor income falls on impact. Thus the impact output response is milder when the proportion of RoT consumers is high enough, and it can even be negative as in our model. Likewise, the response of total consumption, and hence of output, is stronger when the proportion of consumers that trade in the financial market increases. The expansionary effect on output of the reduction in the proportion of constrained individuals more than offsets the expansionary impact of lower (nominal and real) interest rates in the case of an independent monetary policy that partially accommodates movements in the exchange rate. Besides, the MU regime avoids the appreciation of the currency that takes place in the benchmark case after two periods and hence induces a stronger increase in the real wage and in consumption of the restricted consumers.

The relaxation of financial constraints makes little difference on the impact on output and inflation of a common demand shock. In the case of a common technology shock, output falls less in the new regime than in the benchmark case as a higher number of unconstrained individuals permits the economy -through a permanent income effect- to moderate the short-term contractionary impact of the technology shock. Although the shock is common, easier access to credit in the home economy prompts a significant country-specific expansionary effect.

We now turn to check how the relative forecasting ability of pre-MU models is affected when the MU regime also involves a relaxation of financial constraints. Table 4.1 presents the corresponding RMSEs and Diebold-Mariano tests. As can be seen, in the new benchmark, the mean squared error of output in the pre-MU VARs is 21% larger than that of the corresponding MU VARs and the hypothesis of equal output forecasts can be rejected at conventional confidence levels. The

RMSE for inflation is quite large (1.41) and highly significant. As expected, given the impulse response functions above, the main difference with respect to the results in the previous section in which only the monetary rule changed is that now pre-MU VARs display a poorer output forecasting performance (rows 2 to 5). This worse performance, relative to the case in which the proportion of RoT consumers remains constant, is largely due to the impact of supply shocks.

5. Concluding remarks

The results discussed in the previous sections help assess the actual relevance of the Lucas critique for models of countries that have recently joined the euro zone. Modellers are bound to experience considerable difficulties in representing the dynamics followed by the main economic variables. Even considering similar attitudes by National Central Banks towards price and output stabilisation in the pre-EMU period, the focus on euro-wide aggregates of the single monetary policy constitutes a substantial modification of the prevailing monetary regime that may have non-trivial implications for output and price dynamics, particularly if country-specific disturbances continue to be relevant.

Still, we have seen that, from a practical point of view, the shift in the monetary regime may not jeopardise much, by itself, the ability of standard reduced-form models to forecast output. This is broadly in line with previous research on the relevance of changes in the Fed policy rules for the stability of VAR models in the US. In the MU case, however, our results suggest that problems are likely to be much more severe when conducting inflation projections, as the elimination of exchange variability between EMU countries does modify the inflation process in a statistically significant manner. Moreover, as EMU has been accompanied by other structural transformations, the effects of the changes in the monetary regime are likely to underestimate the relevant changes experienced in the dynamics followed by macroeconomic variables in the recent past. Our exercise draws on the fact that the reduction in interest rates together with greater competition and integration in financial markets have increased the ability of individuals to obtain credit, and this has helped them to make more efficient intertemporal expenditure decisions. We have seen that these developments, alongside the shift in the monetary regime, may significantly damage the accuracy of both inflation and output forecasts based on available VAR models.

These results tend, in principle, to provide support for the effort, now undertaken by many Eurosystem central banks, to develop DSGE models whose parametrisation could be robust to changes in the monetary policy strategy. However, our findings also stress the complexity of the task. Failure by standard micro-founded models to properly address the relevant structural changes leads to an inaccurate and, as we have seen, sometimes misleading representation of the response of the economy to specific shocks.

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Table 2.1
CALIBRATION OF BASELINE MODEL

σ	β	α	γ		φ	ε_W	Γ	Γ^*
2.0	$0.98^{0.25}$	0.40	0.75		5	6	0.6	0.3
ω	θ	θ_W	ρ_r	ρ_π	ρ_y	ρ_s	ρ	$\frac{C}{C^*}$
0.5	0.75	0.75	0.5	1.5	0.5	-0.5	1.5	0.1
$\frac{C_H}{C}$	$\frac{C_H^*}{C}$	$\frac{C_F}{C^*}$	$\frac{C_F^*}{C^*}$	Φ	σ_a	ρ_a	σ_z	ρ_z
0.6	0.4	$0.4\left(\frac{C}{C^*}\right)$	$1\text{-}0.4\left(\frac{C}{C^*}\right)$	0.0007	0.0168	0.9	0.0056	0.9

Table 3.1
FORECASTING ACCURACY UNDER CHANGING RULES[1]

	OUTPUT		INFLATION	
	RMSE	D-M	RMSE	D-M
All shocks for closed economy $\left(\frac{C_H}{C} = 0.95\right)$	1.01	0.20	1.32	1.38
All shocks for open economy	1.14	1.61	2.06	1.16
Idiosyncratic demand shock only	0.98	-0.21	2.00	4.06 *
Idiosyncratic supply shock only	1.36	4.17 *	8.60	5.79 *
Common demand shock only	1.16	1.29	2.20	4.18 *
Common supply shock only	1.10	1.70	2.80	4.48 *

[1]Compares forecasting accuracy of 4-variable VAR models estimated with simulated data under first rule with VAR models estimated with data under second rule. RMSE is the ratio of mean-squared errors for a 4-quarter horizon. D-M is Diebold-Mariano Test of equal forecasts. Rules change from very tight $\left(\rho_\pi = 3, \rho_\gamma = 0\right)$ to loose $\left(\rho_\pi = 1, \rho_\gamma = 0,5\right)$. (*) denotes significance at a 95% confidence level.

Table 3.2
FORECASTING ACCURACY OF PRE-MU MODELS[1]

	OUTPUT		INFLATION	
	RMSE	D-M	RMSE	D-M
Benchmark	0.97	0.32	1.35	2.91*
Idiosyncratic demand shock only	1.04	0.81	1.54	3.32*
Idiosyncratic supply shock only	1.15	1.28	2.30	4.24*
Common demand shock only	1.07	0.94	1.34	1.59
Common supply shock only	1.03	0.45	1.45	2.65*
Smaller e.i.s.($\sigma = 4$)	1.01	0.49	1.23	3.05*
Closer economy $\left(\frac{C_H}{C} = 0.8\right)$	1.04	0.53	1.70	2.81*
Larger size (50% of MU)	0.93	-0.57	2.80	4.06*
Flexible prices ($\theta = 0$)	1.03	0.28	1.11	0.87
Flexible prices and wages ($\theta = \theta_\omega = 0$)	1.04	0.76	0.99	-0.20

[1]Compares forecasting accuracy of 4-variable VAR models estimated with simulated pre-MU data with VAR-models estimated with simulated MU data. RMSE is the ratio of mean-squared errors for a 4-quarter horizon D-M is Diebold-Mariano Test of equal forecasts. (*) denotes significance at 95% confidence level.

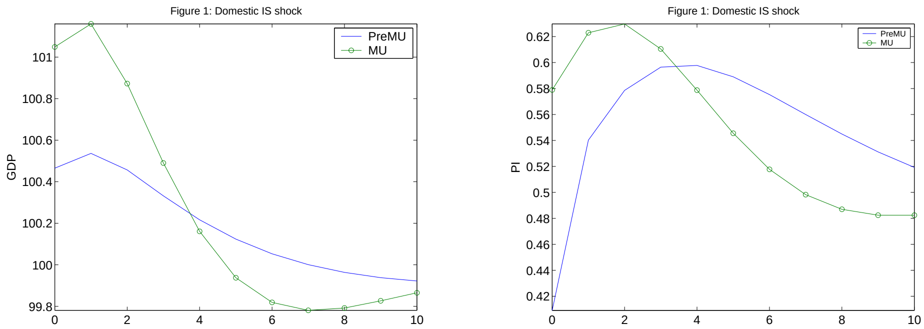
Table 4.1

FORECASTING ACCURACY OF PRE-MU MODELS[1]

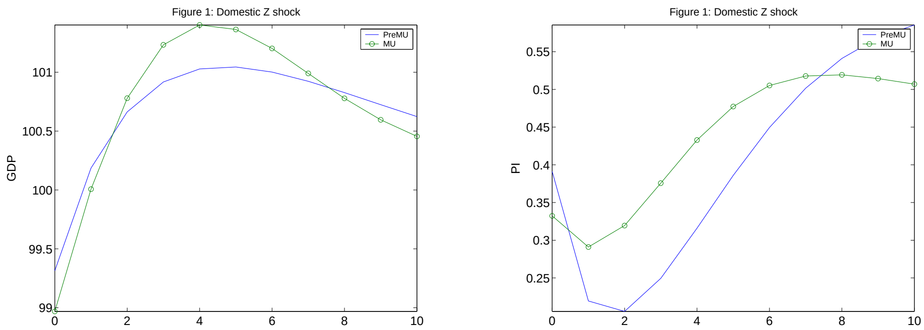
-Including relaxation of financing constraints-

	OUTPUT		INFLATION	
	RMSE	D-M	RMSE	D-M
Benchmark	1.21	2.03 *	1.41	2.76 *
Idiosyncratic demand shock only	1.06	0.71	1.27	0.74
Idiosyncratic supply shock only	1.00	2.28 *	2.46	2.24 *
Common demand shock only	1.12	0.94	1.08	3.31 *
Common supply shock only	1.86	3.27 *	1.31	2.30 *
Smaller e.i.s.$(\sigma = 4)$	1.56	3.40 *	1.33	2.17 *
Closer economy $\left(\frac{C_H}{C} = 0.8\right)$	1.22	0.88	1.71	3.44 *
Larger size (50% of MU)	1.53	2.82 *	3.00	4.63 *
Flexible prices $(\theta = 0)$	1.04	0.69	1.11	1.06
Flexible prices and wages $(\theta = \theta_\omega = 0)$	1.09	1.16	0.99	-0.16

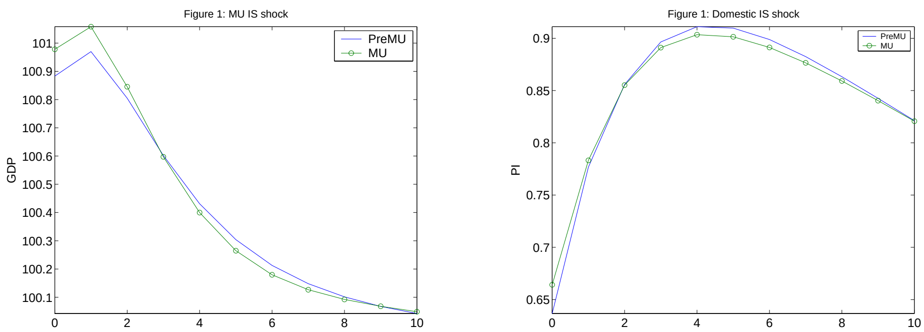
[1]Proportion of constrained (RoT) consumers (Γ) goes from 0.6 in the pre-MU regime to 0.3 in the MU regime. Rest as in Table 3.2.



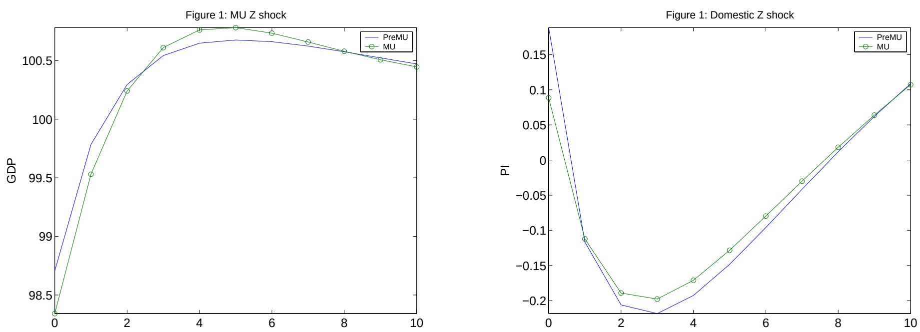
Idiosyncratic demand shock



Idiosyncratic supply shock

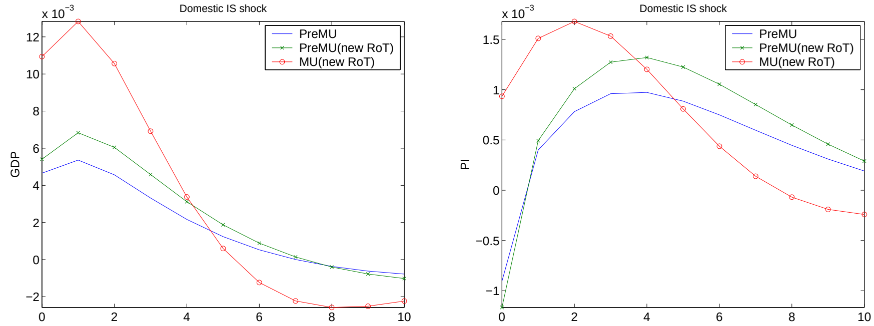


Common demand shock

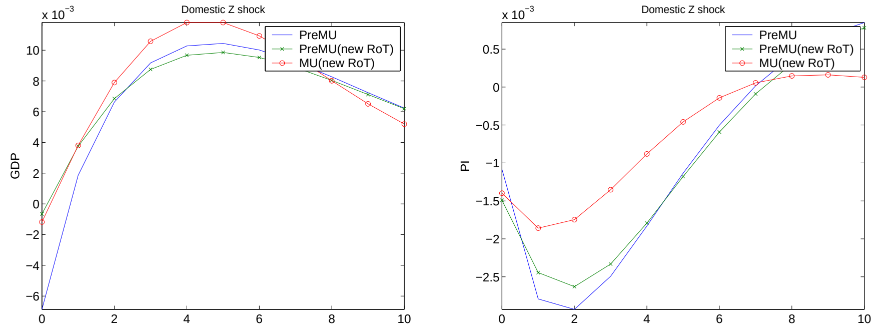


Common supply shock

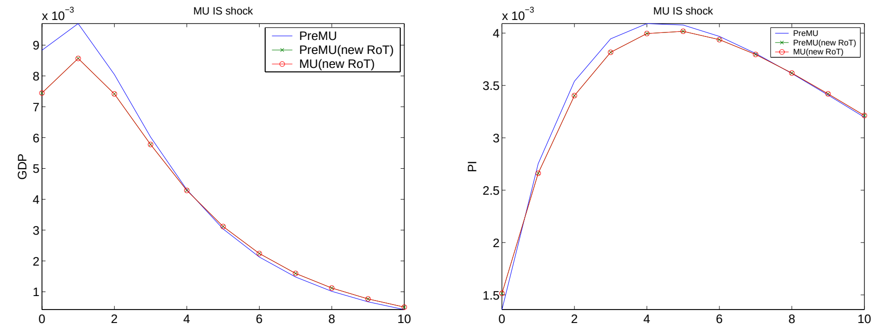
Graph 1: Output and inflation responses under alternative monetary rules. PreMU, vs MU



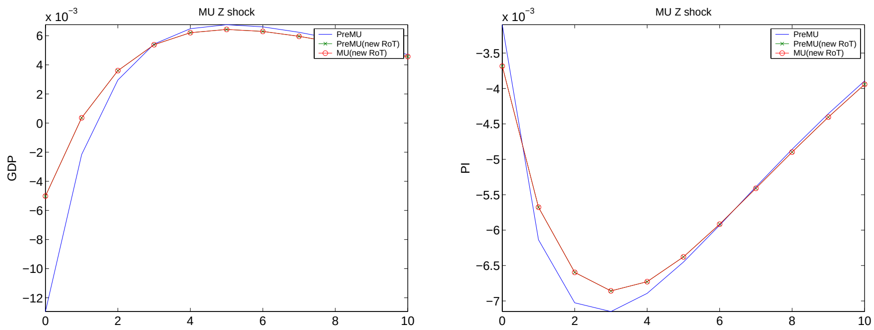
Idiosyncratic demand shock



Idiosyncratic supply shock



Common demand shock



Common supply shock

Graph 2: Output and inflation responses.
PreMU vs MU (New RoT)

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