THE ROLE OF FISCAL POLICY IN A MONETARY UNION: ARE NATIONAL AUTOMATIC STABILIZERS EFFECTIVE?

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Abstract

We assess the role of national fiscal policies, as automatic stabilizers, within a monetary union. We use a two-country New Keynesian DGE model which incorporates non-Ricardian consumers (as in Galì *et al*. 2004) and a home bias in the composition of national consumption bundles. We find that fiscal policies stabilize the aggregate economy but, in some cases, generate conflicting views among national policymakers. Finally, model determinacy requires that national fiscal feedbacks on debt accumulation be designed with reference to the debt dynamics of the entire monetary union. This is in sharp contrast with the "Brussels consensus" based on the view that the ECB alone should stabilize the union-wide economy and national fiscal policies should react to idiosyncratic shocks and to national debt levels.

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1 Introduction

There is a general consensus that national fiscal policies should play an enhanced role in adjusting to macroeconomic shocks within EMU. The absence of national monetary policies, and the potentially destabilising impact of inflation differentials on real interest differentials only leave fiscal policy as a tool to offset country-specific shocks.

Some economists have gone as far as advocating a greater emphasis on fiscal policy as a key policy instrument in macroeconomic adjustment (see Ball, 1999, Wren-Lewis, 2000). In the context of EMU, this has also led to calls to radically reform the Stability and Growth pact (SGP henceforth). Calmfors (2003) argues for a more transparent institutional framework for national (discretionary) fiscal policies within EMU, based on national fiscal committees. Other economists have challenged this perspective and see automatic stabilisers, within the constraints of a reformed SGP, as the key to macroeconomic adjustment within EMU (Buti et al., 1998, 2001). This 'Brussels consensus' is based on the view that the ECB alone should stabilize the union-wide economy.

In this paper we examine the validity of this latter proposition and assess the performance of fiscal stabilisers within a monetary union. We do this using a two-country model. Our model is an extension of the Christiano *et al.* (2005) New Keynesian dynamic general equilibrium model. Until recently, New Keynesian models of this type have been used to study the design of monetary policy, with little or no role for fiscal policy, except for the assumption that lump-sum taxes are employed to ensure fiscal solvency.

Although we employ the basic framework used by Christiano *et al.* (2005), which incorporates wage and price-setting inertia as well as capital utilisation and costs of adjustment in capital accumulation, we extend it in a number of important respects. First, our model includes a greater number of fiscal policy transmission channels than usually found in New Keynesian models[1]. Second, we introduce some "non-Ricardian" effects on consumption due to 'rule-of-thumb' (RT henceforth) consumers (as in Galì *et al.* 2004, 2005, Amato and Laubach, 2003, and Muscatelli *et al.* 2003b). These consumers have limited access to financial markets and hence are constrained to consume out of current disposable income. The presence of limited participation in financial markets introduces an important source of inertia in consumption

[1] For an exception see Andres and Domenech (2005)

behaviour and an important channel through which fiscal policy can operate. Third, we extend the model to a two-country setting. Our two-country model features a home bias in consumption which, as we shall demonstrate, impacts on how automatic fiscal stabilisers interact with monetary policy in a monetary union.

Our analysis does not specifically focus on the 'Fiscal Theory of the Price Level' [2] (see for instance Leith and Wren-Lewis, 2001, 2004), although we do examine under what conditions fiscal policy has to operate to ensure determinacy. Nor we analyze the strategic interactions between the two policymakers, as discussed for instance in Alesina and Tabellini (1987) and more recently in Dixit and Lambertini (2001a,b, 2003)[3]. Instead, the main focus of the paper is on whether fiscal policy, through automatic stabilisers modeled as feedback rules on output, usefully complements the central bank monetary policy.

Earlier contributions to the literature of fiscal policy in the context of New Keynesian models (Andres and Domenech, 2005; Gordon and Leeper, 2003; Muscatelli *et al.*, 2003a) found that countercyclical fiscal policy can be welfare-reducing in the presence of optimizing consumers. Muscatelli *et al.* (2003b) estimate the proportion of RT consumers in the US and show that automatic stabilizers based on taxation improve the performance of the economy. Within EMU, the presence of consumers who do not fully participate in financial markets may be even greater. Asdrubali and Kim (2004) find that, following an output shock, EU capital markets enable a very limited degree of consumption smoothing relative to the US. Fair (2001) finds that, unlike the US, in most EU countries there is little evidence of real interest rate effects on aggregate consumption. Muscatelli *et al.* (2005) also show that the Euro-area seems to have a greater proportion of consumers constrained to consume out of current disposable income[4], and these estimates are used to calibrate our model in order to analyse the relevance of our results for the case of EMU.

Our contribution extends some of the current work in the area of monetary-

[2] Leith and Wren-Lewis (2001) show that under EMU in a model with non-Ricardian consumers (Blanchard-Yaari consumers with finite horizons) no matter what the ECB's monetary policy rule the policy interaction will be unstable unless the fiscal authorities take action to stabilise their debt stock. We analyze this issue below.

[3] For a survey see Beetsma and Debrun (2004).

[4] Our estimates are consistent with the cross country evidence about the share of current income consumers presented in Sarantis and Stewart (2003).

fiscal policy interactions. Benigno and Woodford (2003) examine a specific optimal policy problem involving both fiscal and monetary policy, and make a contribution to the optimal taxation problem. However, in order to derive a linear-quadratic optimal policy problem and focus on analytical solutions the model neglects the existence of non-Ricardian consumers. Galì and Monacelli (2005) analyse fiscal policy within a monetary union, with a large number of small countries (the world economy is modelled a continuum of small open economies), and again to maintain analytical tractability they neglect capital accumulation and non-Ricardian consumers. The closest contribution to our approach is Ferrero (2005), who extends the Benigno-Woodford analysis to a two-country DSGE framework with a monetary union. Ferrero also allows for distortionary taxation, but still maintains the assumption of optimizing consumers with infinite horizons.

The existing literature on fiscal policy in a monetary union has privileged analytical tractability, in order to convey a clear message about the optimality of fiscal policy actions. In this paper we take a different approach. By simulating a calibrated model, we are able to introduce broader range of nominal and real rigidities which have proven crucial to explain some key features of the business cycle. In addition, our contribution about the potential role of national fiscal policies is closely related to the ongoing debate on how fiscal policy should be implemented within the constraints of the SGP, that is, national fiscal policies should be restricted to the working of automatic stabilizers. We believe that such a framework is still relevant because, despite the recent "loosening" of the Pact, it seems unlikely that national policymakers will revert to discretionary policies in the near future.

Our main findings can be summarised as follows. First, using a single closed-economy framework to model union-wide fiscal policy, we demonstrate that fiscal policy can effectively complement monetary policy in stabilising output and inflation for the whole union. The main channel of operation is through the impact of automatic stabilizers on the disposable income of RT consumers. Second, in the context of a two-country monetary union, the analysis of determinacy conditions shows that national fiscal policy feedbacks on debt accumulation cannot be designed separately without reference to the debt dynamics of the entire monetary union. Third, we consider a variety of country-specific shocks to the monetary union. We find that home fiscal policy does tend to stabilise the domestic economy, but that there is some potential conflict in terms of destabilising the other country's output and inflation. Fourth, we find that the stabilising effects of fiscal policy on the home economy (particularly government expenditure) are partly dependent on the existence of a home bias in the composition of national consumption bundles.

In sum, our results suggest a novel approach to the philosophy of EMU macroeconomic policymaking. At the Euro area level, the action of automatic stabilisers should be regarded as a useful complement to the ECB actions. But there are important caveats. First, each country's fiscal policy cannot ignore the union's overall fiscal position, and in particular the total stock of union debt. This calls for a reconsideration of the 'keep-your-own-house-in-order' approach underlying the SGP. Second, the usual case for fiscal stabilisation of within-EMU country-specific shocks using government expenditure is confirmed only if the composition of national aggregate demand functions is sufficiently biased towards domestic production, and only holds unambiguously for certain types of country-specific shock. By contrast, tax rules have important stabilizing effects for the aggregate economy. This is in sharp contrast with the "Brussels consensus" based on the view that the ECB alone should stabilize the union-wide economy and national fiscal policies should react to idiosyncratic shocks (Buti et al., 2001).

In the next section we outline our structural model. Section 3 sets out the way in which we model the policy rules. Section 4 outlines our simulations of the model following various shocks both using a closed-economy and a full two-country version of the model. This will allow us to describe the properties of the model. We describe the main results including the impact of allowing automatic stabilisers alongside the monetary policy rule operated by the central bank. This allows us to quantify the value added of having national fiscal stabilisers in EMU using our two country monetary union model. Section 5 concludes.

2 A Two-country New Keynesian Model with Home-Biased Consumer Preferences

2.1 General Approach

Early vintages of New Keynesian DSGE models involved a limited role for fiscal policy, by assuming lump-sum and representative agents with infinite planning horizons. The standard forward-looking IS curve is driven by "Ricardian" forward-looking consumers, who have full access to complete financial markets. This assumption is contradicted by empirical evidence supporting the view that a significant proportion of consumers are non Ricardian (Campbell and Mankiw, 1989, Mankiw, 2000). Studies of the business cycle using VAR-type models do not provide empirical support for this simple description of demand-side effects in the New Keynesian model. Giavazzi *et al.* (2000) show that both Keynesian and neoclassical (Ricardian) effects are present. Fatas and Mihov (2001), Blanchard and Perotti (2002) and Muscatelli *et al.* (2004) show that fiscal shocks have conventional Keynesian effects, in that an increase in government spending causes a persistent rise in output[5] and consumption.

Galí *et al.* (2005) demonstrate that this problem can be addressed by adding non-optimising behavior to the conventional New Keynesian model. They assume that a proportion of consumers are constrained to consume out of current income and show that, under plausible parameterizations, this provides an explanation for the positive response of consumption to a temporary government spending shock. The increase in government spending generates an increase in the real wage (providing the substitution effect between consumption and leisure dominates the wealth effect), and causes an increase in aggregate consumption because 'RT' consumers spend out of current income.[6] Bilbiie (2005) provides microfoundations of Non-Ricardian behaviour assuming limited participation to financial markets.

Introducing non-optimising consumers also potentially allows for other transmission channels for fiscal policy. Even if taxes are lump sum, they will impact on aggregate consumption behaviour through their effect on the current nominal income of RT consumers[7]. Furthermore, in our model we include payroll taxes that affect marginal costs and inflation. This, in turn, has an obvious impact on aggregate consumption if wages are sticky.

[5] The implied fiscal multiplier is close to or greater than unity.

[6] Whether consumption actually increases in such models depends crucially on the assumptions made about labour supply and price-stickiness, given the linkage between consumption and leisure (and hence the real wage) via the consumer's optimization problem.

[7] There are other ways, however, to model non-ricardian consumers. Debt-financed fiscal deficits will have an impact on aggregate demand in versions of the New Keynesian model which depart from Ricardian equivalence because of the presence of finite horizons, as in the classic Blanchard-Yaari model (Leith and Wren-Lewis, 2000). Other effects of government debt on consumer behavior can also be considered, such as the impact that financial wealth has on household transactions costs, which can explain the observed positive correlation between public expenditure shocks and consumption (see Schabert, 2004).

3 The Model

The global economy (monetary union) consists of two symmetrical countries, the Home (H) and Foreign (F) country. We ignore third-country effects. The global economy is a cashless dynamic general equilibrium model, in many aspects akin to Christiano *et al.* (2005) and Schmitt-Grohe and Uribe (2005). The model accounts for nominal and real rigidities. The former are characterised as stickyness of both prices and wages. The latter originate from internal habit formation in consumption, monopolistic competition in factor and goods markets, costs of adjusting both investment and capacity utilization. In addition, we use the approach of Galì *et al.* (2005), who assume that a fraction of households are constrained to consume out of current income.

Within-Union interactions are modeled as follows: all goods are traded, each country specializes in a subset of consumed goods, the law of one price holds throughout, and consumers exhibit a preference bias towards domestically produced goods.

3.1 Households

Population size is normalized to one at the union level. Each country is populated by a continuum of households of size $\frac{1}{2}$. Intervals $[0, \vartheta)$ and $\left[\frac{1}{2}, \frac{1}{2} + \vartheta\right)$ identify non-Ricardian households (see Galì *et.al* 2005) in country H and F respectively. Symetrically, optimizing households in country H and F are identified by intervals $\left[\vartheta, \frac{1}{2}\right)$ and $\left[\frac{1}{2} + \vartheta, 1\right]$. Variables relative to country F are denoted with an asterisk. Countries H and F are symmetric by construction. Variables relative to Ricardian households are denoted with the superscript o, while those relative to non Ricardian households are denoted with the superscript rt. Households preferences are defined over consumption C_t and and labor effort h_t, and are described by the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\exp\left(\varepsilon_t^c\right) u\left(C_t^i - bC_{t-1}^i\right) - \exp\left(\varepsilon_t^h\right) v\left(h_t^i\right)\right] \tag{1}$$

for $i = rt, o$. E_t denotes the expectation operator conditional on the information set available at time t, $\beta \in (0,1)$ represents the subjective discount factor, C_t^i represents a consumption bundle (to be defined below), $b \in (0,1)$ displays internal habit formation in consumption decisions. The function $u(\cdot)$ is concave and strictly increasing in its argument, while the function

$v(\cdot)$ is convex and strictly increasing in h_t^i. ε_t^c and ε_t^h are preference shocks. ε_t^c represents a "consumption shock" and evolves according to:

$$\varepsilon_t^c = \rho^c \varepsilon_{t-1}^c + \eta_t^c \tag{2}$$

where $0 \leqslant \rho^c < 1$ and η_t^c is a *i.i.d.* random variable with zero mean and variance $\sigma_{\eta^c}^2$. ε_t^h represents instead a shock to the disutility of labor, and evolves according to:

$$\varepsilon_t^h = \rho^h \varepsilon_{t-1}^h + \eta_t^h \tag{3}$$

where $0 \leqslant \rho^h < 1$ and η_t^h is a *i.i.d.* random variable with zero mean and variance $\sigma_{\eta^h}^2$.

3.1.1 Labor Market Description

Our description of the imperfectly competitive labor market follows Schmitt-Grohe and Uribe (2005). In each country[8] there is a continuum of size $\frac{1}{2}$ of differentiated labor inputs indexed by j. Wage-setting decisions are taken by a continuum of unions. More precisely union j monopolistically supplies labor input j on the country-specific labor market j. The union sets the nominal wage, W_t^j, taking as given firms' demand for its labor service. This is given by $h_t^j = 2\left(\frac{W_t^j}{W_t}\right)^{-\alpha_w} h_t^d$ where h_t^d is aggregate labor demand, and W_t is a measure of the average wage in the economy. Formal treatment of labor demand and of W_t can be found in the sub-section devoted to firms. As in Schmitt-Grohé and Uribe (2005) agent i supplies all country-specific labor inputs. Further, following Galì *et al.* (2005), we assume that agents are distributed uniformly across unions[9]. Once the union has determined W_t^j, agent i stands ready to supply as many hours as required by firms. However, the total number of hours allocated to the different labor markets must satisfy the time resource constraint

$$h_t^i = \int_0^{\frac{1}{2}} h_t^j dj \quad \text{and} \quad \left(h_t^i\right)^* = \int_{\frac{1}{2}}^1 \left(h_t^j\right)^* dj$$

Combining the latter with labor demand it follows that

$$h_t^i = 2h_t^d \int_0^{\frac{1}{2}} \left(\frac{W_t^j}{W_t}\right)^{-\alpha_w} dj \quad \text{and} \quad \left(h_t^i\right)^* = 2\left(h_t^d\right)^* \int_{\frac{1}{2}}^1 \left(\frac{\left(W_t^j\right)^*}{W_t^*}\right)^{-\alpha_w} dj \tag{4}$$

[8] We rule out intercountry labor mobility.

[9] This implies that a share ϑ of the associates of the unions are non ricardian consumers

Recalling that i=rt,o, it follows that Ricardian and non Ricardian households belonging to the same country work for the same amount of time, h_t, since labor effort does not depend on any household specific variable. Further, the labor income of a household is

$$2h_t^d \int_0^{\frac{1}{2}} W_t^j \left(\frac{W_t^j}{W_t}\right)^{-\alpha_w} dj \quad \text{and} \quad 2\left(h_t^d\right)^* \int_{\frac{1}{2}}^1 \left(W_t^j\right)^* \left(\frac{\left(W_t^j\right)^*}{W_t^*}\right)^{-\alpha_w} dj \qquad (5)$$

Once again this does not depend on household type, but just on the country of residence[10]. Finally notice that (5) can be written in terms of the country of residence aggregate wage index as:

$$2h_t^d \int_0^{\frac{1}{2}} W_t^j \left(\frac{W_t^j}{W_t}\right)^{-\alpha_w} dj \ = h_t^d W_t$$

and

$$2\left(h_t^d\right)^* \int_{\frac{1}{2}}^1 \left(W_t^j\right)^* \left(\frac{\left(W_t^j\right)^*}{W_t^*}\right)^{-\alpha_w} dj \ = \left(h_t^d\right)^* W_t^*$$

3.1.2 Consumption Bundles

As mentioned above, C_t^i represents the demand of a composite consumption good. This implies, that a given time t each household is called to solve an *intratemporal* problem for the optimal choice of consumption bundles and differentiated consumption goods.

Preferences over consumption bundles are modelled according to a constant elasticity of substitution (CES) specification with parameter $0.5 < \chi < 1$ capturing idiosyncratic taste or *home bias.* The final consumption good is a composite index

$$C_t = \left[\chi^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + (1-\chi)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \qquad (6)$$

where $C_{H,t}$ and $C_{F,t}$ are themselves constructed as CES aggregators of domestically and foreign produce goods respectively. These are defined as:

$$C_{H,t} = \left[2^{1/\theta} \int_0^{\frac{1}{2}} C_{H,t}(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \text{ and } C_{F,t} = \left[2^{1/\theta} \int_{\frac{1}{2}}^1 C_{F,t}(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}}.$$

[10] Firms allocate labor demand on the basis of the relative wage. Since on labor market j there is a unique wage, ricardian and non-ricardian households work the same amount of time on each market.

The parameter $\eta > 1$ measures the elasticity of substitution between consumption bundles $C_{H,t}$ and $C_{F,t}$. The parameter $\theta > 1$ measures, instead, the elasticity of substitution among each of the differentiated goods that form $C_{H,t}$ and $C_{F,t}$.

The national production price indexes are given by[11]:

$$P_{H,t} = \left[2 \int_0^{1/2} P_{H,t}(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}} \text{ and } P_{F,t} = \left[2 \int_{1/2}^{1} P_{F,t}(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

Solving the cost minimization problem for the purchase of one unit of the composite consumption $C_{H,t}$ yields the Home household's demand schedules for goods z produced in country H and F [12]:

$$C_{H,t}(z) = 2 \left(\frac{P_{H,t}(z)}{P_{H,t}} \right)^{-\theta} C_{H,t} \text{ and } C_{F,t}(z) = 2 \left(\frac{P_{F,t}(z)}{P_{F,t}} \right)^{-\theta} C_{F,t}$$

where:

$$C_{H,t} = \chi \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \text{ and } C_{F,t} = (1-\chi) \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} C_t$$

and

$$P_t = \left[\chi P_{H,t}^{1-\eta} + (1-\chi) P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (7)$$

defines the consumption price index which minimizes the cost of purchasing one unit of C_t.

By symmetry, in country F the following relations hold true:

$$C_t^* = \left[(1-\chi)^{\frac{1}{\eta}} \left(C_{H,t}^* \right)^{\frac{\eta-1}{\eta}} + \chi^{\frac{1}{\eta}} \left(C_{F,t}^* \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

$$C_{H,t}^* = \left[2^{1/\theta} \int_0^{\frac{1}{2}} C_{H,t}^*(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \qquad C_{F,t}^* = \left[2^{1/\theta} \int_{\frac{1}{2}}^{1} C_{F,t}^*(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$$

$$C_{H,t}^*(z) = 2 \left(\frac{P_{H,t}(z)}{P_{H,t}} \right)^{-\theta} C_{H,t}^* \qquad C_{F,t}^*(z) = 2 \left(\frac{P_{F,t}(z)}{P_{F,t}} \right)^{-\theta} C_{F,t}^*$$

$$C_{H,t}^* = (1-\chi) \left(\frac{P_{H,t}}{P_t^*} \right)^{-\eta} C_t^* \qquad C_{F,t}^* = \chi \left(\frac{P_{F,t}}{P_t^*} \right)^{-\eta} C_t^*$$

$$P_t^* = \left[\chi P_{F,t}^{1-\eta} + (1-\chi) P_{H,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

[11] $P_{H,t}$ and $P_{F,t}$ are the price of a unit of $C_{H,t}$ and $C_{F,t}$ respectively, when the allocation of demand to each individual good forming $C_{H,t}$and $C_{F,t}$ is optimal.

[12] Notice that $P_{H,t}(z)$ is the price of good z produced in country H, while $P_{F,t}(z)$ is the price of good z produced in country F.

The price of each differentiated good is the same in both countries because there are no impediments to trade. However, due to the idiosyncratic taste introduced in the preferences over consumption bundles, purchasing power parity does not hold: $P_t \neq P_t^*$.

Let us define two others variables that we will be useful throughout the analysis. The CPI-based real exchange rate

$$Q_t = \frac{P_t^*}{P_t}$$

and the terms of trade:

$$S_t = \frac{P_{F,t}}{P_{H,t}} \ .$$

3.1.3 Ricardian Households

In each country, the representative optimizing household makes a sequence of decisions in each period. First it makes a consumption/saving decision. Second, it decides portfolio allocation over physical capital and riskless financial assets. Simultaneously, it decides how many units of capital services to supply[13]. Third, it negotiates contingent claims traded across the Union (as in Galì and Monacelli, 2005). In other words, (1) is maximized subject to the sequence of budget constraints

$$\frac{X_{t+1}}{1+R_t} + P_t \left(C_t^o + i_t \right) = X_t + A_t + \left[r_t^k u_t - a\left(u_t \right) \right] P_t k_t + h_t^d W_t + P_t \left(\phi_t - \tau_t \right) \quad (8)$$

where P_t defines the consumption price level, $h_t^d W_t$ is time t nominal labour income, A_t is the nominal net cash flow from participating at time t in the union-wide state-contingent security market, ϕ_t represents firms' real profits. X_t denotes time t holdings of riskless nominal bonds issued by home and foreign government, which are perfect substitutes. R_t is the nominal interest rate on bond issued at time t. τ_t defines real lump-sum taxes. As pointed out above, optimizing households own the physical stock of capital[14] k_t, and rent it to firms at the real rental rate r_t^k. Furthermore, owners of physical

[13] Up to this stage, the sequence of decisions closely follows Christiano et al. (2005)

[14] We assume that households only hold capital used by domestically located firms. The existence of a union-wide state-contigent securities market makes this assumption innocuous.

capital control the degree of its utilization, u_t. The term $a(u_t)$ defines the real cost of using the capital stock with intensity u_t. Finally, i_t denotes time t real purchases of investment goods. Following Christiano et al (2005) and Schmitt-Grohe and Uribe (2005), the household's stock of physical capital evolves as:

$$k_{t+1} = (1-\delta) k_t + i_t \left[1 - S\left(\frac{i_t}{i_{t-1}} \right) \right] \tag{9}$$

where δ denotes the physical rate of depreciation and the function S introduces investment adjustment costs.

Maximising (1) subject to (8), (9) yields the following set of first order conditions:

$$C_t^o : u_C \left(C_t^o - bC_{t-1}^o \right) \exp\left(\varepsilon_t^c \right) - b\beta u_C \left(E_t C_{t+1}^o - bC_t^o \right) \exp\left(\varepsilon_{t+1}^c \right) = \lambda_t^o P_t \tag{10}$$

$$X_{t+1} : 1 = (1+R_t) E_t \beta \left(\frac{\lambda_{t+1}^o}{\lambda_t^o} \right) \tag{11}$$

$$k_{t+1}^o : \lambda_t^o q_t = \beta E_t \left\{ \lambda_{t+1}^o \left[r_{t+1}^k u_{t+1} - a(u_{t+1}) + (1-\delta) q_{t+1} \right] \right\} \tag{12}$$

$$i_t^o : \left\{ \begin{array}{c} q_t \left[1 - S\left(\frac{i_t^o}{i_{t-1}^o} \right) - S'\left(\frac{i_t^o}{i_{t-1}^o} \right) \frac{i_t^o}{i_{t-1}^o} \right] + \\ +\beta E_t \left[\frac{\lambda_{t+1}^o q_{t+1} \pi_{t+1}}{\lambda_t^o} S'\left(\frac{i_{t+1}^o}{i_t^o} \right) \left(\frac{i_{t+1}^o}{i_t^o} \right)^2 \right] \end{array} \right\} = 1 \tag{13}$$

$$u_t : r_t^k = a'(u_t) \tag{14}$$

Again, note that in our set up consumers delegate wage decisions to the unions and therefore labor supply simply adjusts to meet firms' labour demand.

Following Gali and Monacelli (2005) the international risk sharing implies that the nominal stochastic discount factor be equalized across agents resident in the two countries. This in turn implies that differences in consumption dynamics across the two countries arise as a consequences of consumer price inflation differentials:

$$E_t \left(\frac{u_{C,t+1}}{u_{C,t}} \frac{P_t}{P_{t+1}} \right) = E_t \left(\frac{u_{C,t+1}^*}{u_{C,t}^*} \frac{P_t^*}{P_{t+1}^*} \right)$$

or equivalently

$$E_t \left(\frac{u_{C,t+1}}{u_{C,t}} \right) = E_t \left(\frac{u_{C,t+1}^*}{u_{C,t}^*} \frac{Q_t}{Q_{t+1}} \right)$$

where $u_{C,t} = \lambda_t^o P_t$.

3.1.4 Non Ricardian Households

In each country non-Ricardian households maximize (1) subject to the flow budget constraint:

$$P_t C_t^{rt} = h_t^d W_t - P_t \tau_t$$

First order condition with respect to consumption is given by:

$$u_c\left(C_t^{rt} - bC_{t-1}^{rt}\right) - \beta b u_c\left(C_{t+1}^{rt} - bC_t^{rt}\right) = \lambda_t^{rt} P_t. \tag{15}$$

3.2 Unions and Wage setting

We model nominal rigidities following the mechanism spelled out in Christiano *et al.* (2005). In each period a union faces a constant probability $1-\lambda_w$ of being able to reoptimize the nominal wage[15]. Unions that cannot reoptimize simply index their wages to lagged *consumer price inflation*:

$$W_t^j = (1+\pi_{t-1})^{\gamma_w} W_{t-1}^j$$

where the parameter $0 \leq \gamma_w \leq 1$ represents the degree of wage indexation, and $(1+\pi_{t-1}) = \frac{P_{t-1}}{P_{t-2}}$. In general, if $\widetilde{W}_t$ is the wage that is optimally set at period t, the wage at time $t+s$ reads as $\widetilde{W}_t \Pi_{t,t+s-1}^{\gamma_w}$, where $\Pi_{t,t+s-1} = (1+\pi_t)\ldots(1+\pi_{t+s-1}) = \frac{P_{t+s-1}}{P_{t-1}}$.

The union's objective function, based on the utility functions of both Ricardian and non-Ricardian households, is derived in the Appendix. Let $\widetilde{W}_t$ be the optimal wage chosen at time t in country H. The first order condition for the union's problem is

$$\sum_{T=t}^{\infty} (\beta\lambda_w)^{T-t} \left(\Pi_{t,T-1}^{\gamma_w}\right)^{-\alpha_w} h_T^d \left(W_T^{\alpha_w}\right) \Psi_T \left\{ \frac{\widetilde{W}_t \Pi_{t,T-1}^{\gamma_w}}{P_T} - \frac{\alpha_w \exp\left(\varepsilon_t^h\right) v_h\left(h_T\right)}{(\alpha_w - 1)\Psi_T} \right\} = 0 \tag{16}$$

where we defined $\Psi_T = \left[(1-\theta) P_T \lambda_T^o + \theta P_T \lambda_T^{rt}\right]$ as the average marginal utility of consumption. This implies that $\frac{\exp\left(\varepsilon_t^h\right) v_h(h_T)}{\Psi_T}$ can be interpreted as the time T average marginal rate of substitution between labor and consumption in the domestic country. $\frac{\alpha_w}{\alpha_w - 1}$ represents, instead, the markup over the

[15]By the law of large numbers the wage will be newly reset on a fraction $1-\lambda_w$ of randomly chosen labor markets. Notice that we assume that λ_w does not depend on the country where unions are based.

average marginal rate of substitution which would prevail in the case of wage flexibility. Clearly, if wages were perfectly flexible, the real wage w_t would satisfy

$$w_t = \frac{\alpha_w}{\alpha_w - 1} \frac{\exp\left(\varepsilon_t^h\right) v_h\left(h_T\right)}{\left[\left(1-\theta\right) P_t \lambda_T^o + \theta P_t \lambda_T^{rt}\right]}$$

or[16]

$$\left(\frac{1-\theta}{mrs_t^o} + \frac{\theta}{mrs_t^{rt}}\right) w_t = \frac{\alpha_w}{\alpha_w - 1}$$

3.3 Firms

Goods are indexed by $z \in [0,1]$. We let goods $z \in \left[0, \frac{1}{2}\right)$ and $\left[\frac{1}{2}, 1\right]$ to be produced in countries H and F respectively. Complete integration of national goods markets and the common currency ensure that the price of each differentiated good is the same in both countries. Good z is produced by a monopolist with the following technology:

$$y_t\left(z\right) = \exp(\varepsilon_t^a)\left(k_t\left(z\right)\right)^{\alpha}\left(h_t\left(z\right)\right)^{1-\alpha}$$

where $0 < \alpha < 1$ is the share of income which goes to capital in the long run and ε_t^a is a productivity shock which evolves according to:

$$\varepsilon_t^a = \rho^a \varepsilon_{t-1}^a + \eta_t^a \qquad (17)$$

where $0 \leqslant \rho^a < 1$ and η_t^a is a *i.i.d.* random variable with zero mean and variance $\sigma_{\eta^a}^2$. $k_t\left(z\right)$ is the time t capital service used by firm z to produce good z, while $h_t\left(z\right)$ is the time t quantity of the labor input. This is assumed to be a composite made by the continuum of differentiated labor services provided by domestic households, which is defined below. Firm *z's* nominal total production cost is given by

$$TC_t\left(z\right) = \left(T_t^{pr} + W_t\right) h_t\left(z\right) + R_t^k k_t\left(z\right)$$

where W_t is the minimum cost of purchasing a unit of the composite labor input h_t. We assume firms are subject to the payment of a pay-roll tax, denoted in nominal terms by T_t^{pr}. Factors demand is obtained minimizing

[16]Notice that the latter is the level of real wage computed by Galì et al. (2005), but under wage flexibility.

total production costs. Solving that problem, it is possible to show that the real marginal cost is common across producers:

$$mc_t = \left(\frac{1}{\alpha}\right)^{\frac{1}{\alpha}} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{T_t^{pr} + W_t}{P_{H,t}}\right)^{1-\alpha} \left(\frac{R_t^k}{P_{H,t}}\right)^{\alpha} \exp(\varepsilon_t^a)^{-1}$$

Notice that the marginal cost is deflated using the domestic production price index[17] $P_{H,t}$. Formally, the domestic country[18] labor input is defined as

$$h_t(z) = \left(2^{\frac{1}{\alpha_w}} \int_0^{1/2} h_t^j(z)^{\frac{\alpha_w - 1}{\alpha_w}} dj\right)^{\frac{\alpha_w}{\alpha_w - 1}} \tag{18}$$

where $\alpha_w > 1$ is the intratemporal elasticity of substitution across different labor inputs. For any given level of its labor demand $h_t(z)$, the firm must decide the optimal allocation across labor inputs. This is given by the allocation which minimizes the labor cost $\int_0^{1/2} W_t^j h_t^j(z)\, dj$ subject to aggregation technology (18). Firm's z demand for labor type j is given by

$$h_t^j(z) = 2\left(\frac{W_t^j}{W_t}\right)^{-\alpha_w} h_t(z) \tag{19}$$

where

$$W_t = \left(2\int_0^{\frac{1}{2}} \left(W_t^j\right)^{1-\alpha_w} dj\right)^{1/(1-\alpha_w)} \tag{20}$$

is a wage index which represents the minimum cost of acquiring a unit of the labor inputs bundle 18[19]. The same variant of the Calvo (1983) mechanism considered in the case of wage setting is adopted here. Firms in each period have a chance $1 - \lambda_p$ to reoptimize their nominal price[20]. Non-reoptimizing firms adjust their price to previous period *domestic production price inflation:*

$$p_{H,t}(z) = (1 + \pi_{H,t-1})^{\gamma_p}\, p_{H,t-1}(z)$$

[17] Obviously in country F the marginal cost is deflated using $P_{F,t}$.

[18] The corresponding expression in the foreign country is $h_t^*(z) = \left(\int_{\frac{1}{2}}^1 \left[\left(h_t^j(z)\right)^*\right]^{\frac{\alpha_w-1}{\alpha_w}} dj\right)^{\frac{\alpha_w}{\alpha_w-1}}$

[19] In country F this is given by $W_t^* = \left(\int_{\frac{1}{2}}^1 \left(\left(w_t^j\right)^*\right)^{1-\alpha_w} dj\right)^{1/(1-\alpha_w)}$

[20] For the law of large numbers this implies that a fraction $1-\lambda_p$ will be able to reoptimize their price in each period. We assume the same λ_p for both countries.

where $(1+\pi_{H,t-1}) = \frac{P_{H,t-1}}{P_{H,t-2}}$ and γ_p represents the degree of price indexation[21]. Let $\widetilde{P}_t$ be the price optimally chosen at time t in country H by firms that reoptimize their price. This does not depend on index z. In general, if $\widetilde{P}_k$ is the price that was optimally set s periods ago, the current price will be $\widetilde{P}_k \left(\Pi_{H,(k,k+s-1)}\right)^{\gamma_p}$, where

$$\Pi_{H,(k,k+s-1)} = (1+\pi_{H,k}) \dots (1+\pi_{H,k+s-1}) = \frac{P_{H,k+s-1}}{P_{H,k-1}}$$

Firm z faces the following demand for its good[22]:

$$y_t(z) = C_{H,t}(z) + C^*_{H,t}(z) + G_t(z) + I_t(z) + a(u_t) K_t(z)$$

Using the definitions of the consumption bundles provided in section 3, we can rewrite $y_t(z)$ as.

$$y_t(z) = 2\left(\frac{P_{H,t}(z)}{P_{H,t}}\right)^{-\theta} \left\{ \begin{array}{c} \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \left[\chi C_t + (1-\chi)\left(\frac{P_t}{P^*_t}\right)^{-\eta} C^*_t\right] \\ + \left[G_t + I_t + a(u_t) K_t\right] \end{array} \right\}$$

or

$$y_t(z) = 2\left(\frac{P_{H,t}(z)}{P_{H,t}}\right)^{-\theta} Y^d_t \tag{21}$$

where Y^d_t is aggregate demand in country H. $\widetilde{P}_t$ is chosen as to maximize a discounted sum of expected future profits:

$$E_t \sum_{T=t}^{\infty} (\beta\lambda_p)^{T-t} \lambda^o_T \left(\widetilde{P}_t \Pi^{\gamma_p}_{H,(t,T)} - P_{H,T} mc_t\right) y_t(z)$$

subject to (21). The FOC for this problem is

$$E_t \sum_{T=t}^{\infty} (\beta\lambda_p)^{T-t} \lambda^o_T P^{\theta}_{H,T} Y^d_t \left(\Pi^{\gamma_p}_{H,(t,T)}\right)^{1-\theta} \left[\begin{array}{c} \widetilde{P}_{H,t} - \\ \frac{\theta}{\theta-1} P_{H,T} mc_T \left(\Pi^{\gamma_p}_{H,(t,T)}\right)^{-1} \end{array} \right] = 0 \tag{22}$$

---

[21] $\gamma_w = 1$ represents the case of full indexation.

[22] Consumption, investment and capital are identified by capital letters in order to distinguish them from individual variables. In fact, since capital and investment are variables specific to ricardian households which have measure $(1-\vartheta)$, aggregate variables assume lower values than individual variables.

3.4 Fiscal Authority

For each country, we model public consumption as defined only on domestically-produced goods:

$$G_t(z) = 2\left(\frac{p_{H,t}(z)}{P_{H,t}}\right)^{-\theta} G_t$$

The Government per period budget constraint is, in nominal terms

$$\frac{D_{t+1}}{1+R_t} = D_t + G_t - T_t^{pr} h_t - \tau_t$$

where D_t is the outstanding level of debt at time t.

3.5 Aggregate Resource Constraint.

Considering country H and integrating over $z \in [0, 1/2]$ equation (21) leads to:

$$Y_t = \tilde{D}_{H,t} Y_t^d$$

where $Y_t \equiv \int_0^{1/2} y_t(z)\, dz$ and $\tilde{D}_{H,t} = 2\int_0^{1/2} \left(\frac{P_{H,t}(z)}{P_{H,t}}\right)^{-\theta} dz$.

In country F, it holds true that:

$$Y_t^* = \tilde{D}_{F,t} \left(Y_t^d\right)^*$$

where $Y_t^* \equiv \int_{1/2}^{1} y_t^*(z)\, dz$ and $\tilde{D}_{F,t} = 2\int_{1/2}^{1} \left[\frac{P_{F,t}(z)}{P_{F,t}}\right]^{-\theta} dz$.

4 Functional Forms Assumptions

For both countries we assume the same functional forms[23]. The functions characterizing utility are:

$$u(\cdot) = \ln\left(C_t - bC_{t-1}\right).$$

$$v(\cdot) = \phi_0 \frac{1}{1+\varphi} h_t^{1+\varphi}$$

[23] For a discussion, see Christiano et al. (2005)

Following Christiano *et al.* (2005) the investment adjustment cost function and the capital utilization function are given by:

$$S\left(\frac{i_t}{i_{t-1}}\right)=\frac{\kappa}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2$$

$$a\left(u_t\right)=\gamma_1\left(u_t-1\right)+\frac{\gamma_2}{2}\left(u_t-1\right)^2$$

The function $S(\cdot)$ satisfies the following properties. $S(1)=S'(1)=0$ and $S''(1)>0$. These restrictions imply the absence of adjustment costs up to a first order approximation around the deterministic steady state. The function $a(\cdot)$, instead, is assumed to satisfy $a(1)=0$ and $a'(1), a''(1)>0$.

5 The log-linearized Model

5.1 Demand side of the economy

In the following analysis variables without time subscript denote the value that a variable would assume at the deterministic steady state, while hatted variables denoted log-deviations from that level. Thus $\overline{X}$ indicates the steady state value of variable X, while $\widehat{X}\equiv\log\frac{X_t}{\overline{X}}$.

A log-linear approximation around the steady state to equations (10)-(14) reads as follows:

$$\begin{aligned}\widehat{C}_t^o &= \frac{\mu_1}{\mu_0+\mu_1}\widehat{C}_{t-1}^o+\frac{\mu_0+\mu_1\beta}{\mu_0+\mu_1}E_t\widehat{C}_{t+1}^o+ \\ & -\frac{\mu_1\beta}{\mu_0+\mu_1}E_t\widehat{C}_{t+2}^o-\frac{1}{\mu_0+\mu_1}\left(\widehat{R}_t-E_t\widehat{\pi}_{t+1}\right)+\nu_t\end{aligned} \tag{23}$$

where

$$\nu_t=\frac{1}{\left(\mu_0+\mu_1\right)}\left[\mu_2\varepsilon_t^c-\mu_2\left(1+b\beta\right)E_t\varepsilon_{t+1}^c+\mu_2 b\beta E_t\varepsilon_{t+2}^c\right] \tag{24}$$

$$\widehat{C}_t^{rt}=\left(\frac{C^{rt}}{C}\frac{C}{Y}\right)^{-1}\left[\left(\frac{h}{Y}w\right)\widehat{h}_t^d+\left(\frac{h}{Y}w\right)\widehat{w}_t-\left(\frac{\tau}{Y}\right)\widehat{\tau}_t\right] \tag{25}$$

Moreover, in each economy, it holds true that:

$$\widehat{C}_t = \left(\frac{1-\vartheta}{2}\right)\left(\frac{C^o}{C}\right)\widehat{C}_t^o + \left(\frac{\vartheta}{2}\right)\frac{C^{rt}}{C}\widehat{C}_t^{rt} \tag{26}$$

$$\widehat{q}_t = -\left(\widehat{R}_t - E_t\widehat{\pi}_{t+1}\right) + \left[\beta\left(1-\delta\right)\right]E_t\widehat{q}_{t+1} + \beta r^k E_t\widehat{r}_{t+1}^k \tag{27}$$

$$\widehat{i}_t^o = \frac{1}{\kappa\left(1+\beta\right)}\widehat{q}_t + \frac{1}{1+\beta}\widehat{i}_{t-1}^o + \frac{\beta}{1+\beta}\widehat{i}_{t+1}^o \tag{28}$$

$$\frac{\gamma_1}{\gamma_2}\widehat{r}_t^k = \widehat{u}_t \tag{29}$$

where $\mu_0 = \frac{1+b^2\beta}{(1-b)(1-b\beta)}$, $\mu_1 = \frac{b}{(1-b)(1-b\beta)}$, $\mu_2 = \frac{1}{1-b\beta}$, $\widehat{R}_t = \ln\left(\frac{1+R_t}{1+R}\right)$.

Log-linear approximations of the capital accumulation equation and the aggregate resource constraint are given by:

$$\widehat{k}_{t+1} = \left(1-\delta\right)\widehat{k}_t + \delta\widehat{i}_t \tag{30}$$

$$\widehat{Y}_t = \Gamma\widehat{S}_t + \chi\frac{C}{Y}\widehat{C}_t + \left(1-\chi\right)\frac{C}{Y}\widehat{C}_t^* + \frac{G}{Y}\widehat{G}_t + \frac{I}{Y}\widehat{I}_t + r^k\frac{K}{Y}\widehat{u}_t \tag{31}$$

where $\widehat{k}_t = \widehat{k}_t^o$, $\widehat{i}_t = \widehat{i}_t^o$ and $\Gamma = 2\eta\left(1-\chi\right)\chi\frac{C}{Y}$. Note that to obtain equation (31) we used the result that up to first order $\widehat{\widetilde{D}}_{H,t} = 0$ and that $\widehat{\left(\frac{P_t}{P_{H,t}}\right)} = \left(1-\chi\right)\widehat{S}_t$ and $\widehat{\left(\frac{P_t^*}{P_t}\right)} = \left(2\chi-1\right)\widehat{S}_t$.

By symmetry in country F the approximated aggregate resource constraint and the capital accumulation equation read as:

$$\widehat{Y}_t^* = -\Gamma\widehat{S}_t + \chi\frac{C}{Y}\widehat{C}_t^* + \left(1-\chi\right)\frac{C}{Y}\widehat{C}_t + \frac{G}{Y}\widehat{G}_t^* + \frac{I}{Y}\widehat{I}_t^* + r^k\frac{K}{Y}\widehat{u}_t^*$$

$$\widehat{k}_{t+1} = \left(1-\delta\right)\widehat{k}_t + \delta\widehat{i}_t$$

5.2 The log-linear real wage schedule with partial indexation to CPI inflation.

Log-linearization of equation (16) leads to

$$\begin{aligned}\widehat{\widetilde{w}}_t + \widehat{w}_t &= (1-\beta\lambda_w)\left(\varphi\widehat{h}_t^d - \widehat{\Psi}_t + \varepsilon_t^h\right) + \\ &\quad \beta\lambda_w E_t\left(\widehat{\pi}_{t+1} - \gamma_w\widehat{\pi}_t\right) + \beta\lambda_w E_t\left(\widehat{\widetilde{w}}_{t+1} + \widehat{w}_{t+1}\right)\end{aligned}$$

where

$$\widehat{\Psi}_t = \frac{1}{2}\frac{1}{(1-\beta b)\,C}\left\{(1-\theta)\,c^{rt}\Omega_t^o + \theta c^o\Omega_t^{rt} + \upsilon_t\right\}$$

is derived in the Appendix. Log-linearization of the wage index (20) is obtained as

$$\widehat{\widetilde{w}}_t + \widehat{w}_t = \frac{1}{(1-\lambda_w)}\widehat{w}_t - \frac{\lambda_w}{(1-\lambda_w)}\left(\hat{w}_{t-1} - (\widehat{\pi}_t - \gamma_w\widehat{\pi}_{t-1})\right) \tag{32}$$

Combining (47) and (32) leads to the following loglinear expression for the deviation of real wage from its steady state level

$$\begin{aligned}\widehat{w}_t &= \frac{(1-\lambda_w)(1-\beta\lambda_w)}{\kappa_w\lambda_w}\left(\varphi\widehat{h}_t^d - \widehat{\Psi}_t + \varepsilon_t^h\right) + \frac{\beta}{\kappa_w}E_t\left(\widehat{\pi}_{t+1} - \gamma_w\widehat{\pi}_t\right) + \\ &\quad \frac{\beta}{\kappa_w}E_t\widehat{w}_{t+1} + \frac{1}{\kappa_w}\left(\hat{w}_{t-1} - (\widehat{\pi}_t - \gamma_w\widehat{\pi}_{t-1})\right)\end{aligned} \tag{33}$$

where $\frac{\left(\beta\lambda_w^2+1\right)}{\lambda_w} = \kappa_w$.

5.3 The new Keynesian Phillips curve with partial indexation to domestic producer price inflation.

Log-linearization of equation (22) leads to

$$\widehat{\widetilde{p}}_t = (1-\beta\lambda_p)\,\widehat{mc}_t + \beta\lambda_p\left(\widehat{\pi}_{H,t+1} - \gamma_p\widehat{\pi}_{H,t}\right) + \beta\lambda_p E_t\widehat{\widetilde{p}}_{H,t+1} \tag{34}$$

As it is well known, the domestic price index can be log-linearized as[24]

$$\widehat{\widetilde{p}}_t = \frac{\lambda_p}{1-\lambda_p}\left[\pi_{H,t} - \gamma_p\pi_{H,t-1}\right] \tag{35}$$

[24] See, *inter alia*, Christiano *et al* (2005). However steps closely follows those for the log-linearization of the wage index in appendix II.

where $\widetilde{p}_t = \frac{\widetilde{P}_t}{P_t}$. Combining equations (34) and (35) we obtain the new keynesian Phillips curve for domestic producer price inflation

$$\widehat{\pi}_{H,t} = \frac{\gamma_p}{\left(1+\beta\gamma_p\right)}\pi_{H,t-1} + \frac{(1-\lambda_p)(1-\beta\lambda_p)}{\lambda_p\left(1+\beta\gamma_p\right)}\widehat{mc}_t + \frac{\beta}{\left(1+\beta\gamma_p\right)}E_t\widehat{\pi}_{H,t+1} \quad (36)$$

Equivalently in country F

$$\widehat{\pi}_{F,t} = \frac{\gamma_p}{\left(1+\beta\gamma_p\right)}\pi_{F,t-1} + \frac{(1-\lambda_p)(1-\beta\lambda_p)}{\lambda_p\left(1+\beta\gamma_p\right)}\widehat{mc}_t^* + \frac{\beta}{\left(1+\beta\gamma_p\right)}E_t\widehat{\pi}_{F,t+1}$$

The real marginal cost is log-linearized as

$$\widehat{mc}_t = (1-\alpha)\frac{\left(t_t^{pr}\widehat{t}_t^{pr} + w\widehat{w}_t\right)}{(t^{pr}+w)} + \alpha\widehat{r}_t^k + (1-\chi)\widehat{S}_t - \varepsilon_t^a$$

where $t_t^{pr} = \frac{T^{pr}}{P_t}$ and where we used the previously derived result that $\widehat{\frac{P_t}{P_{H,t}}} = (1-\chi)\widehat{S}_t$.

5.4 Calibration

The time unit is meant to be one quarter. The calibration, which applies to both countries, is summarized in table 1. Following Christiano *et al.* (2005) we set the subjective discount factor at 0.9926, which corresponds to a steady state real interest rate of 3.02 percent per annum. The share of capital is set at 36 percent. The depreciation rate of capital is set at 10 percent per year. Furthermore, we assume that prices and wages are fully indexed to producer price inflation and consumer price inflation respectively. That is, we set $\gamma_p = \gamma_w = 1$. The degree of nominal rigidity is calibrated so that product prices change on average every 2.5 quarters and nominal wages every 2.8 quarters.

Following Backus *et al.* (1994) and Chari *et al.* (2002), we set $\eta = 1.5$. As in Christiano *et al.* (2005) steady state markups are assumed to be 20 percent in product markets and 5 percent in labor markets. Each economy is characterised by a degree of home bias equal to 0.7. The degree of habit formation, b, is set at 0.65. The steady-state elasticity of the marginal capacity utilization cost, $a''(1)/a'(1)$, is calibrated to be 0.01. Following Muscatelli *et al.* (2005), we set the fraction ϑ of non-Ricardian agents equal to 0.508.

Contrary to Christiano *et al.* (2005), we choose a lower value for the investment adjustment costs parameter κ as the presence of non-Ricardian consumers is sufficient to generate strong inertia in the economy.

Finally, we assume that the output-share of government purchase and investment are both 20 percent.

Parameter	Value	Description
β	0.9926	subjective discount factor
ϑ	0.508	share of non Ricardian consumers
α	0.36	share of capital
ψ	0.5827	fixed cost parameter
δ	0.025	depreciation rate
γ_p	1	price indexation
γ_w	1	wage indexation
α_w	21	wage-elasticity of demand for a specific labor variety
η	1.5	elasticity of substitution between C_H and C_F
θ	6	elasticity of substitution within consumption bundles
χ	0.7	home bias
$1-\xi_P$	0.4	Calvo parameter on prices
$1-\xi_W$	0.36	Calvo parameter on wages
b	0.65	degree of habit persistence
φ	1	preference parameter
κ	0.248	investment adjustment costs
γ_1	0.0324	parameter governing capacity adjustment costs
γ_2	0.000324	parameter governing capacity adjustment costs
$\frac{C}{Y}$	0.6	share of consumption
$\frac{G}{Y}$	0.2	share of government purchase
$\frac{I}{Y}$	0.2	share of investment
$\frac{D}{Y}$	0.6	stady state debt-to-GDP ratio

Table 1: Calibration of structural parameters

6 Policy rules

6.1 Monetary Rule

In contrast to the numerous papers on the behaviour of the Federal Reserve and other central banks, the empirical literature on the behaviour of the ECB is limited, mainly due to its short history. We assume that the ECB's monetary policy rule for the nominal interest rate $\widehat{R}_t$ follows a form similar to the standard forward-looking Taylor rule specification which has become commonplace in the literature[25] :

$$\widehat{R_t} = \phi_1 E_t \widehat{\pi}_{t+q}^{EU} + \phi_2 \widehat{Y}_t^{EU} + \phi_3 \widehat{R}_{t-1} \tag{37}$$

where we also allow for inertia in the rule, due to interest-rate smoothing if $\phi_3 \neq 0$.

This provides us with a benchmark against which to assess the performance of different designs for automatic fiscal stabilizers in our structural model. $\widehat{\pi}_{t+q}^{EU}$ and $\widehat{Y}_t^{EU}$denote the union-wide consumer price inflation rate and aggregate output:

$$\begin{aligned} \widehat{\pi}_{t+q}^{EU} &= \frac{1}{2}\left(\widehat{\pi}_{t+q} + \widehat{\pi}_{t+q}^{*}\right) \\ \widehat{Y}_t^{EU} &= \frac{1}{2}\left(\widehat{Y}_t + \widehat{Y}_t^{*}\right) \end{aligned}$$

In our baseline simulations we set $q = 1$.

6.2 Fiscal Rules

We consider a simple backward-looking format for our fiscal policy rules. This follows, *inter alia,* Van Den Noord (2000), Westaway (2003) and Andres and Domenech (2005). The specification captures the more realistic lagged response of fiscal policy, as automatic stabilizers, to macroeconomic variables.

$$\widehat{G}_t = -\delta_1 \widehat{Y}_{t-1} - \delta_2 \widehat{d}_{t-1} \tag{38}$$

[25]The main difference is that we use a contemporaneous value of the output gap (see Muscatelli *et al.* 2002) as opposed to expected future values, as in Clarida, Gali and Gertler (1998, 2000). For a detailed discussion of these issues, see Giannoni and Woodford (2002a,b). For an alternative approach to modeling interest rate responses, involving nonlinearities in reaction functions, see Cukierman and Muscatelli (2001).

$$\widehat{G}_t^* = -\delta_1 \widehat{Y}_{t-1}^* - \delta_2 \widehat{d}_{t-1}^* \tag{39}$$

$$\widehat{t}_t = \varphi_1 \widehat{Y}_{t-1} + \varphi_2 \widehat{d}_{t-1} \tag{40}$$

$$\widehat{t}_t^* = \varphi_1 \widehat{Y}_{t-1}^* + \varphi_2 \widehat{d}_{t-1}^* \tag{41}$$

$$\widehat{d}_{t+1} = \frac{G}{Y}\widehat{G}_t + \frac{D}{Y}\left(\widehat{R}_t - \widehat{\pi}_{t+1}\right) + \frac{R}{Y}\widehat{d}_t - \left(\frac{T}{Y}\right)\widehat{t}_t \tag{42}$$

where $\widehat{t}_t$ is the vector of our two tax measures, personal taxes $\widehat{\tau}_t$ and payroll taxes, $\widehat{t}_t^{pr}$, $\widehat{d}_{t-1} = \widehat{\left(\frac{D_{t-1}}{Y}\right)}$ denotes real debt normalised with respect to steady state output. Our taxation rule therefore imposes the same adjustment pattern on both taxes, and does not look at how a mix of tax measures might improve the design of policy[26]. The importance of the taxation policy mix is considered further below. As discussed above, we have a limited feedback to the debt accumulation, through a debt to GDP term which approximates to a response to the debt to GDP ratio. Our fiscal rules are largely capturing automatic stabilizers through the output gap terms.

For our baseline case, we set $\delta_1 = \varphi_1 = 0.5$, $\delta_2 = \varphi_2 = 0.05$. A coefficient of 0.5 on output is consistent with the empirical evidence in Van Den Noord (2000) and adopted in studies on fiscal stabilization (e.g. Westaway, 2003). We allow for a coefficient on debt as implicitly required by the SGP.

7 Designing Fiscal Policy in a Monetary Union

We now examine the extent to which national fiscal policies can assist with macroeconomic adjustment in EMU. The key issues we consider are: do automatic stabilisers actually assist the ECB's function of stabilising output and inflation in the union, and in the individual countries, i.e. do the fiscal authorities assist or impede the efforts of the ECB? Which fiscal instruments are more effective in stabilising the union and the individual economies? How do the stabilisation properties of fiscal policy vary in response to different structural shocks?

We consider the following four policy scenarios:

[26] Andres and Domenech (2005) provide an analysis of how different tax measures might impact on output and inflation variability.

1. where the ECB operates its policy rule (37), but where fiscal policy is kept exogenously fixed, i.e. the automatic stabilizers (38) and (40) are kept switched off;

2. where only the government spending rule (38) is switched on together with the monetary policy rule;

3. where only the government taxation rule is switched on (40) together with the monetary policy rule;

4. where both fiscal rules are switched on, (38) and (40), together with the monetary policy rule .

Before turning to our full two-country monetary union model, we first of all simulate a closed-economy (single-country) version in order to demonstrate the properties of the model. In essence this involves aggregating across all optimising and RT households in the two economies, and focusing on overall consumption and production outcomes, assuming that wage and price-settring is unified across the union, and there is a single union-wide fiscal authority.

7.1 Results Using the Closed Economy Model

We simulate the closed-economy version of our model following each of the four shocks outlined in the section above: a cost-push shock (ε^{θ}), a demand (preferences shock) (ε_t^c), a technology shock (ε_t^a), and a wage shock (ε_t^h). These are shown in Figures 1-4. In each Figure we show the impulse responses of the model following a persistent shock (with an autoregressive parameter, $\rho = 0.5$), and under three of the four policy scenarios: first, when monetary policy alone is active (M); second, when the taxation rules are also active in addition to the monetary policy rule (M+T); third, when both government expenditure and taxation rules are also active (M+G+T). Policy scenario 2 with government expenditure switched on alongside monetary policy (M+G) is not shown to avoid excessive cluttering of the graphs. This case will be analysed in greater detail in the next sub-section when we focus on the two-country model. In any case, the contribution of government spending in Figures 1-4 can be evaluated by comparing the impulse responses for M+G+T and M+T.

In Figure 1 we see that a cost-push shock has a negative impact on investment and capital accumulation. As explained above, the Christiano *et al.* (2005) modelling of capacity utilisation and costs of adjustment in capital accumulation induces some very persistent dynamics in the capital stock. It is interesting to note that optimising consumers marginally reduce their consumption in response to the shock. Such effect is dwarfed by the decline (over 3%) in the first two periods consumption of RT consumers, who cannot smooth consumption by adjusting investment and capacity utilization. In essence, the RT consumers are constrained and require fiscal policy to help reduce volatility in their labour income and consumption. In fact taxation is particularly effective in raising the RT consumers' disposable income. This is obtained both through the direct effect of lump-sum taxes on disposable income, and through the impact of the payroll tax on inflation. The latter effect is unambiguously beneficial for real wages. By contrast, government expenditure only has an indirect effect on RT consumption, by marginally stabilising output.

Turning to Figure 2, we see that the demand (preference) shock directly raises the consumption of optimizing consumers. This, in turn, raises output and inflation, which adds further to the aggregate demand expansion due to the inertial monetary policy rule. The increase in aggregate demand raises worked hours and the real wage. As a consequence RT consumers' disposable income and consumption also increase until the monetary policy rule begins to counteract the inflationary pressures and gradually adjusts output and inflation towards the initial equilibrium. Optimizing consumers' consumption also gradually returns to equilibrium, but the dynamics of adjustment are slow, as in Christiano *et al.* (2005) due to the very slow capital stock adjustment. Fiscal policy has no significant impact on optimising consumers, but it dampens the volatility in the consumption of RT consumers. Inflation volatility is increased slightly but wage inflation volatility is reduced as payroll taxation intervenes directly on the wage equation .

A positive technology shock (Figure 3) increases investment and the capital stock, and gradually boosts optimising consumers' expenditure over the long capital accumulation cycle. Wage inflation increases as the demand for labour rises and this causes RT consumers' disposable income to rise and their consumption to increase. Consumer price inflation falls with marginal costs. Interestingly, as in the case of the cost-push shock, fiscal policy stabilises the economy by attenuating the increase in RT consumers' disposable income. This in turn stabilises output and inflation.

Finally a wage shock adversely affects investment and capital accumulation, as optimising consumers recognise that rising inflation will result in tighter monetary policy. This stagflationary shock gives a very temporary boost to RT consumption, as wage inflation raises disposable income, and for the first period overall output actually rises. However, as monetary policy is tightened output falls. Once again, fiscal policy has no significant impact on the optimising consumers, who are Ricardian and will discount fiscal policy over the cycle. Instead fiscal policy stabilises the consumption of RT consumers, stabilising output and wage inflation, with very little impact on overall consumer price inflation.

In concluding our discussion it is worth recall the effect of fiscal stabilization rules on debt accumulation. For any shock, the debt feedback embedded in the fiscal rule was sufficient to dampen debt adjustment, which was of limited amplitude[27].

7.2 Results for a Monetary Union

Having examined the closed-economy properties of the model, we now turn to an analysis of the interactions between the Union's two countries in the face of country-specific shocks. Before we present our simulations, it is worth discussing the dynamic properties of the two-country model. Under the fiscal policy rules (38) (39) (40) (41) the model was indeterminate, with an excess number of jump variables relative to the unstable eigenvalues in the system[28]. By using Aoki's factorization[29] (Aoki 1981) and focusing on national differences we found that the indeterminacy problem could be solved by removing the fiscal feedback on national debt differences. The reason why this happens can be easily understood by looking at the role of (forward-looking) inflation differentials. In a monetary union, the latter drive real interest rate differentials, the real exchange rate and the accumulation of debt differences across countries. Absent the fiscal feedback on debt differences, the forward-looking inflation difference is sufficient to ensure that the model is stable and

[27] Results available upon request

[28] This result was robust to an extensive sensitivity analysis on the parameter values of the model. Details available upon request.

[29] This solution method first requires to derive expressions for the world weighted averages: $X_t^W = \frac{1}{2}(X_t + X_t^*)$ and differences $X_t^d = (X_t - X_t^*)$. Factorization then allows to decompose the model in two independent blocks and separately analyse the dynamic properties of each block.

uniquely determined[30]. Adding a fiscal feedback on debt differences renders the model overdetermined. A fiscal feedback on debt was instead necessary in the closed economy version, because in that case the real interest rate component of debt accumulation is controlled by monetary policy and targeted on inflation and output control. This is an interesting and novel result. Combining the closed-economy and the national differences yields important implications for fiscal policy design. In order to ensure a stable and unique determinate solution, fiscal policy in each country should not respond to each country's own debt position. Instead, it is necessary that in each country the fiscal feedbacks react to the union-wide debt-to-GDP ratio.

Once again, we consider the four types of structural shocks outlined above, and analyse the four policy scenarios, M, M+G, M+T and M+G+T. We show the impulse responses of a cost-push shock in the home country in Figure 5, including the impact on home country and foreign country variables. (As before the M+G case is not plotted to make the graphs clearer). For completeness, we also show the outcome for the stock of government debt in each country following the shock.

To save space, we do not show the impulse responses for all four shocks, and instead tabulate the impact of the different policy rules on the variance of output (Y), consumer price (π) and wage inflation (π^w) in each country, the real exchange rate (Q), as well as the consumption expenditure of optimising (C^o), RT consumers (C^{rt}), and aggregate consumption (C). These variances are shown in Tables 2-9.

Turning to Figure 5, we see that for both economies the biggest impact of fiscal policy is to reduce the volatility of expenditure of RT consumers. As for the closed economy, the initial impact of a cost push shock on the domestic economy is to reduce output and wage inflation, and hence the consumption of RT consumers. The shock is transmitted positively to the foreign economy, mainly through the real exchange rate effect, which boosts demand for foreign output and increases the consumption of RT consumers abroad. In both countries the impact on optimising consumers is very small and given the dynamics of capital accumulation, it is spread over a long period of time. The consumption of optimisers is mainly driven by the dynamics of the real interest rate, which initially falls in the home country and rises in the foreign country because of the inflation differential which opens up. As before the

[30] This conclusion holds even if the proportion of forward-looking price setters becomes very small. The simulation results are available on request.

main stabilisation channel of fiscal policy in both countries is through the reduction in the volatility of RT expenditure. If we look at the dynamics of government debt in the two countries, the key point to note is that the rules are such as to produce a stable dynamics of government debt.

Turning to Tables 2 and 3, which show the impact on the variances of the vey variables following a cost push shock. Is it clear that the expenditure of RT consumers (C^{rt}) and wage inflation is stabilised by combining any of the fiscal policy rules with the central bank's interest rate rule. The consumption of optimisers (C^{o}) is slightly destabilised when fiscal rules are switched on (M+G+T and M+T). Interestingly, the variance of C^{o} significantly increases if government expenditure alone is combined with monetary policy (M+G). The reason for this is that government spending reacts to the domestic fall in output by increasing expenditure, which, with an inertial monetary policy rule actually causes inflation to rise and the domestic real interest rate to fall. The impact is to raise C^{o} (and C^{rt}), when a fall in output is necessary to discipline the cost push. The policy combination (M+G) is also less stabilising for the other country, as the boost in consumption is transmitted abroad. In essence, government expenditure alone impacts exclusively on aggregate demand, and hinders the operation of the interest-rate adjustment mechanism. In contrast, when taxation operates (even if in combination with government expenditure as in the M+G+T scenario), it does so through both aggregate demand and supply because of the impact of payroll taxes: this results in a reduction in the volatility of wage and consumer price inflation, stabilising both economies.

Turning to Tables 2-9, we see that the pattern outlined above is repeated but that the desirable combination of instruments is, as one might expect, shock-dependent. From the point of view of the domestic economy, having both active taxation and government expenditure stabilisers seems efficient in the case of a demand shock (Tables 4 and 5). However, it turns out that using only government spending is better for the foreign country. This happens because under the preference shock the main transmission across the two economies is through the demand channel. The wage shock (Table 6 and 7) produces a similar profile to that of a cost-push shock (Table 2 and 3), but here government expenditure is more effective in stabilising the domestic economy, mainly because a wage shock has a more direct demand-side effect than a cost-push shock through the disposable income and expenditure of RT consumers. Finally in the case of a technology shock, the use of both G and T produces better stabilisation, as the shock requires both an aggregate supply and aggregate demand response, which payroll taxes can provide.

One issue which has to be addressed is the importance of our assumption of home bias in the composition of national consumption bundles, which also directly impacts on the way in which government spending is transmitted in the monetary union. In order to gauge the impact which this has on our results, we show in Tables 10 and 11 (demand shock) how the results would change if the home bias assumption were removed (i.e. if we set $\chi = 0.5$). By comparing Tables 10 and 11 and Tables 4 and 5 we see that if there is no home bias, government expenditure becomes less useful as a stabilisation tool. In essence it is less able to act as a counter to an country-spcific aggregate demand shock by acting purely through the demand side. In fact, government spending on its own increases the volatility of the expenditure of both optimising and RT consumers in the domestic economy, and therefore is less effective than taxation in stabilising output. In combination with taxation policy government spending is still effective. For the domestic economy there is a trade-off with inflation stabilisation, although the differences are small.

8 Conclusions

Our results may be summarized as follows. First, fiscal policy does generally help macroeconomic stabilisation in a monetary union, and is most effective if it combines elements of both government expenditure and taxation in the automatic stabilisers. The main channel of operation is through the automatic stabilizers impact on the disposable income of RT consumers. Second, potential conflicts do emerge in the way in which the fiscal authorities within the union respond to different structural shocks. In some cases (cf. the technology shock in Table 8 and 9) it is evident that the most efficient design of fiscal policy would require a different emphasis between the two countries, with one faring better with a greater emphasis on government expenditure to stabilise output and inflation and the other faring better if a greater emphasis were put on taxation policy. Third, there are some redistributive effects in terms of consumer welfare. It is apparent that if one were to look at the utility of the two consumer groups, they would fare very differently under different fiscal regimes. In general, a more active fiscal policy will tend to favour RT consumers who cannot actively participate in financial markets and for whom risk sharing in the face of country-specific shocks is absent: in essence fiscal policy acts on their behalf. Fourth, the degree of home bias is crucial in designing appropriate fiscal policy rules. The absence of home bias in general reduces the effectiveness of government expenditure as a stabilisation tool in the face of country-specific shocks. If market integration progresses further within EMU, this would have implications for the effectiveness of government spending as an automatic stabiliser.

Further research should take into account distortionary taxation and (beyond the payroll tax case discussed here) the possibility of productive government spending. Moreover, it would be interesting to extend the potential role of fiscal policy by introducing Blanchard-Yaari optimizing consumers.

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A Union Objective Function.

This is a variant of Galì *et al.* (2005), adapted to account for wage stickyness. Assume that the union maximizes the following objective function

$$L = E_t \sum_{T=t}^{\infty} (\beta\lambda_w)^{T-t} \left\{ \begin{array}{c} \vartheta \left[\lambda_T^{rt} \left(\widetilde{W}_t \Pi_{t,T}^{\gamma_w}\right) \widetilde{h}_t - \exp\left(\varepsilon_t^h\right) v\left(h_T\right)\right] + \\ (1-\vartheta)\left[\lambda_T^{o} \left(\widetilde{W}_t \Pi_{t,T}^{\gamma_w}\right) \widetilde{h}_t - \exp\left(\varepsilon_t^h\right) v\left(h_T\right)\right] \end{array} \right\}$$

subject to the constraint

$$h_T = 2h_T^d \int_0^{\frac{1}{2}} \left(\frac{W_T^j}{W_T} \right)^{-\alpha_w} dj$$

Differencing with respect to $\widetilde{W}_t$:

$$E_t \sum_{T=t}^{\infty} (\beta \lambda_w)^{T-t} \left(\Pi_{E;t,T}^{\gamma_w} \right)^{-\alpha_w} h_{E,T}^d \left(W_{E,T}^{\alpha_w} \right) \left\{ \begin{array}{c} \frac{\widetilde{W}_t \Pi_{t,T}^{\gamma_w}}{P_T} P_T \left[(1-\theta) \lambda_{E,T}^o + \theta \lambda_{E,T}^{rt} \right] + \\ -\frac{\alpha_w}{\alpha_w - 1} \exp\left(\varepsilon_t^h \right) v_h \left(h_{E,T} \right) \end{array} \right\}$$

Rearranging and setting equal to zero we get equation 16 in the text.

B Derivation of wage equation.

We follow Christiano *et al.* and define

$$\widetilde{w}_t = \frac{\widetilde{W}_t}{W_t}; \; w_t = \frac{W_t}{P_t}$$

this is because we want to linearise around a well defined steady state. Defining $\omega_T = \frac{\widetilde{W}_t (\Pi_{tT})^{\gamma_w}}{P_T}$, equation (16) in the text can be loglinearized as:

$$E_t \sum_{T=t}^{\infty} (\beta \lambda_w)^{T-t} \left\{ \widehat{\omega}_T - \varphi \widehat{h}_T - \varepsilon_t^h + \widehat{\Psi}_T \right\} = 0 \tag{43}$$

Consider ω_T

$$\omega_T = \frac{\widetilde{W}_t}{W_t} \frac{W_t}{P_t} \frac{P_t}{P_T} (\Pi_{tT})^{\gamma_w} = \widetilde{w}_t w_t \frac{P_t}{P_T} (\Pi_{tT})^{\gamma_w}$$

which can be log-linearized as

$$\widehat{\omega}_T = \left(\widehat{\widetilde{w}}_t + \widehat{w}_t \right) - E_t \sum_{T=t+1}^{T} (\pi_T - \gamma_w \pi_{T-1})$$

Consider h_t

$$h_t = 2h_t^d \int_0^{\frac{1}{2}} \left(\frac{W_t^j}{W_t} \right)^{-\alpha_w} dj \tag{44}$$

define

$$d_t^w = 2\int_0^{\frac{1}{2}} \left(\frac{W_t^j}{W_t}\right)^{-\alpha_w} dj \tag{45}$$

With this definition at hand, equation 44 can be written as

$$h_t = h_t^d d_t^w \tag{46}$$

where d_t^w is a measure of the degree of wage dispersion. Schmitt-Grohe and Uribe (2005) show that d_t^w is a constant up to a first order approximation. Hence

$$\widehat{h}_t = \widehat{h}_t^d$$

Given the derivations above, 43 becomes

$$E_t \sum_{T=t}^{\infty} (\beta\lambda_w)^{T-t} \left\{ \left(\widehat{\widetilde{w}}_t + \widehat{w}_t\right) - \sum_{T=t+1}^{T} (\pi_T - \gamma_w \pi_{T-1}) - \varphi \widehat{h}_T^d + \widehat{\Psi}_T - \varepsilon_T^h \right\} = 0$$

or

$$\begin{aligned}
\widehat{\widetilde{w}}_t + \widehat{w}_t &= (1-\beta\lambda_w) E_t \sum_{T=t}^{\infty} (\beta\lambda_w)^{T-t} \sum_{T=t+1}^{T} (\pi_T - \gamma_w \pi_{T-1}) \\
&\quad + (1-\beta\lambda_w) E_t \sum_{T=t}^{\infty} (\beta\lambda_w)^{T-t} \left(\varphi \widehat{h}_T^d - \widehat{\Psi}_T + \varepsilon_T^h\right)
\end{aligned}$$

Since

$$\begin{aligned}
& (1-\beta\lambda_w) E_t \sum_{T=t}^{\infty} (\beta\lambda_w)^{T-t} \sum_{T=t+1}^{T} (\pi_T - \gamma_w \pi_{T-1}) \\
= \; & E_t \sum_{T=t+1}^{\infty} (\beta\lambda_w)^{T-t} (\pi_T - \gamma_w \pi_{T-1})
\end{aligned}$$

we can write

$$\begin{aligned}
\widehat{\widetilde{w}}_t + \widehat{w}_t &= E_t \sum_{T=t+1}^{\infty} (\beta\lambda_w)^{T-t} (\pi_T - \gamma_w \pi_{T-1}) \\
&\quad + (1-\beta\lambda_w) E_t \sum_{T=t}^{\infty} (\beta\lambda_w)^{T-t} \left(\varphi \widehat{h}_T^d - \widehat{\Psi}_T + \varepsilon_T^h\right)
\end{aligned}$$

Quasi-differencing the latter it follows that

$$\begin{aligned}\widehat{\widetilde{w}}_t + \widehat{w}_t &= (1-\beta\lambda_w)\left(\varphi\widehat{h}_t^d - \widehat{\Psi}_t + \varepsilon_t^h\right) + \\ &\quad \beta\lambda_w E_t\left(\widehat{\pi}_{t+1} - \gamma_w\widehat{\pi}_t\right) + \beta\lambda_w E_t\left(\widehat{\widetilde{w}}_{t+1} + \widehat{w}_{t+1}\right)\end{aligned} \tag{47}$$

B.1 Dynamic of the Wage index

The wage index is given by

$$W_t = \left[(1-\lambda_w)\widetilde{W}_t^{1-\alpha_w} + \lambda_w\left(\pi_{t-1}^{\gamma_w}W_{t-1}\right)^{(1-\alpha_w)}\right]^{1/(1-\alpha_w)}$$

divide by P_t and manipulate in order to get the variables in which we are interested in (those which are constant at the steady state and we defined earlier)

$$\frac{W_t}{P_t} = \left[(1-\lambda_w)\left(\frac{\widetilde{W}_t}{W_t}\frac{W_t}{P_t}\right)^{1-\alpha_w} + \lambda_w\left(\pi_{t-1}^{\gamma_w}\frac{W_{t-1}}{P_{t-1}}\frac{P_{t-1}}{P_t}\right)^{(1-\alpha_w)}\right]^{1/(1-\alpha_w)}$$

or

$$w_t^{(1-\alpha_w)} = \left[(1-\lambda_w)\left(\widetilde{w}_t w_t\right)^{(1-\alpha_w)} + \lambda_w\left(\pi_{t-1}^{\gamma_w}w_{t-1}\pi_t^{-1}\right)^{(1-\alpha_w)}\right]$$

log-linear approximation is obtained as

$$(1-\alpha_w)\widehat{w}_t = (1-\lambda_w)(1-\alpha_w)\left(\widehat{\widetilde{w}}_t + \widehat{w}_t\right) + \lambda_w(1-\alpha_w)\left(\gamma_w\widehat{\pi}_{t-1} + \hat{w}_{t-1} - \widehat{\pi}_t\right)$$

rearranging

$$\widehat{\widetilde{w}}_t + \widehat{w}_t = \frac{1}{(1-\lambda_w)}\widehat{w}_t - \frac{\lambda_w}{(1-\lambda_w)}\left(\hat{w}_{t-1} - \left(\widehat{\pi}_t - \gamma_w\widehat{\pi}_{t-1}\right)\right) \tag{48}$$

B.2 Real Wage Dynamic

Substituing 48 into 47 we get

$$\begin{aligned}&\frac{1}{(1-\lambda_w)}\widehat{w}_t + \beta\lambda_w\frac{\lambda_w}{(1-\lambda_w)}\hat{w}_t \\ = &\ (1-\beta\lambda_w)\left(\varphi\widehat{h}_t^d - \widehat{\Psi}_t + \varepsilon_t^h\right) + \beta\lambda_w E_t\left(\widehat{\pi}_{t+1} - \gamma_w\widehat{\pi}_t\right) + \beta\lambda_w\frac{1}{(1-\lambda_w)}E_t\widehat{w}_{t+1} + \\ &\ \beta\lambda_w\frac{\lambda_w}{(1-\lambda_w)}E_t\left(\widehat{\pi}_{t+1} - \gamma_w\widehat{\pi}_t\right) + \frac{\lambda_w}{(1-\lambda_w)}\left(\hat{w}_{t-1} - \left(\widehat{\pi}_t - \gamma_w\widehat{\pi}_{t-1}\right)\right)\end{aligned}$$

multiplying both sides by $\frac{(1-\lambda_w)}{\lambda_w}$ it follows that

$$\begin{aligned}\left[\frac{1}{\lambda_w}+\beta\lambda_w\right]\widehat{w}_t &= \frac{(1-\lambda_w)(1-\beta\lambda_w)}{\lambda_w}\left(\varphi\widehat{h}_t^d-\widehat{\Psi}_t+\varepsilon_t^h\right)+\beta E_t\left(\widehat{\pi}_{t+1}-\gamma_w\widehat{\pi}_t\right)+\\ &\quad \beta E_t\widehat{w}_{t+1}+\left(\hat{w}_{t-1}-\left(\widehat{\pi}_t-\gamma_w\widehat{\pi}_{t-1}\right)\right)\end{aligned}$$

Defining

$$\left[\frac{1}{\lambda_w}+\beta\lambda_w\right]=\frac{\left(\beta\lambda_w^2+1\right)}{\lambda_w}=\kappa_w$$

we finally get the desired expression:

$$\begin{aligned}\widehat{w}_t &= \frac{(1-\lambda_w)(1-\beta\lambda_w)}{\kappa_w\lambda_w}\left(\varphi\widehat{h}_t^d-\widehat{\Psi}_t+\varepsilon_t^h\right)+\frac{\beta}{\kappa_w}E_t\left(\widehat{\pi}_{t+1}-\gamma_w\widehat{\pi}_t\right)+\\ &\quad \frac{\beta}{\kappa_w}E_t\widehat{w}_{t+1}+\frac{1}{\kappa_w}\left(\hat{w}_{t-1}-\left(\widehat{\pi}_t-\gamma_w\widehat{\pi}_{t-1}\right)\right)\end{aligned}$$

which is equation (33) in the text.

B.3 Derivation of $\widehat{\Psi}_t$.

Recall that:

$$\Psi_t=\left[\vartheta P_t\lambda_t^{rt}+(1-\vartheta)P_t\lambda_t^o\right]$$

From households first order conditions, it follows that

$$\begin{aligned}\Psi_t &= \vartheta\left[\exp\left(\varepsilon_t^c\right)u_c\left(c_t^{rt}-bc_{t-1}^{rt}\right)-E_t\exp\left(\varepsilon_{t+1}^c\right)\beta bu_c\left(c_{t+1}^{rt}-bc_t^{rt}\right)\right]\\ &\quad +(1-\vartheta)\left[\exp\left(\varepsilon_t^c\right)u_c\left(c_t^o-bc_{t-1}^o\right)-E_t\exp\left(\varepsilon_{t+1}^c\right)\beta bu_c\left(c_{t+1}^o-bc_t^o\right)\right]\end{aligned}$$

Given the selected functional forms

$$\Psi_t=(1-\vartheta)\left(\frac{\exp\left(\varepsilon_t^c\right)}{c_t^o-bc_{t-1}^o}-\beta bE_t\frac{\exp\left(\varepsilon_{t+1}^c\right)}{c_{t+1}^o-bc_t^o}\right)+\vartheta\left(\frac{\exp\left(\varepsilon_t^c\right)}{c_t^{rt}-bc_{t-1}^{rt}}-\beta bE_t\frac{\exp\left(\varepsilon_{t+1}^c\right)}{c_{t+1}^{rt}-bc_t^{rt}}\right)$$

The first term on the RHS can be log-linearized as

$$(1-\vartheta)\left(c^o\right)^{-1}(1-b)^{-1}\left\{\begin{array}{c}\left(\varepsilon_t^c-\beta bE_t\varepsilon_{t+1}^c\right)-\left(1+\beta b^2\right)(1-b)^{-1}\left(\widehat{c}_t^o\right)\\ +b(1-b)^{-1}\widehat{c}_{t-1}^o+\beta b(1-b)^{-1}E_t\widehat{c}_{t+1}^o\end{array}\right\}$$

while the second

$$\vartheta\left(c^{rt}\right)^{-1}(1-b)^{-1}\left\{\begin{array}{c}\left(\varepsilon_t^c-\beta bE_t\varepsilon_{t+1}^c\right)-\left(1+\beta b^2\right)(1-b)^{-1}\left(\widehat{c}_t^{rt}\right)\\ +b(1-b)^{-1}\widehat{c}_{t-1}^{rt}+\beta b(1-b)^{-1}E_t\widehat{c}_{t+1}^{rt}\end{array}\right\}$$

Summing the two terms

$$\Psi\widehat{\Psi}_t = (1-b)^{-1}\left\{(1-\vartheta)(c^o)^{-1}\Omega_t^o + \vartheta\left(c^{rt}\right)^{-1}\Omega_t^{rt} + \upsilon_t\right\}$$

where

$$\upsilon_t = \varepsilon_t^c - \beta b E_t \varepsilon_{t+1}^c$$

$$\Omega_t^o = \left[\begin{array}{c} b(1-b)^{-1}\widehat{c}_{t-1}^o + \beta b(1-b)^{-1}E_t\widehat{c}_{t+1}^o + \\ -(1+\beta b^2)(1-b)^{-1}(\widehat{c}_t^o) \end{array}\right]$$

$$\Omega_t^{rt} = \left[\begin{array}{c} b(1-b)^{-1}\widehat{c}_{t-1}^{rt} + \beta b(1-b)^{-1}E_t\widehat{c}_{t+1}^{rt} + \\ -(1+\beta b^2)(1-b)^{-1}(\widehat{c}_t^{rt}) \end{array}\right]$$

Notice that the steady state value of Ψ is

$$\Psi = \frac{(1-\beta b)}{(1-b)}\left[\frac{\vartheta}{C^{rt}} + \frac{(1-\vartheta)}{C^o}\right]$$

where C is aggregate steady state consumption level. Thus

$$\widehat{\Psi}_t = \frac{1}{2}\frac{1}{(1-\beta b)C}\left\{(1-\vartheta)C^{rt}\Omega_t^o + \vartheta C^o\Omega_t^{rt} + \upsilon_t\right\}$$

C Derivation of Steady State Ratios

In this Appendix we compute the steady state values of the ratios that enter log-linearised equations. We refer to the notion of symmetrical steady state discussed in Gali and Monacelli (2005).

>From equation (11) and (12), and assuming zero inflation steady state, it holds true that

$$1 + R = \frac{1}{\beta} \tag{49}$$

$$r^k = \frac{1}{\beta} - 1 + \delta \tag{50}$$

From cost minimization problem we can also derive:

$$w = mc(1-\alpha)\left(\frac{K}{h}\right)^{\alpha} \tag{51}$$

$$r^k = mc\left(\alpha^{\frac{1}{\alpha-1}}\frac{K}{h}\right)^{\alpha-1} \tag{52}$$

Combining equation (52) and $mc = \theta / (\theta - 1)$ we can pin down the value for the ratio:

$$\frac{K}{h} = \left[r^k \frac{\theta}{\theta - 1} \frac{1}{\alpha} \right]^{\frac{1}{\alpha - 1}}$$

Next we compute the real wage in the steady state using equation (51):

$$w = \frac{1 - \alpha}{\alpha} \left(\frac{K}{h} \right) r^k.$$

From the production function moreover:

$$\frac{Y}{h} = \left(\frac{K}{h} \right)^{\alpha}$$

Now consider the aggregate resource constraint which reads as:

$$Y = \vartheta \left(hw - \tau \right) + (1 - \vartheta) C^o + \delta K + G$$

Dividing through Y and rearrenging yields:

$$1 = \vartheta \left(\frac{h}{Y} \right) w - \vartheta \left(\frac{\tau}{Y} \right) + (1 - \vartheta) \frac{C^o}{Y} + \delta \left(\frac{K}{h} \right) \left(\frac{h}{Y} \right) + \left(\frac{G}{Y} \right)$$

From this equation we can compute $\frac{C^o}{Y}$ as:

$$\frac{C^o}{Y} = \frac{1}{1 - \vartheta} \left[1 - \vartheta \left(\frac{h}{Y} \right) w + \vartheta \left(\frac{T}{Y} \right) - \delta \left(\frac{K}{h} \right) \left(\frac{h}{Y} \right) - \left(\frac{G}{Y} \right) \right]$$

To retrive C^o/C, which enters equation (26), we can use

$$\frac{C}{Y} = 1 - \delta \left(\frac{K}{h} \right) \left(\frac{h}{Y} \right) - \left(\frac{G}{Y} \right)$$

and thus $\frac{C^o}{C} = \left(\frac{C^o}{Y} \right) \left(\frac{Y}{C} \right)$.

In addition

$$\frac{C^{rt}}{C} = \frac{1}{\vartheta} \left[1 - (1 - \vartheta) \frac{C^o}{C} \right].$$

D Tables

Rule	C^o	C^{rt}	C	π	Y	mc	π^w
M	0.007	0.712	0.293	0.136	0.422	0.199	0.157
M+G	0.352	0.595	0.216	0.174	0.347	0.184	0.144
M+T	0.038	0.593	0.251	0.124	0.375	0.205	0.145
M+G+T	0.061	0.570	0.247	0.127	0.355	0.203	0.145

Table 2: Cost-push shock to country H. Variance of key variables

Rule	$(C^o)^*$	$(C^{rt})^*$	$(C)^*$	π^*	Y^*	mc^*	$(\pi^w)^*$
M	0.042	0.531	0.226	0.111	0.296	0.164	0.134
M+G	0.431	0.664	0.369	0.083	0.405	0.178	0.145
M+T	0.015	0.432	0.175	0.111	0.25	0.165	0.124
M+G+T	0.003	0.418	0.173	0.112	0.239	0.164	0.125

Table 3: Cost-push shock to country H. Variance of key variables

Rule	C^o	C^{rt}	C	π	Y	mc	π^w
M	1.419	0.687	0.932	0.093	0.556	0.056	0.062
M+G	1.423	0.639	0.939	0.109	0.536	0.059	0.062
M+T	1.419	0.553	0.891	0.102	0.485	0.070	0.041
M+G+T	1.420	0.501	0.873	0.099	0.426	0.064	0.040

Table 4: Demand shock to country H . Variance of key variables

Rule	$(C^o)^*$	$(C^{rt})^*$	$(C)^*$	π^*	Y^*	mc^*	$(\pi^w)^*$
M	1.162	0.579	0.771	0.075	0.466	0.043	0.048
M+G	1.182	0.488	0.718	0.057	0.349	0.035	0.040
M+T	1.162	0.472	0.741	0.088	0.417	0.057	0.031
M+G+T	1.163	0.424	0.725	0.085	0.364	0.052	0.030

Table 5: Demand shock to country H. Variance of key variables

Rule	C^o	C^{rt}	C	π	Y	mc	π^w
M	0.596	1.348	0.743	0.277	1.237	0.142	0.155
M+G	0.207	1.369	0.626	0.340	1.272	0.159	0.166
M+T	0.695	0.985	0.643	0.266	1.113	0.148	0.145
M+G+T	0.807	0.939	0.675	0.269	1.081	0.145	0.145

Table 6: Labor disutility shock to country H. Variance of key variables

Rule	$(C^o)^*$	$(C^{rt})^*$	$(C)^*$	π^*	Y^*	mc^*	$(\pi^w)^*$
M	0.497	1.047	0.588	0.248	0.949	0.114	0.123
M+G	1.096	0.957	0.785	0.190	0.869	0.093	0.105
M+T	0.452	0.787	0.475	0.255	0.877	0.126	0.115
M+G+T	0.539	0.739	0.497	0.256	0.847	0.121	0.114

Table 7: Wage shock to country H. Variance of key variables

Rule	C^o	C^{rt}	C	π	Y	mc	π^w
M	0.003	0.323	0.133	0.061	0.191	0.069	0.071
M+G	0.160	0.270	0.098	0.079	0.157	0.074	0.065
M+T	0.017	0.269	0.114	0.056	0.170	0.067	0.066
M+G+T	0.027	0.258	0.112	0.057	0.161	0.068	0.066

Table 8: Technology shock to country H. Variance of key variables

Rule	$(C^o)^*$	$(C^{rt})^*$	$(C)^*$	π^*	Y^*	mc^*	$(\pi^w)^*$
M	0.019	0.241	0.102	0.050	0.134	0.054	0.060
M+G	0.195	0.301	0.167	0.037	0.183	0.051	0.065
M+T	0.007	0.196	0.079	0.050	0.113	0.054	0.056
M+G+T	0.001	0.189	0.078	0.051	0.108	0.054	0.056

Table 9: Technology shock to country H. Variance of key variables

Rule	C^o	C^{rt}	C	π	Y	mc	π^w
M	1.420	0.681	0.940	0.109	0.556	0.061	0.065
M+G	1.521	0.684	0.898	0.075	0.456	0.049	0.054
M+T	1.419	0.551	0.901	0.119	0.488	0.075	0.045
M+G+T	1.419	0.496	0.883	0.117	0.429	0.070	0.044

Table 10: Demand shock to country H in the case of no Home Bias Variance of key variables

Rule	$(C^o)^*$	$(C^{rt})^*$	$(C)^*$	π^*	Y^*	mc^*	$(\pi^w)^*$
M	1.168	0.587	0.764	0.061	0.466	0.039	0.045
M+G	1.242	0.508	0.800	0.104	0.543	0.045	0.048
M+T	1.166	0.476	0.731	0.073	0.413	0.051	0.027
M+G+T	1.168	0.431	0.715	0.070	0.360	0.047	0.026

Table 11: Demand shock to country H in the case of no Home Bias Variance of key variables

E Figures

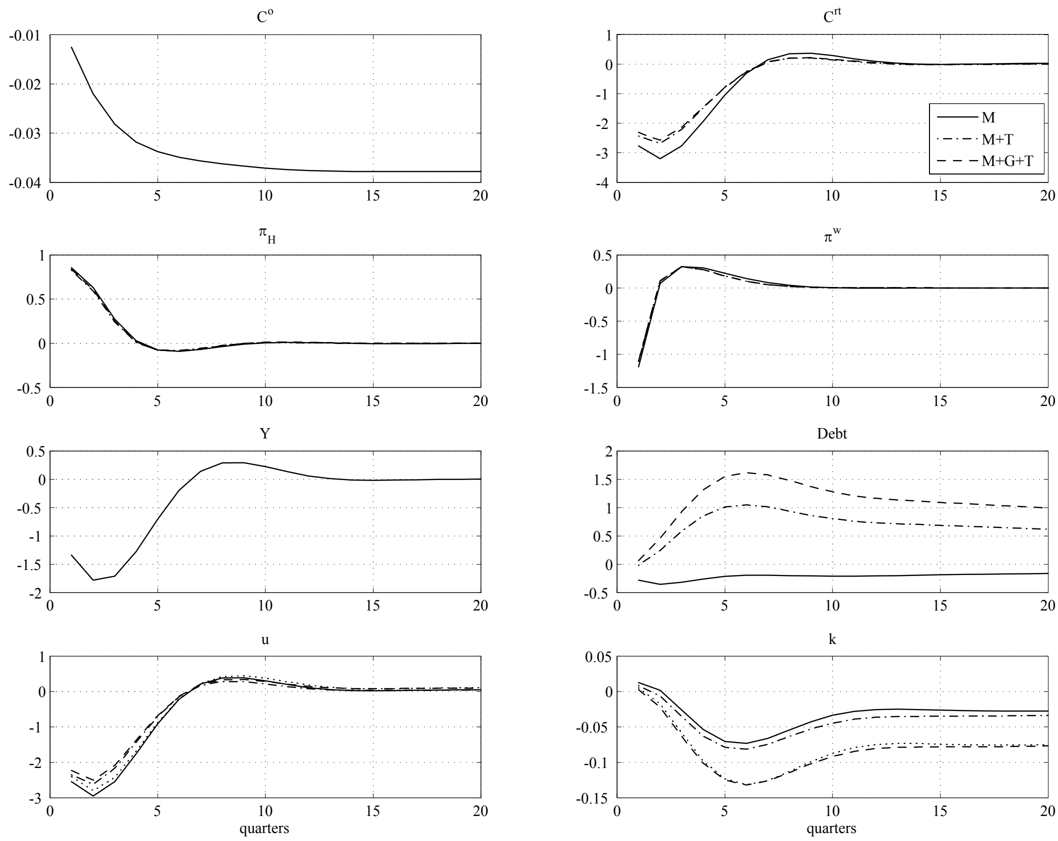

Figure 1: Cost-push shock.

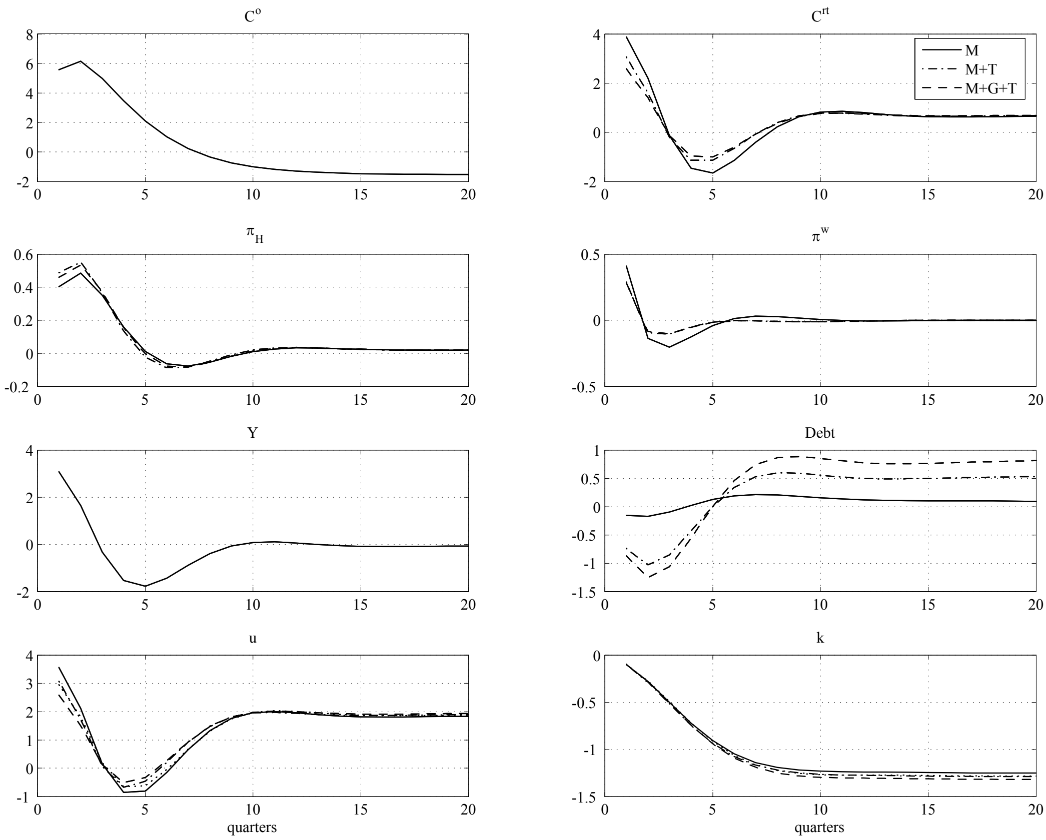

Figure 2: Demand (preference) shock.

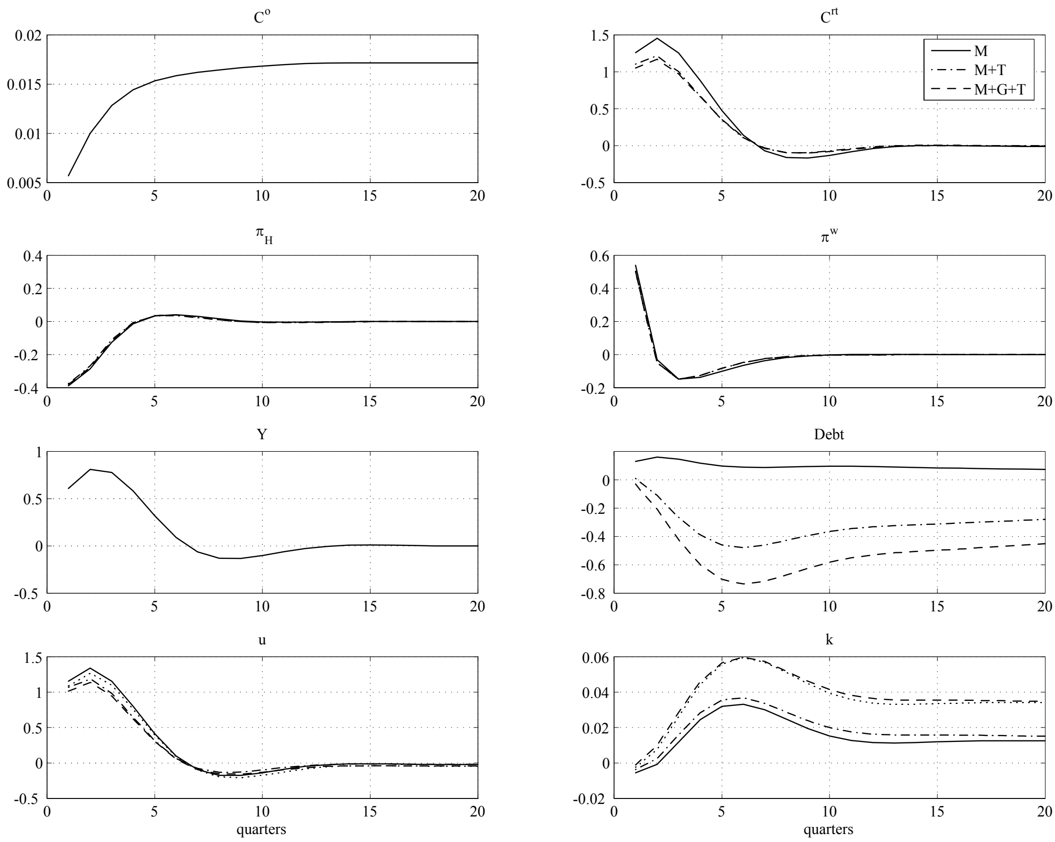

Figure 3: Positive technology shock.

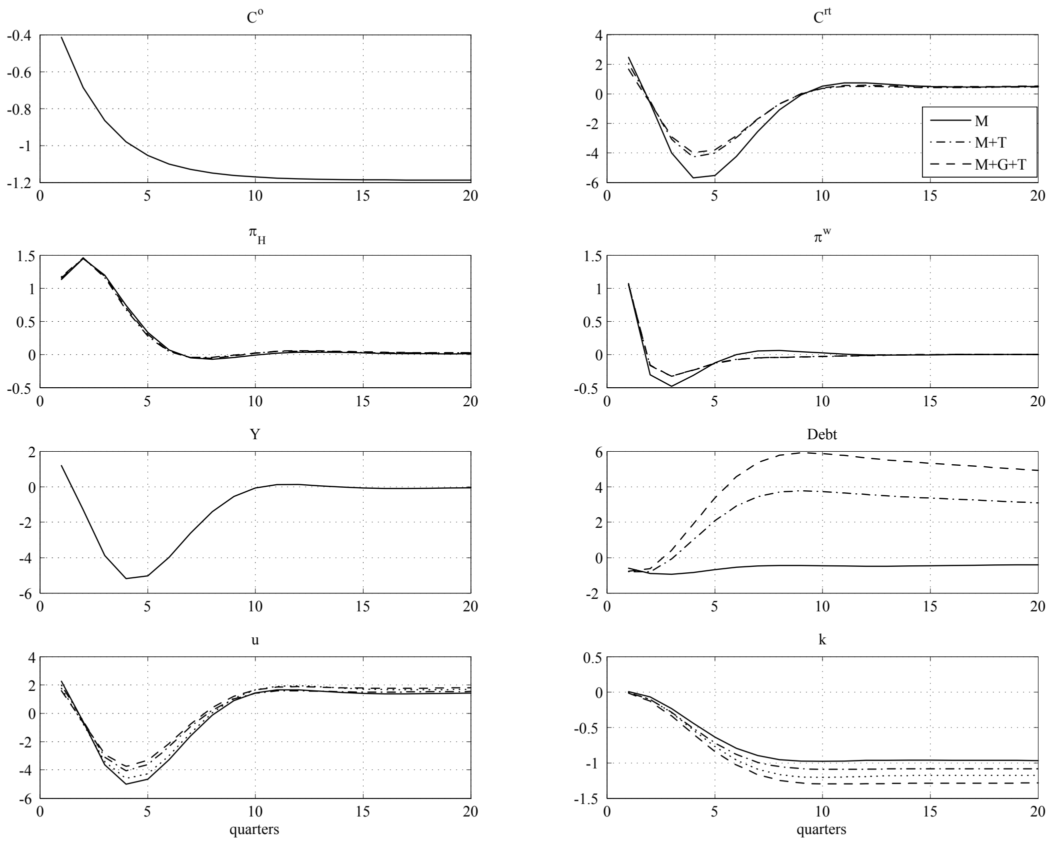

Figure 4: Wage shock

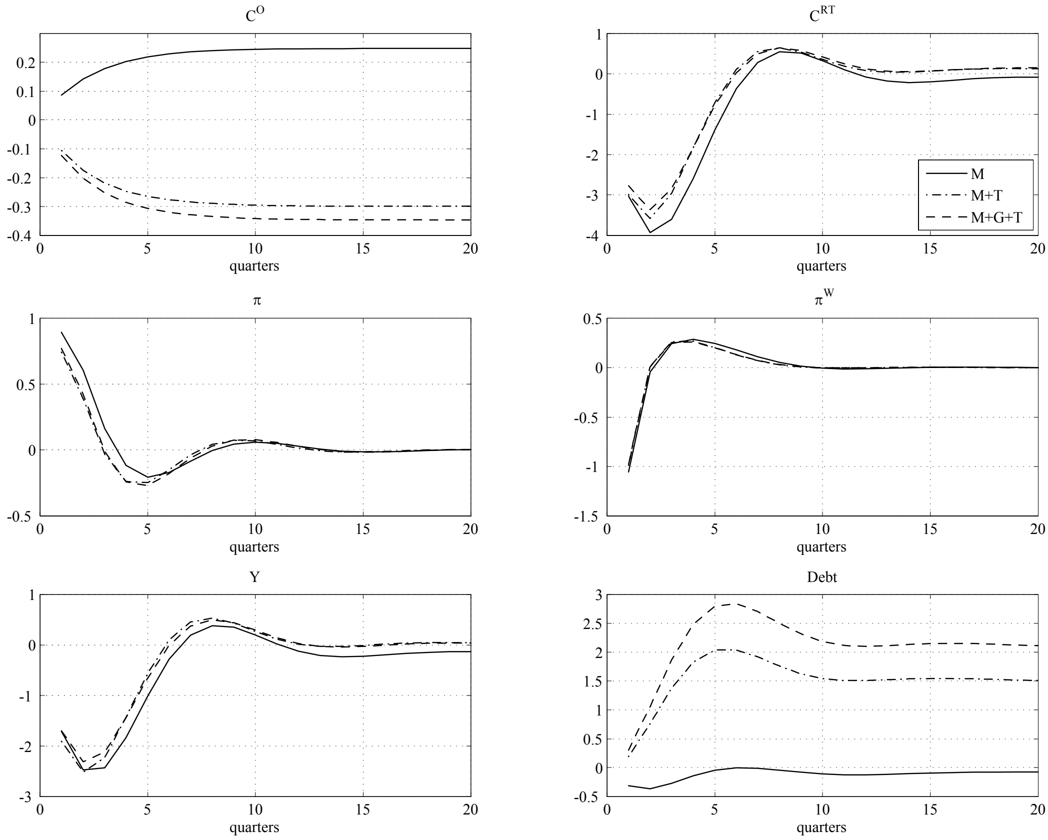

Figure 5: Domestic response of key variables to cost-push shock in country H.

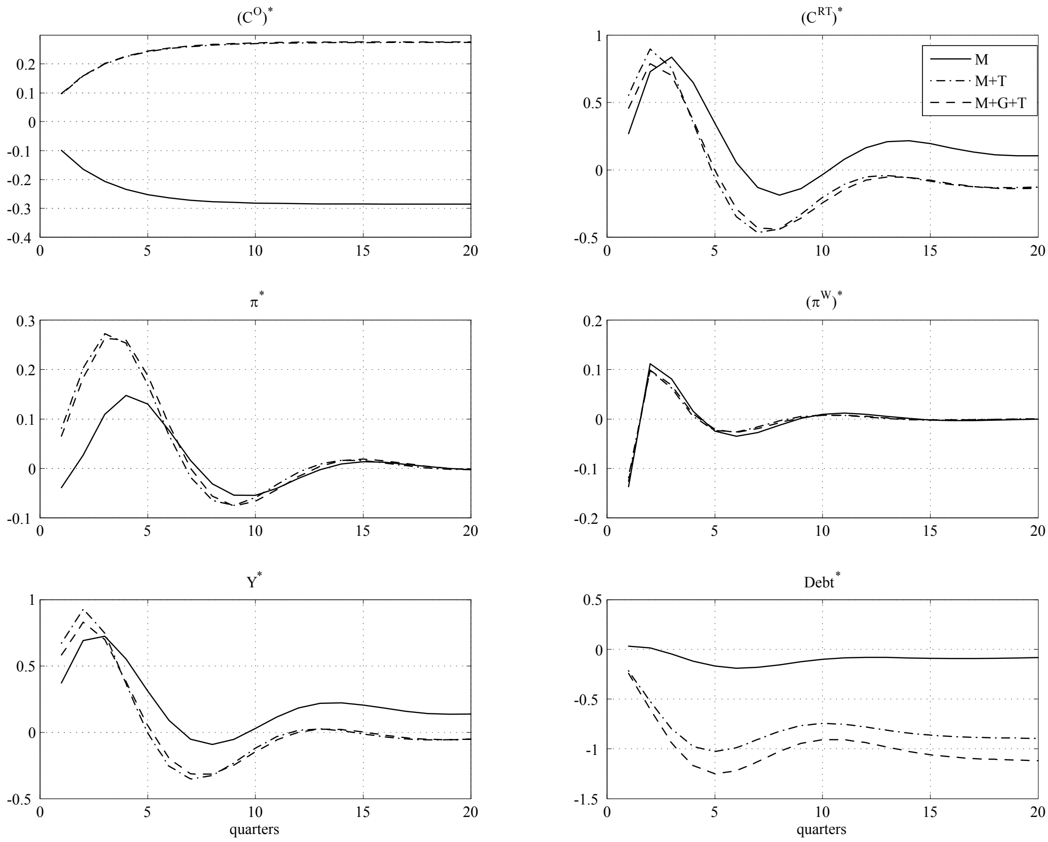

Figure 6: Foreign response of key variables to cost-push shock in country H.

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