Fiscal policy in a monetary union:
Optimal policy and cross-country spillovers

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Abstract

What are the effects of fiscal policy in a monetary union? This article explores the role of government spending, the optimal policy design and the various spillovers of public spending shocks in an integrated union. To this purpose, we develop a two-countries model with "large economies", updating the conclusions at stake in "small open economy" models, and providing a general framework where countries differ on many aspects – home-bias, agents preferences, price rigidities and labor supply. We show first that interaction effects and structural heterogeneity matter for optimal policy: the clear separation between central bank stabilizing the union and fiscal policies stabilizing country-specific shocks will not hold in this setting. Our second set of results is to identify the main transmission mechanisms of fiscal policy, with first a trade channel, through relative prices, and second a monetary response from the union central bank. Our main conclusion is that spillovers of fiscal policy shocks crucially depend on the central bank mandate and the second channel largely dominates the first in this setting. This framework provides arguments supporting coordination between union central bank and fiscal authorities in the context of the European Monetary Union.

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1 Introduction

The recent crisis has revealed that one of the major challenges of European Union is fiscal. If one hopes to *complete the EU*, in particular the Eurozone, its main currency and monetary union, one would have to rethink the role of fiscal policy. According to the "Five Presidents' Report", the Euro Area needs to introduce an advisory European Fiscal Board "coordinating and complementing national fiscal councils", before implementing a "common stabilisation function" with budgetary instruments. When monetary policy fails to stabilize large adverse shocks in situations of liquidity trap, such fiscal framework would strengthen the policy responses, while leaving idiosyncratic national shocks to the member states.

However, such clear-cut separation between asymmetric vs. aggregate stabilization – performed at country vs. union-level – may fail to address several issues at stake: the European crisis has shown powerful cross-country transmission channels, due to trade and financial integration. In particular, fiscal policy may react to shocks originated from neighboring countries or may itself generate policy spillovers to the rest of the Union.

This paper addresses these two questions: what are the transmission channels of government spending shocks and should fiscal policy be used to stabilize asymmetric shocks in a monetary union? The contribution of this paper is twofold: I first identify the cross-country spillovers of fiscal policy, and then determine the optimal policy in this monetary union. To this purpose, I develop a two-countries DSGE model with two *large* economies: I advocate that Small-Open-Economy models fail to identify cross-country transmission channels due to the lack of interaction effects: shock in one country affects the other country's decisions, which in turn amplify the original shock. Moreover, I provide a general framework where the two countries differ on many aspects: home-bias, agents preferences, price rigidities, labor supply, etc. As cross-country effects are not symmetrical anymore, the consequences of an aggregate shock or central bank policy will affect one country more severely than the other.

With these two characteristics, I provide a more accurate vision of the spillovers of government spending, and how interact the two countries' households, local fiscal authorities and the union-central bank. I choose to focus on a tractable New-Keynesian model, adding governments that provide public goods to representative households. This general environment differs from the preexisting literature mainly to account for structural heterogeneity and interaction effects.

This paper offers both normative and positive analyses. First, I establish general results about optimal policies – at the first and second best – and I build upon this analysis to discuss policy implications for the EMU. The main message is that country structural heterogeneity complicate the welfare investigation and requires a greater cooperation between the different stabilisation instruments. In particular, both the first-best allocation and the union loss function display novel "wedges" and "weights" depending on home-bias and labor supply elasticity. Using this welfare criterion for policy analysis, the *optimal policy* for central bank and national fiscal authorities reduces fourfold the welfare loss in case of asymmetric supply shocks. Fiscal policies can reduce trade imbalances and relative price differential that overload labor markets of one country. Moreover, I show that optimal policy can be *replicated* by means of simple monetary and fiscal policy *rules* – where central bank follows the standard Taylor principle and government spendings react to terms-of-trade and output gaps. The presence of structural heterogeneity provide a rationale for cooperation: to reach the optimum, the central bank should account for government spending adjustment and conversely.

Second, I turn to more positive implications and identify spillovers of fiscal policy shocks. The main result is the presence of two transmission channels: public spending in one country results in domestic inflationary pressures: This policy distorts terms-of-trade, as foreign goods are relatively cheaper, and private consumption for domestic-good decreases. This first *trade channel* appears both in small-open economy and large economy framework. The key insight when focusing on large-economies is to understand the impact of *monetary policy reaction*. In small-open economies, the domestic country, being negligible, has no impact on the union, while with two large economies, the effects of government purchases affects the union inflation: the central bank will therefore react to spending shocks by raising interest rate. As a result, this interest hike affects negatively the foreign country, where consumption decreases, output gap widens and prices fall. Therefore, the fiscal policy in a country may have a deflationary impact on its neighbor through central bank reaction. Such transmission channel is at the heart of our result and undermine common assessments from the small-open economy framework. The spillovers of fiscal policy of one country for its neighbors show a positive trade effect due to distorted terms-of-trade and a negative impact of central bank reaction, the second being much stronger in this setting.

Therefore, the nature of cross-country spillovers depends crucially on the central bank mandate, as well as country structural parameters: (i) if the monetary policy accounts for both consumption gap and inflation, i.e. following a Taylor rule, or if it sets interest rate with a high degree of inertia, then the outcome of a domestic fiscal policy shock may not cause foreign depression or deflation as in the benchmark model, (ii) when countries are heterogeneous, transmission of inflation may be stronger – through price flexibility, labor rigidity and openness – and both monetary and fiscal policy should focus on stabilizing the inflationary country. Our general conclusion is that the Foreign country does not really "benefit" from a Home spending shock. Under some specific restriction the spillover can be positive in terms of consumption, but at a cost of an higher inflation.

Literature: Before turning to the model, I briefly review how this paper stands in the literature. Since the appearance of the concept of *"Optimum currency area"*, the resilience of economic unions to asymmetric shocks, in particular with fiscal policies coordination, has been an important question. In the Public economics literature, since Tiebout's model to frameworks including game-theoretical features, many articles investigated the conditions for tax competition, public goods (mis-)allocation and interaction effects between regional units of federations[1]Considering the three public sector tasks (cf. Musgrave (1959)), I focus on government purchasing and providing public goods, both as an *allocation* and a *stabilization* policy.

This model is primarily interested in describing a microfounded New-Keynesian framework to analyze the nature of optimal policy in a currency union and is close to four articles from the New-Keynesian literature. First, Galí and Monacelli (2008) is a standard model investigating the role of fiscal and monetary policy in a "small-open economy" framework. However, as the union is made of a continuum of infinitesimal countries, a country policy have no impact on union inflation, output and central bank policy. I will show that such an environment is not suitable to identify cross-country policy transmission.

Beetsma and Jensen (2005) is the equivalent model with two countries and fiscal-monetary interaction, and is directly inspired from Benigno (2004). In terms of policy analysis, this article is very close to our setting. However, the main difference lies in the question of openness and Home-bias: as Benigno (2004), they consider "fully-open" households, without Home-bias and, as a result, both countries have identical consumption and CPI because of risk-sharing. This

[1]One can refer to Gordon (1983), Wilson (1986), Wildasin (1988) and Frankel and Rockett (1988), as well as Kehoe (1987), Devereux (1991) who adopt a macroeconomics approach.

restriction changes the general result, as trade transmission channel is absent. For this reason, the gains from stabilization of asymmetric shocks by fiscal policy are likely to be underestimated. Hence, I differ from this model, and adopt a more general setting.

Nevertheless, they also study country heterogeneity on policy tradeoffs, focusing on nominal rigidities. They conclude that monetary policy should implement a weighted-average inflation targeting rule, with more weight on the region with higher degree of price stickiness. I obtain a similar – but more general – result with weighted average, the weight accounting for supply-side factors: price stickiness but also labor-supply elasticity and agent preferences. In a different fashion, Liu and Pappa (2008) emphasize the importance of dissimilarity in trading structures – tradable/non-tradable sector – for macroeconomic coordination.

This paper also stands in the literature on the government spending effects and fiscal multipliers. Christiano, Eichenbaum and Rebelo (2011), Galí, López-Salido and Vallés (2007) and Farhi and Werning (2012*b*) emphasize the importance of either non-separable preferences, presence of credit-constrained households or the absence of monetary reaction – at the ZLB – to generate high fiscal multipliers. Inflationary public spending, in situation of positive wealth effects of labor supply or liquidity trap, reduces real interest rate and consumption reacts positively. In a *currency union* however, these effects are strikingly different, due to terms-of-trade distortion. When government spending appreciates terms-of-trade, this dampens consumption and the multiplier can be lower than one. Most of our result are analogous to the analysis of Farhi and Werning (2012*b*), but our framework displays interaction effects and implications from structural heterogeneity, absent from the small-economy model of their article.

Several articles such as Correia, Farhi, Nicolini and Teles (2013), Farhi, Gopinath and Itskhoki (2014), Farhi and Werning (2012*a*), also discussed innovative actions for government intervention. Using distortive taxes, government can "mimic" the path on interest rate or exchange rate, or fiscal-union can provide insurance via contingent transfers to cover against asymmetric shocks. However, distortive taxation can undermine greatly the positive impact of government spending, as in Drautzburg and Uhlig (2015). Ferrero (2009) use a similar framework but includes distortive taxation and government debt. However, I choose to focus solely on government spending policy, as taxes are always slower to react for stabilization motives.

Considering the research question and motivation I draw inspiration from the recent article by Blanchard, Erceg and Lindé (2017). This article measures the effect of a fiscal expansion in the "Core" economies of Euro Area that improves the outcomes of the "Periphery". Using a

medium/large-scale DSGE model, they show that the trade channel is key, along with the lack of reaction by central bank. As they use quantitative models with many features, it can be relevant to describe the transmission channels with a simpler and tractable model.

A last word on the empirical relevance of the two channels of fiscal policy in currency unions. As described in Beetsma and Giuliodori (2011) a fiscal shock can be followed by a rise in output and consumption but a reduction in trade-balance. This characterizes the "leakage effect" I describe, due to terms-of-trade distortions. Carlino and Inman (2013) also study the spillover of state-deficit policy in terms of employment. This question is also addressed in Hebous and Zimmermann (2013), who study the spillover of a fiscal shock in Euro Area, and compare unilateral vs. coordinated fiscal actions, showing that the latter have larger effect.

In the next section, I describe the main relations of the model[2] and the optimal policy design, before explaining the spillovers of fiscal policy shocks.

2 The model – a brief description

The economy is made of two countries (Home and Foreign), each country composed of a representative household, consuming private (C_t) and public (G_t) goods. The public good is supplied by the government in each country, financing these purchases through lump-sum taxes.

The Household has a taste for diversity consuming a continuum of goods (elasticity ϵ). However, consumption is subject to *Home-bias*, with a share α of foreign goods and $\alpha < 1/2$.

The union is a currency union where the exchange rate is pegged. The price-differential between Home- and Foreign- produced goods is thus measured with *term-of-trade* $\mathcal{S}_t = \frac{P_{F,t}}{P_{H,t}}$.

The household utility function is logarithmic in public and private consumption (with weight i.e. "taste" Γ for public goods) and separable in labor. The labor is subject to disutility, with a inverse-Frisch elasticity φ. Therefore, the household optimization yields a *Euler equation* and a *Labor-consumption trade-off*. The first relation rules the consumption path and will yield the dynamic IS-equation. Moreover, the economy is a monetary union where the interest rate is set by the union central bank.

The currency union financial markets are *complete* and the stochastic discount factors are equalized between the two households. As a result, the union risk-sharing implies the equalization

[2]The main relations are log-linearized. The equations in level are presented in appendix A

of consumption between Home and Foreign households. However, the differential between the two consumptions depends on terms-of-trade due to home-bias (when home-goods are cheaper, the domestic household consumes more) and a structural wedge because of different tastes for public goods (if Home household has a stronger taste for private goods than the Foreign country, its (private) consumption will be higher).

A continuum of firms produce goods under *monopolistic competition*. The technology is linear in labor, with a productivity shifter A_t subject to productivity shocks. Marginal cost is equal for all firms (due to constant return to scale) and real-wage and terms-of-trade affect positively marginal costs.

Prices are subjects to *Calvo-Yun rigidities*, with a share θ of firms not allowed to reset prices. Optimal pricing yields a price level as function of mark-up ($\mathcal{M} = \frac{\epsilon}{\epsilon-1}$). Under flexible prices we obtain $MC_t = \mathcal{M}^{-1}$ but employment subsidy offset monopolistic competition. Along the labor-consumption trade-off and the definition for marginal costs, inflation dynamics imply a standard *New-Keynesian Philipps-Curve* (NKPC). The aggregate-demand, with consumption and government spending of *both* countries, and future-prices affect positively present inflation.

2.1 Countries heterogeneity

The two countries are heterogenous on many aspects. Concerning *demand* factors, the countries are heterogenous in home-bias $\alpha \neq \alpha^*$ (for private consumption) and government openness $\alpha_{\mathrm{G}} \neq \alpha_{\mathrm{G}}^*$ (for public good consumption), the taste for public goods $\Gamma \neq \Gamma^*$ (compared to private goods). Moreover, each agent (Household and Government in the Home or Foreign) have heterogenous weight is the steady-state output of the union: $\gamma_{\mathrm{C}}, \gamma_{\mathrm{C}^*}, \gamma_{\mathrm{G}}, \gamma_{\mathrm{G}^*}$, i.e. respectively, share of Home consumption, Foreign consumption, Home government spending, Foreign government spending in aggregate demand at steady-state.

Turning to *supply-side factors*, the countries differ in: labor supply (and Frisch) elasticity, $\varphi \neq \varphi^*$, the degree of price stickiness $\theta \neq \theta^*$, and thus the inflation reaction to a rise in marginal cost (and ultimately aggregate demand) in the Phillips-Curve $\chi \neq \chi^*$.

These factors will appear in the NKPC, under a new parameter I denote $\xi_h \equiv \frac{2\,\gamma_{\mathrm{C}}\,\chi\,\varphi}{\gamma_{\mathrm{C}}+\gamma_{\mathrm{C}^*}}$ (and $\xi_f \equiv \frac{2\,\gamma_{\mathrm{C}^*}\,\chi^*\,\varphi^*}{\gamma_{\mathrm{C}}+\gamma_{\mathrm{C}^*}}$). It influences the resilience of a country to inflation: inelastic labor supply, high price flexibility and higher relative weight for domestically produced goods, will all have a higher impact on the union-economy's inflation rate. This parameter is key to understand the role of heterogeneity in optimal policy design and cross-country spillovers.

2.2 Log-linearization and deviation from the efficient allocation

Variables can be measured as log-difference compared to the efficient allocation. With nominal rigidities, policy trade-offs arise due to staggered price and terms-of-trade adjustment. These tradeoff are summarized with gaps, i.e. deviation from the first-best allocation. The variables under this optimal allocation are summarized in appendix B. As a result, the model' linear relations are presented with these gaps, e.g. output gap $\widetilde{y}_{H,t} = \hat{y}_{H,t} - \hat{\bar{y}}_{H,t}$, government spending gap: $\widetilde{g}_t$ or consumption gap: $\widetilde{c}_t$. The natural rate prevailing under flexible prices (where all gaps are closed) is denoted r_t^{nat}. After this description, we now turn to the main equations.

2.3 Main relations of the model

1) Among the different relations representing the link between the two countries, we can highlight:

The definition for the terms of trade gap:

$$\Delta \widetilde{s}_t = \pi_{F,t} - \pi_{H,t} - (\Delta a_t - \Delta a_t^*)$$

Terms-of-trade gap changes with productivity differential and evolution of inflation.

The union risk-sharing:

$$\widetilde{c}_t = \widetilde{c}_t^* + (1 - \alpha - \alpha^*)\, \widetilde{s}_t$$

Simply the differential version of union-risk sharing. In particular, when countries are more open, i.e. $(1 - \alpha - \alpha^*) \to 0$, the trade-channel disappears and consumptions are perfectly equalized.

2) The equations representing the dynamics at play *inside a country* are the following[3]:

The definition of Home output

$$\widetilde{y}_{H,t}/2 = \gamma_{\mathrm{C}}\,(1-\alpha)\,\widetilde{c}_t + \gamma_{\mathrm{C}^*}\,\alpha^*\,\widetilde{c}_t^* + \gamma_{\mathrm{G}}(1-\alpha_{\mathrm{G}})\,\widetilde{g}_t + \gamma_{\mathrm{G}^*}\,\alpha_{\mathrm{G}}^*\,\widetilde{g}_t^* + \omega\,\widetilde{s}_t$$

This accounting identity shows how consumption, government spending and trade affects demand for Home goods. In particular ω is the elasticity of this demand to terms-of-trade[4]

The IS-equation for the Home-country:

$$\widetilde{c}_t = \mathbb{E}_{\mathrm{t}}\,\widetilde{c}_{t+1} - (i_t - r^{nat}) + \mathbb{E}_{\mathrm{t}}\,\pi_{w,t+1} - \frac{\gamma_{\mathrm{C}^*}\,(1-\alpha-\alpha^*)}{\gamma_{\mathrm{C}}+\gamma_{\mathrm{C}^*}}\,\mathbb{E}_{\mathrm{t}}\,\Delta\widetilde{s}_{t+1}$$

$$r_t^{nat} = \rho + \frac{1}{\gamma_{\mathrm{C}}+\gamma_{\mathrm{C}^*}}\left[\,\gamma_{\mathrm{C}}\,\mathbb{E}_{\mathrm{t}}(\Delta\bar{a}_{t+1}) + \gamma_{\mathrm{C}^*}\,\mathbb{E}_{\mathrm{t}}(\Delta\bar{a}_{t+1}^*)\right]$$

[3] These relationships represents the dynamics in Home country H. For the relation in the Foreign country F, add stars $(*)$ for the variables and parameters, and change the sign for the terms-of-trade.

[4] Defined as $\omega \equiv (1-\alpha)\alpha\,\gamma_{\mathrm{C}} + (1-\alpha^*)\alpha^*\,\gamma_{\mathrm{C}^*} + (1-\alpha_{\mathrm{G}})\,\alpha_{\mathrm{G}}\,\gamma_{\mathrm{G}} + (1-\alpha_{\mathrm{G}}^*)\,\alpha_{\mathrm{G}}^*\,\gamma_{\mathrm{G}^*}$, It increases in openness and is zero in autarky. When terms of trade are depreciated, home goods are relatively cheaper for all the agents, increasing demand for Home-goods by a factor ω.

Directly implied by the household-Euler equation, the IS equation shows the role of monetary policy on consumption. In particular, the central bank reaction – through the interest rate – will affect much more consumption than the trade channel – implied by a relative price change $\widetilde{s}_t$.

The New Keynesian Philipps Curve (NKPC) equation, at Home:

$$\pi_{H,t} = \beta\, \mathbb{E}_t\, \pi_{H,t+1} + \chi \left[1 + 2\Xi^H\, \varphi\right] \widetilde{c}_t + 2\chi\, \varphi \left\{(1-\alpha_G)\, \gamma_G\, \widetilde{g}_t \;+\; \alpha_G^*\, \gamma_{G^*}\, \widetilde{g}_t^*\right\} + \chi \left[\alpha + 2\varphi(\omega - \alpha^*\, \gamma_{C^*}(1-\alpha-\alpha^*))\right] \widetilde{s}_t$$

This relation reflects the forward-looking price setting of firms. Inflation reacts to aggregate demand through its impact on marginal cost. Demand from consumption, public spending or exports directly implies higher work effort and labor disutility, the worker demanding higher wages. Another indirect effect appears with terms-of-trade depreciation, through the "relative price" of real wage. Wages are chosen by workers on account of CPI level, increasing in terms-of-trade, especially in "open" economy (high α). Moreover, marginal costs thus affect inflation faster when prices are fully-flexible, i.e. when $\theta \to 0$ and $\chi \to \infty$ the NKPC is vertical.

3) Aggregating, we can compute the consumption and inflation *in the union as a whole*:

The union-level Euler/IS equation:

$$\widetilde{c}_{w,t} = \mathbb{E}_t\, \widetilde{c}_{w,t+1} - (\gamma_C + \gamma_{C^*})[i_t - \mathbb{E}_t\, \pi_{w,t+1} - r^{nat}]$$

The union consumption reacts as in the standard closed-economy model, at the only difference that inflation is weighted by the Home goods share in household consumption basket[5].

The union-level Philipps Curve:

$$\pi_{w,t} = \beta\, \mathbb{E}_t\, \pi_{w,t+1} + \Xi^H \left(\tfrac{\chi}{\gamma_C + \gamma_{C^*}} + \xi_h\right) \widetilde{c}_t + \Xi^F \left(\tfrac{\chi^*}{\gamma_C + \gamma_{C^*}} + \xi_f\right) \widetilde{c}_t^* + \gamma_G \left\{(1-\alpha_G)\xi_h + \alpha_G\, \xi_f\right\} \widetilde{g}_t + \gamma_{G^*} \left\{(1-\alpha_G^*)\xi_f + \alpha_G^*\, \xi_h\right\} \widetilde{g}_t^* + \left[\tfrac{\alpha\, \gamma_C}{\gamma_C + \gamma_{C^*}}(\chi - \chi^*) + (\xi_h - \xi_f)\right] \widetilde{s}_t$$

This is the most important equation of the model: This shows how spillovers of demand shocks – in particular from government spending – matter for the union. The lesson is the following: a surge in demand have a greater impact on union-wide inflation through the country which has the "most *inflationary*" supply-side factors i.e. the *highest parameter* ξ. The greater the price-flexibility, the stickier the labor markets and the higher the share of domestic good in consumer

[5] In particular, this aggregation holds because I made the assumption that (i) the countries have equal size, and (ii) because of risk-sharing the consumption is equalized at steady-state, and therefore the trade-balance is null in the long-run. If trade differential persists, the union-IS-equation would feature a terms-of-trade term

baskets, the stronger will be the inflationary pressure on the union. Moreover, in our version of the model, the last the terms-of-trade variable is new: When countries are heterogeneous, terms-of-trade *differential* may affect the inflation *average* of the union: additional heterogeneity (e.g. higher ξ_h) implies a new transmission channel from terms-of-trade depreciation ($\widetilde{s}_t > 0$) to union inflation (higher π_w).

3 Welfare, Optimal policy design and simple rules

To determine the optimal policy, one should first derive the welfare criterion. I consider an utilitarian welfare function aggregating equally the two utilities, and take the second-order Taylor approximation of these utilities. The welfare function provides some insights : it displays quadratic terms in inflation, and – instead of output gaps – a quadratic form with consumption, government spending and terms-of-trade gaps, with squared terms but also with cross-products. Specifically, the interaction between terms-of-trade depreciation and private or public goods consumption will matter for the labor supply and thus the utility of the Union-household. The formal expression of the welfare loss is detailed and explained in eq. (2) in appendix.

The characterization of the *optimal policy under commitment* is the solution of the linear-quadratic optimization problem, minimizing the Loss function subject to the linear structural equations, i.e. the relation detailed above. However, the optimal path of central bank interest rate and both country government spending is relatively heavy[6] and provides almost no relevant economic intuitions. Therefore, I choose not the expose it here. Instead, I show how fiscal and monetary policy can replicate the optimal policy using *simple monetary and fiscal rules*. Following the simulation, there are several main lessons to remember:

First, *Central Bank* considers the union as a whole when setting the interest rate, but weighted for countries heterogeneity. This result is similar to Benigno (2004) – focusing on price flexibility (here χ) – but another important parameter in this model is the degree of labor disutility φ representing the labor supply responsiveness to demand shocks. The Taylor principle still holds and central bank reacts "more than one-to-one" to union inflationary pressure.

Second, the *two fiscal policies* should stabilize "relative" prices and output distortions. In particular, the main goal of government spending in this setting is to counteract aggregate demand changes that induce an "overloading" of the labor market of one country. Therefore,

[6]Seven additional (and very long) equations, including five non-instructive Lagrange multipliers

when a country faces output gaps, fiscal policy should act in order to close it, but without causing inflation at the Union level. The main point here is that the two fiscal policies should coordinate to close those gaps: in the presence of heterogeneity and interaction effects, a slight deviation from one of the country should generate important feedback on the neighboring country – as explained in the analysis of fiscal policy spillovers (cf. below).

Third, the optimal characterization can be replicated by three simple rules: for central bank and for the two fiscal authorities. This "fiscal rule" replication is accurate (less than 10^{-10} differences in the symmetric case), and the path of the main variables is perfectly replicated. The monetary rule is a simple rule to follow the natural interest rate and react to inflation – standard in the New Keynesian literature. The fiscal policy rule, however, is aimed at reacting to terms-of-trade gaps (here each country should react to half of it) and consumption gaps:

$$i_t = r_t^{nat} + \phi_\pi \, \pi_{w,t}$$

$$\widetilde{g}_t = -1/2 \, \psi_s \, \widetilde{s}_t - \psi_c \, \widetilde{c}_t$$

$$\widetilde{g}_t^* = +1/2 \, \psi_s^* \, \widetilde{s}_t - \psi_c^* \, \widetilde{c}_t^*$$

However, country structural heterogeneity, as we will see in section 5 makes the separation between aggregate and relative stabilization much less clear: fiscal policy act against a negative asymmetric supply shock and such policy can be transmitted to the other country through relative-prices and trade, triggering a rising interest rate from Central Bank. As a consequence, fiscal and monetary policies should work hand-in-hand.

4 Transmission of fiscal policy

In this section, we focus mainly on the spillover effects of a fiscal policy shock. The dynamics of the model following an exogenous productivity shocks and the optimal policy, are detailed in appendix D. Using the *symmetric* calibration, the economy is hit by a *fiscal spending shock* ε_t^f to the AR(1) "fiscal disturbance" process f_t^ε that shifts up the level of public spending above its efficient level, i.e. $\widetilde{g}_t > 0$ in one country only (at Home).

First, we suppose that beside the fiscal spending shock, the *fiscal policy is passive*: In the two countries, government are only concerned by closing the public spending gap, i.e. $\widetilde{g}_t = \widetilde{g}_t^* = 0$ and securing the efficient level of public goods[7]

[7]Here, we mainly consider the case where government purchase is "autarkic", i.e. purchase goods only from domestic production, with a complete Home-bias ($\alpha_G = \alpha_G^* = 0$)

Second, the central monetary authority follows simple *monetary rules*:

$$i_t = r_t^{nat} + \phi_\pi \, \pi_{w,t} \qquad \textit{Inflation rule}$$

$$i_t = r_t^{nat} + \phi_\pi \, \pi_{w,t} + \phi_c \, \widetilde{c}_{w,t} \qquad \textit{Taylor rule}$$

$$i_t = \rho_i \, i_{t-1} + (1 - \rho_i) \, (r_t^{nat} + \phi_\pi \, \pi_{w,t} + \phi_c \, \widetilde{c}_{w,t}) \qquad \textit{Inertial (Taylor)-rule}$$

We will differentiate these alternative cases, in the following impulse response functions and the results in terms of welfare and fiscal multipliers are displayed in table 1. The multiplier is the integral of output gaps[8] over the integral of fiscal gaps:

$$\frac{\Delta Y_t}{\Delta G_t} \approx \frac{\frac{Y_h}{Y_w} \sum_{t=1}^{T} \widetilde{y}_t}{\frac{G}{Y_w} \sum_{t=1}^{T} \widetilde{g}_t} \qquad \textit{Fiscal multiplier} \tag{1}$$

The 1% increase in government spending raises aggregate demand with a direct impact on Home inflation (through labor and wage bargaining, cf. the NKPC). This raises union-wide inflation and central bank reaction. Depending on the central bank mandate, the dynamics are the following:

(i) If the central-bank only reacts to *inflation*, the key mechanism is the "threat" of interest rate hike (high ϕ_π) at the root of the Taylor principle. Therefore, on the short-run, inflationary government spending results in a sharp drop of consumption – a crowding-out effect. However, the main difference here is that union-wide inflation – which stays low at the union level – and the strong monetary reaction affects *both* Households, inducing a large union-wide negative consumption gap. The Foreign household is hurt by the central bank response, with highly depressed demand (consumption and output) and deflation. On the medium run, when prices adjust, Home inflation appreciates terms-of-trade and Foreign goods are relatively cheaper. This shifts aggregate demand from Home to Foreign goods and this trade rebalancing creates inflationary pressures on the Foreign country, leading to a term-of-trade reversal. To sum up, here the spillovers are mainly negative due to monetary reaction and it is difficult to conclude that Foreign country can "benefit" from Home government spending.

(ii) When the monetary policy follows a *Taylor-rule*: The crowding-out effect in consumption is significantly smaller, and it does not dampen Foreign consumption as much as before, nor does it imply deflation[9]. Note that all the differences appear at the Union-level. In particular, terms-of-trade dynamics are identical. Interestingly, the higher inflation and smaller consump-

[8] More precisely, we compute the *difference* in output gaps with or without fiscal policy intervention.
[9] Even though the Union Inflation is ten time higher, the union consumption is seven time smaller

tion gap are implied by the "Taylor-rule" mandate, but the Central Bank effectively implement a sharp increase in interest rate – five times higher than before. The key point is the internalization of the central bank mandate by consumers. Again, as prices adjust – Home inflation and terms-of-trade appreciation – Home consumption gap widen even more, because of Home-bias, and aggregate demand is redirected toward Foreign goods, leading to the same terms-of-trade reversal. To conclude, the change in the central bank mandate is key to understand how the Foreign country benefit from Home fiscal shock. A "balanced" mandate between consumption and inflation prevents deflationary episode and implies positive output gap for the Foreign country.

(iii) When central bank policy reacts with *inertia*: The slow pace of interest rate adjustment on the short-run changes the dynamics, and this time, there *is no consumption drop* at the Union level. Even more, the inflationary pressure and the slow pace of terms-of-trade adjustment lead them to increase their consumption: as aggregate demand shift toward Foreign goods, inflation rise. After adjustment of interest rate, both consumption and inflation drop, especially for Home. As a result, the Foreign Household is less affected when Central Bank takes time to adjust: for a similar level of inflation, the Foreign consumption and output gaps are positive.

In this experiment, the fiscal multiplier is rather small – around 0.68 – meaning that for 1 unit of public spending, output rises by 0.68 on average. This ratio is smaller than 1 because consumption is crowded-out after the shock hits[10].

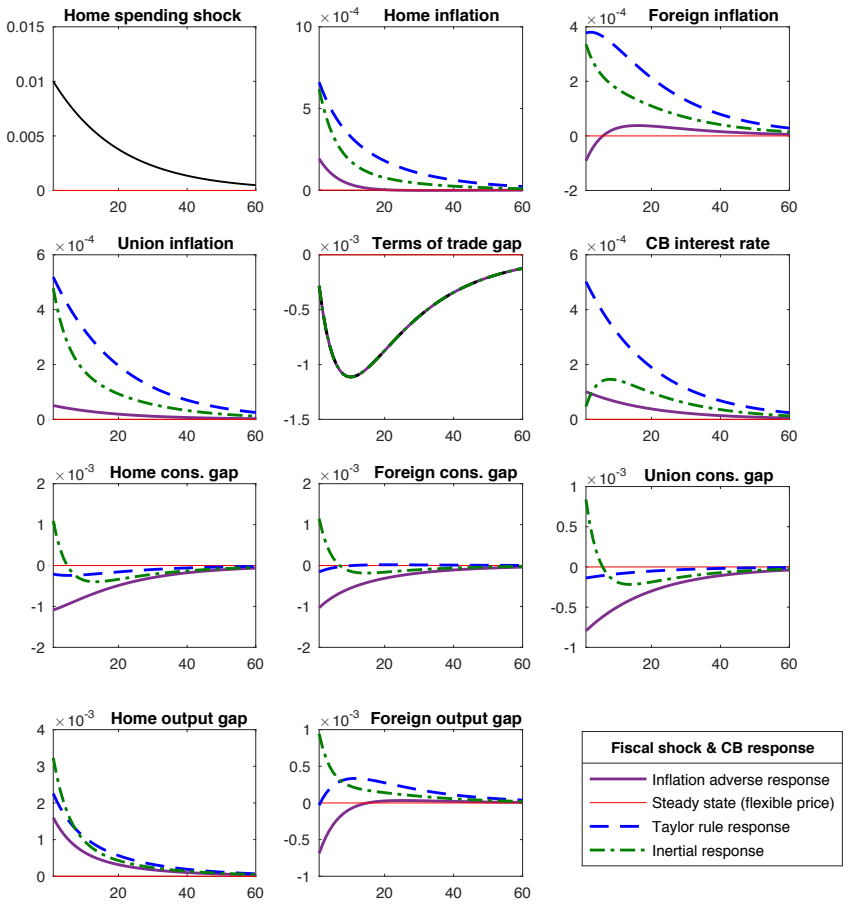
Table 1: Spillovers of fiscal shocks, welfare loss, Fiscal multipliers and country heterogeneity

Type of shock	Parameter ξ		Monetary response	Welfare loss	Home Fiscal multiplier
	Home	Foreign			
Home shock	Symmetric (0.027)		*Inflation rule*: $\phi_\pi = 2$	0.034	0.414
Home shock	Symmetric (0.027)		*Taylor-rule*: $\phi_\pi = 1.1$ & $\phi_c = 0.5$	0.035	0.676
Home shock	Symmetric (0.027)		*Inertial-Taylor-rule*: $\rho_i = 0.95$	0.036	0.650
Home shock	High (0.064)	Low (0.0093)	Taylor rule	0.038	0.643
Home shock	Low (0.0093)	High (0.064)	Taylor rule	0.034	0.617
Union shock	High (0.064)	Low (0.0093)	Taylor rule	0.080	0.770
Union shock	Low (0.0093)	High (0.064)	Taylor rule	0.080	0.883

Notes: Central Bank follows a simple policy rules. Welfare loss is expressed as percent of consumption.
Calibration: when Home have "low" / "high" parameter value ξ_h, it is the reverse for Foreign ("high" / "low" ξ_f)

[10]As quantitative results are highly dependent on parameter calibration, I tested numerical computation of multipliers in function of three key parameters: openness α, labor supply elasticity φ and price flexibility χ. We could note three simple facts: (i) the size of the fiscal multiplier does not change much with openness, as would conclude "small open economy" models, but welfare loss is much greater in autarky, (ii) complete price rigidity ($\theta > 0.97$) raises the spending multiplier much closer to one, (iii) labor inelasticity can undermine greatly the effectiveness of government spending.

Figure 1: Response to a 1% spending shock



Public spending shock follows a AR(1) process, Central bank reacts to inflation under the rules detailed in **??**, and fiscal policy is passive after the shock, i.e. $\widetilde{g}_t = \widetilde{g}_t^* = 0$

5 Structural heterogeneity: a rationale for policy cooperation

Our model presents heterogeneity in most parameters. However, some of the structural parameters – what we can call "supply-side factors" in a new parameter ξ_h for Home and ξ_f for Foreign – affects inflation in the same direction through the New-Keynesian Philipps Curve. More rigorously, low Frisch elasticity (high φ), more flexible prices (low θ, high χ) and higher tastes for private goods (high γ_C), all increases ξ_h, and, as a result, inflation at Home is relatively more reactive than in the Foreign country. Such difference will have important implications for policy, and I try to provide a succinct view on this issue. We use the following calibration.

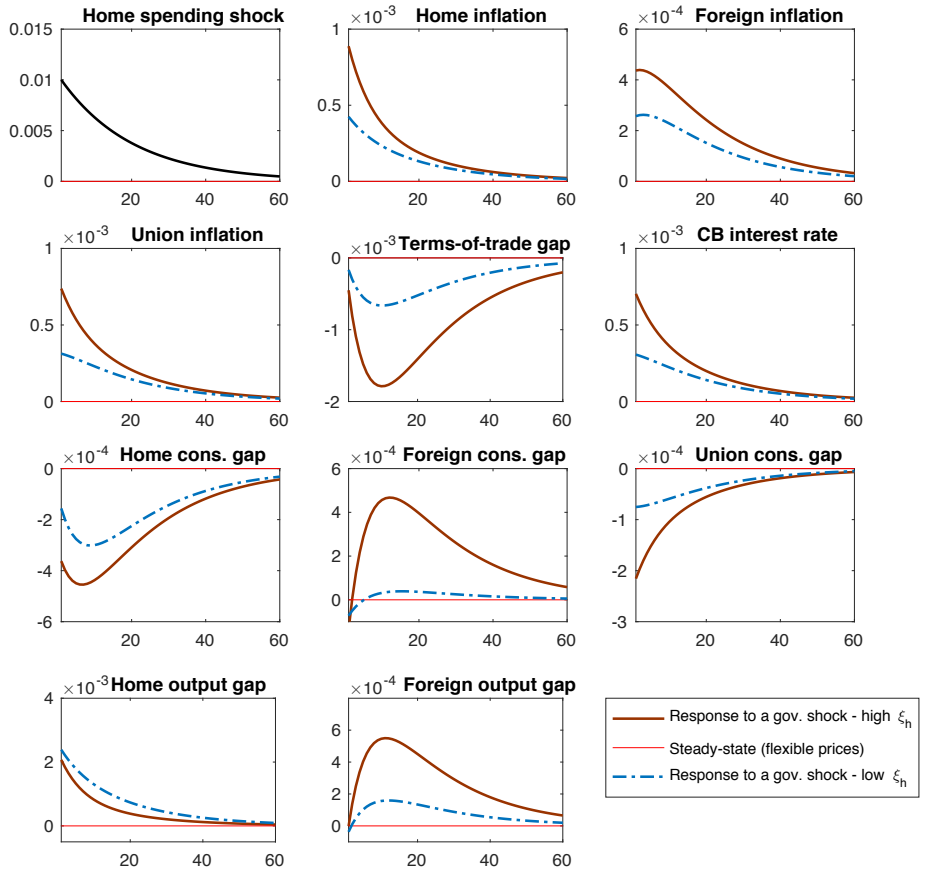
Again, leaving the analysis of productivity shock to the appendix, we focus on the spillovers of an *asymmetric fiscal spending shock*. We distinguish two cases: in the first (a), Home economy

Table 2: Comparison and *heterogeneity* in structural parameters value

Parameter	High value of ξ	Low value of ξ	Signification
φ	4	2	Inverse Frisch elasticity
χ	0.012	0.007	Slope of NKPC
θ	0.898	0.922	Price stickiness (measure of firms who can't reset prices)
γ_C	0.5	0.25	Union demand for Home good
α	0.2	0.3	Openness in private consumption
ξ_i	0.064	0.0093	Inflationary effect of supply-side factors $\xi_i \equiv \frac{2\gamma_C \chi \varphi}{\gamma_C + \gamma_{C^*}}$

has a high ξ_h and is more affected by price changes. In (b) it is exactly the opposite (low ξ_h). Here the difference is mostly quantitative. Rather intuitively, the inflationary effect of the government spending increases with ξ, i.e. stronger in case (a) than in (b). More, the terms-of-trade gap in favor of the Foreign country is much largely emphasized with high ξ, which benefit more or less the Foreign country in terms of positive consumption gap and inflation.

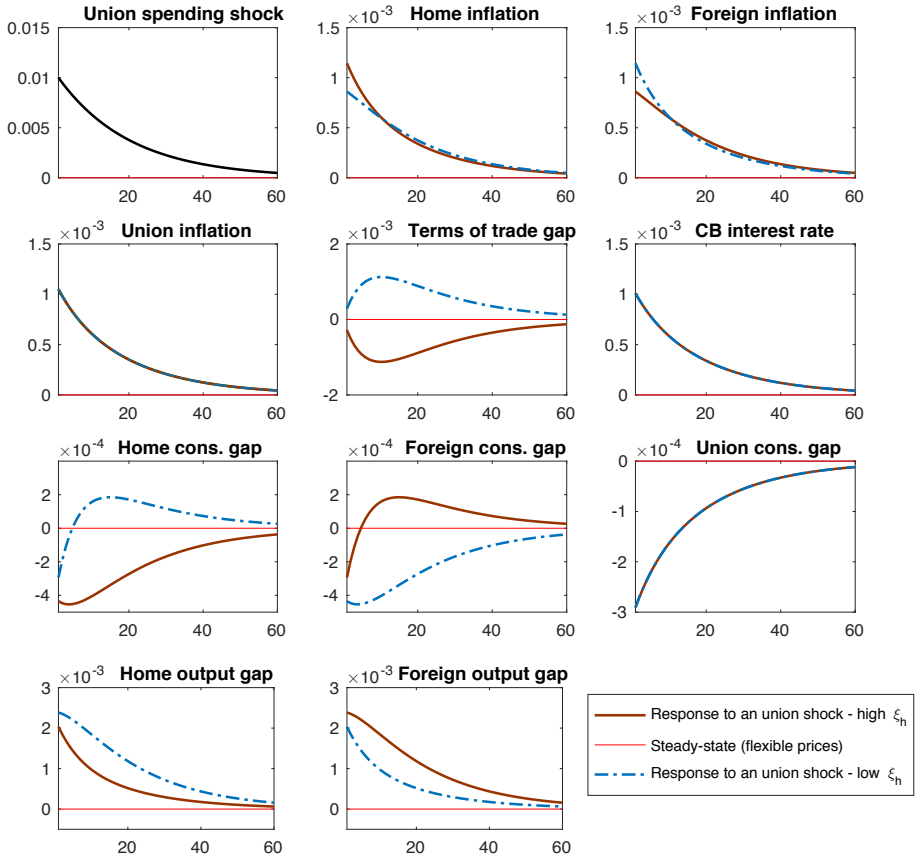
Figure 2: Response to a 1% asymmetric gvt. spending shock, comparison with two heterogeneous countries



Public spending shock follows a AR(1) process. Countries are heterogeneous on structural parameters, summarized in $\xi_h \equiv \frac{2\Xi^H \chi \varphi}{\gamma_C + \gamma_{C^*}}$. Central bank policy follows a Taylor rule and fiscal policy is passive. Results are shown in table 5

This model was well suited to study asymmetric shock. However, heterogeneity in structural parameters provides the two economies with different resilience to a *common aggregate* shock, which, in turn, results in asymmetric spillovers. We simulate a common fiscal shock, or equivalently a rise in government purchases affecting both countries equally: the government sizes are the same, and both fiscal shock are "autarkic": AR(1) processes out of a passive fiscal mandate. This kind of experiment could be relevant, for example, if the Currency Union is involved in a political conflict and should rise military spending in all its region. The consequence is an asymmetric diffusion of inflation, higher in the region with the highest parameter ξ_i. As we note in the following graph, when ξ_h is high, inflation is higher at Home, even though government spending is the same, and this distorts terms-of-trade for the benefit of the Foreign country, with a positive consumption gap.

Figure 3: Response to a 1% aggregate government spending shock, analysis with heterogeneity



Spending shock follows a AR(1) process and hits both economies. Countries are heterogeneous on structural parameters, summarized in $\xi_h \equiv \frac{2\Xi^H \chi \varphi}{\gamma_C + \gamma_{C^*}}$. CB follows a Taylor rule and fiscal policy is passive.

6 Conclusion

In this master thesis, I provide a two country DSGE model with "large economies" in a monetary union. Our New-Keynesian framework emphasized the transmission channels due to interactions between the two economies, their fiscal policies and a common central bank. In particular, I allow for Home bias as well as heterogeneity in preferences and structural supply-side factors: share of goods production, labor elasticity, price flexibility.

From this very general setting, I extracted different results: I first determined the co-operating optimal allocation at the first-best: private consumption and public spending track productivity of the two countries, weighted by structural preferences. Second, when nominal rigidities exists, there exists policy trade-off, in terms of consumption gaps, inflation and terms-of-trade gap. I determined how to achieve optimal policy by the mean of simple rules: inflation rule for central bank policy and reaction to terms-of-trade and consumption gap for fiscal policy.

Third, this environment was suitable to study the spillovers of fiscal policy. The reaction of the central bank is key: in case of spending shock, the reaction of the central bank creates depression and deflation abroad. With Taylor-rule mandate, inertia in interest rate and structural heterogeneity can all induce more inflationary spillover to the Foreign country.

This last observation brings about a key question: *when one country experiences a supply or demand shock, what are the gains from policy cooperation?* I studied welfare gains when fiscal policy is optimal – substantial gains due to labor inelasticity and trade imbalances between the two countries. However, I did not study non-cooperative situations. For example, if Home country experiences a supply shock, is the Foreign country willing to "help" the Home country for stabilizing this shock? or would it "deviates" and let Home fiscal policy hold all the burden of the fiscal adjustment? If we are able to compare the diverse outcomes, the answer to this question would require an extended game-theoretical framework and in particular dynamic games and recursive contracts. We consider this question relevant and would like to pursue on these questions in the future.

However, we could describe many policy implications. In our simple framework, there exist transmission channels through central bank reaction and trade spillovers, and heterogeneity transforms an "asymmetric" issue – e.g. terms-of-trade or relative consumption gap – into an "aggregate" one. Therefore, this is a strong case for macroeconomic coordination between the national fiscal authorities and the union central bank. We believe this article provides a clearer view on these topics and can shed light on several policy issues in the context of European Union.

Appendices

A Main relations of the models

- Household relations

$$U(C_t, G_t, N_t) \equiv (1-\Gamma)\log(C_t) + \Gamma\log(G_t) - \frac{N_t^{1+\varphi}}{1+\varphi} \qquad \text{Utility function}$$

$$\int_0^1 C_{H,t}(i)P_{H,t}(i)di + \int_0^1 C_{F,t}(i)P_{F,t}(i)di + \mathbb{E}_t\{Q_{t,t+1}D_{t+1}\} \leq D_t + W_t N_t - T_t \qquad \text{Budget constraint}$$

$$\mathcal{S}_t = \frac{P_{F,t}}{P_{H,t}} \qquad \mathcal{R}_t = \frac{P_t^*}{P_t} = \mathcal{S}_t^{(1-\alpha-\alpha^*)} \qquad \text{Terms-of-trade \& Real-Exchange Rate}$$

$$Q_{t,t+1} = \beta\Big(\frac{P_t}{P_{t+1}}\Big)\Big(\frac{C_t}{C_{t+1}}\Big) \qquad \text{Euler equation}$$

$$C_t\, N_t^{\varphi} = (1-\Gamma)\frac{W_t}{P_t} \qquad \text{Labor-consumption tradeoff}$$

$$\frac{C_{t+1}}{C_t} = \frac{C_{t+1}^*}{C_t^*}\Big(\frac{\mathcal{R}_{t+1}}{\mathcal{R}_t}\Big) \qquad \text{Union risk-sharing}$$

$$\Rightarrow \quad C_t = \vartheta_0\, C_t^*\, \mathcal{R}_t \;=\; \vartheta_0\, C_t^*\, \mathcal{S}_t^{1-\alpha-\alpha^*} \qquad \text{Consumption equalization}$$

ϑ_0 introduces a wedge between Home and Foreign consumption. It is caused by asymmetric preferences for public good (and thus government size) between the two countries: $\vartheta_0 = \frac{1-\Gamma}{1-\Gamma^*}$ This is consistent with a null-trade-balance at steady-state between the two countries.

- Firms relations

$$Y_t = A_t\, N_t\, \Delta_t \qquad \text{Production, with } \Delta_t \text{ price dispersion}$$

$$MC_t = (1-\tau)\frac{W_t}{P_t}\,\frac{N_t}{Y_t}\,(S_t)^{\alpha} \qquad \text{Marginal cost}$$

B Cooperating allocation, optimum at the first-best

The cooperating optimal allocation corresponds to the situation where the union's social-planner maximizes the weighted sum of Household utility $\omega_H U_H(C_t, N_t, G_t) + \omega_F U_F(C_t^*, N_t^*, G_t^*)$ subject to both resource constraints of the two countries, $Y_{J,t} = C_{J,t} + C_{J,t}^* + G_{J,t} + G_{J,t}^*$ and technological constraint: $Y_{J,t} = A_t^J \, N_t^J$ for $J = H, F$.

$$C_{H,t} = \omega_H \, (1-\Gamma)(1-\alpha) \, A_t \eta^{-\frac{\varphi}{1+\varphi}} \qquad C_{F,t}^* = \omega_F \, (1-\Gamma^*)(1-\alpha^*) \, A_t^* \, \eta*^{-\frac{\varphi*}{1+\varphi*}}$$

$$C_{H,t}^* = \omega_F \, (1-\Gamma^*)\alpha^* \, A_t \, \eta^{-\frac{\varphi}{1+\varphi}} \qquad C_{F,t} = \omega_H \, (1-\Gamma)\alpha \, A_t^* \, \eta*^{-\frac{\varphi*}{1+\varphi*}}$$

$$G_{H,t} = \omega_H \, \Gamma(1-\alpha_{\mathrm{G}}) \, A_t \, \eta^{-\frac{\varphi}{1+\varphi}} \qquad G_{F,t}^* = \omega_F \, \Gamma^*(1-\alpha_{\mathrm{G}}^*) \, A_t^* \, \eta*^{-\frac{\varphi*}{1+\varphi*}}$$

$$G_{H,t}^* = \omega_F \, \Gamma^* \, \alpha_{\mathrm{G}}^* \; A_t \, \eta^{-\frac{\varphi}{1+\varphi}} \qquad G_{F,t} = \omega_H \, \Gamma \, \alpha_{\mathrm{G}} \, A_t^* \eta*^{-\frac{\varphi*}{1+\varphi*}}$$

$$N_t = \eta^{\frac{1}{1+\varphi}} \qquad N_t^* = \eta^{*\frac{1}{1+\varphi}} \qquad \mathcal{S}_t = \frac{A_t}{A_t^*} \, \frac{\eta*^{\frac{\varphi*}{1+\varphi*}}}{\eta^{\frac{\varphi}{1+\varphi}}}$$

$$\eta = \omega_H \, (1-\Gamma)(1-\alpha) + \omega_F \, (1-\Gamma^*)\alpha^* \; + \omega_H \, \Gamma(1-\alpha_{\mathrm{G}}) + \omega_F \, \Gamma^* \, \alpha_{\mathrm{G}}^*$$

$$\eta^* = \omega_F (1-\Gamma^*)(1-\alpha^*) + \omega_H \, (1-\Gamma)\alpha \; + \omega_F \, \Gamma^*(1-\alpha_{\mathrm{G}}^*) + \omega_H \, \Gamma \, \alpha_{\mathrm{G}}$$

Define the parameter η (and resp. η^*) as "preferences" for Home (resp. Foreign) good. The key point is that labor supply is only function of structural parameters (this new η and labor disutility φ), and thus a function of the "tastes" of the four agents (Home/Foreign, Household/Government). The expression for terms of trade $\mathcal{S}_t$ is worth noting: if the tastes differ between Home and Foreign ($\eta \neq \eta^*$), the ratio displays a long-run price differential between the two countries, *even in absence of productivity differential*. This permanent "unbalanced" terms-of-trade arise in a cooperating equilibrium mainly because agents interiorize both Home and Foreign resource and technological constraints.

To simplify the result, we make the hypothesis that $\eta = \eta* = 1$. Without this assumption, structural heterogeneity leads to persistent differences in output, labor supply, consumptions and terms-of-trade, implying a persistent increase in the market share of one country. We obtain a new constraint on the structural parameters for preferences: $(\alpha^* - \alpha) + \Gamma(\alpha - \alpha_{\mathrm{G}}) = \Gamma^*(\alpha^* - \alpha_{\mathrm{G}}^*)$. This assumption implies that Home and Foreign Households should not have "too different" tastes – to impose unitary labor supply and equal size in each country. Consequently, this imposes a trade-balance that is null at steady-state. For example, a trade surplus of private consumption should be balanced by a trade deficit in public consumption. With this simplification, it is easy to rewrite optimal allocation, in much closer fashion as the one in Galí and Monacelli (2008)

C Welfare loss function

The second order approximation of Households utility function yields the following expression, with *t.i.p.* terms independent of policy (i.e. productivity) and $\mathcal{O}(\|\xi\|^3)$ terms of third order:

$$\mathbb{W} = \sum_{t=0}^{\infty} \beta^t \, \mathbb{E}_t(\mathbb{L}_t^w) \; + \; t.i.p. \; + \; \mathcal{O}(\|\xi\|^3) \tag{2}$$

$$\mathbb{L}_t^w = \tfrac{\epsilon}{2\chi}\,\pi_{H,t}^2 + \tfrac{\epsilon}{2\chi^*}\,\pi_{F,t}^2 \; + \; \gamma_{\mathrm{C}}\;\widetilde{c}_t^{\,2} \; + \; \gamma_{\mathrm{C}^*}\;\widetilde{c}_t^{*\,2} + \gamma_{\mathrm{G}}\;\widetilde{g}_t^{\,2} + \gamma_{\mathrm{G}^*}\;\widetilde{g}_t^{*\,2} + \omega\,\widetilde{s}_t^{\,2}$$
$$(\widetilde{c}_t^{w,pol})^2 \; + \; (\widetilde{g}_t^{w,pol})^2 \; + \; (\widetilde{s}_t^{w,pol})^2 \; + \; \widetilde{c}_t^{w,pol}\cdot\widetilde{g}_t^{w,pol} \; + \; \widetilde{c}_t^{w,pol}\cdot\widetilde{s}_t^{w,pol} \; + \; \widetilde{g}_t^{w,pol}\cdot\widetilde{s}_t^{w,pol}$$

where the terms denoted by "*w,pol*" are defined as weighted average of variables at Home and in the Foreign country. They are represented using vectors (and quadratic terms are thus product of two vectors) and account for the countries heterogeneity, in particular agents tastes and labor disutility. As a result, we defined "*w,pol*", the "policy average" as follow:

$$\widetilde{c}_t^{w,pol} \equiv M_l \begin{pmatrix} \widetilde{c}_t^{w,H} \\ \widetilde{c}_t^{w,F} \end{pmatrix} \qquad \widetilde{g}_t^{w,pol} \equiv M_l \begin{pmatrix} \widetilde{g}_t^{w,H} \\ \widetilde{g}_t^{w,F} \end{pmatrix} \qquad \widetilde{s}_t^{w,pol} \equiv M_l \begin{pmatrix} 2\,\omega\,\widetilde{s}_t \\ -2\,\omega\,\widetilde{s}_t \end{pmatrix}$$

where $\widetilde{c}_t^{w,H/F}$ (resp. $\widetilde{g}_t^{w,H/F}$ and $\pm\,2\,\omega\,\widetilde{s}_t$) are the gaps in union-consumption (resp. public spending and terms-of-trade) that affects supply of Home/Foreign goods. Therefore, differences in labor supply elasticity are included in M_l. More formally:

$$M_l \equiv \begin{pmatrix} \sqrt{2\,\varphi} & 0 \\ 0 & \sqrt{2\,\varphi^*} \end{pmatrix} \qquad \begin{cases} \widetilde{c}_t^{w,H} \equiv \gamma_{\mathrm{C}}(1-\alpha)\,\widetilde{c}_t + \gamma_{\mathrm{C}^*}\,\alpha^*\,\widetilde{c}_t^* \\ \widetilde{c}_t^{w,F} \equiv \gamma_{\mathrm{C}^*}(1-\alpha^*)\,\widetilde{c}_t^* + \gamma_{\mathrm{C}}\,\alpha\,\widetilde{c}_t \end{cases} \qquad \begin{cases} \widetilde{g}_t^{w,H} \equiv \gamma_{\mathrm{C}}(1-\alpha_{\mathrm{G}})\,\widetilde{g}_t + \gamma_{\mathrm{G}^*}\,\alpha_{\mathrm{G}}^*\,\widetilde{g}_t^* \\ \widetilde{g}_t^{w,F} \equiv \gamma_{\mathrm{C}^*}(1-\alpha_{\mathrm{G}}^*)\,\widetilde{g}_t^* + \gamma_{\mathrm{G}}\,\alpha_{\mathrm{G}}\,\widetilde{g}_t \end{cases}$$

Welfare loss features quadratic terms and cross products, in inflation (i), in consumption and public spending (ii), in weighted average of consumption and government spending (iii), and in terms-of-trade (iv). We use a notation using matrices, slightly more convenient and synthetic[11].

D Technology shocks, optimal policy and simple rules

To illustrate the model dynamics, we run Impulse Response Functions (IRF) using Dynare software. A word on the model ***calibration***. We use standard value for structural parameters, and we consider a *symmetric* equilibrium, where Home and Foreign are homogeneous.

When the economy is hit by an exogenous *productivity (TFP) shock* – i.e. ε_t^a affecting an AR(1) technological process a_t – this shock is asymmetric, *hitting only the Home country*. We

[11] In particular, with vectors, it is easier to express cross-products in terms of union-level variable. However, we misused the notation and we should more rigorously note that quadratic terms $\widetilde{c}_t^{w,pol}$ are in fact product of matrices, i.e. $(\widetilde{c}_t^{w,pol})^2 = (\widetilde{c}_t^{w,pol})^T\,(\widetilde{c}_t^{w,pol})$

Table 3: Baseline – *symmetric* – structural parameters value

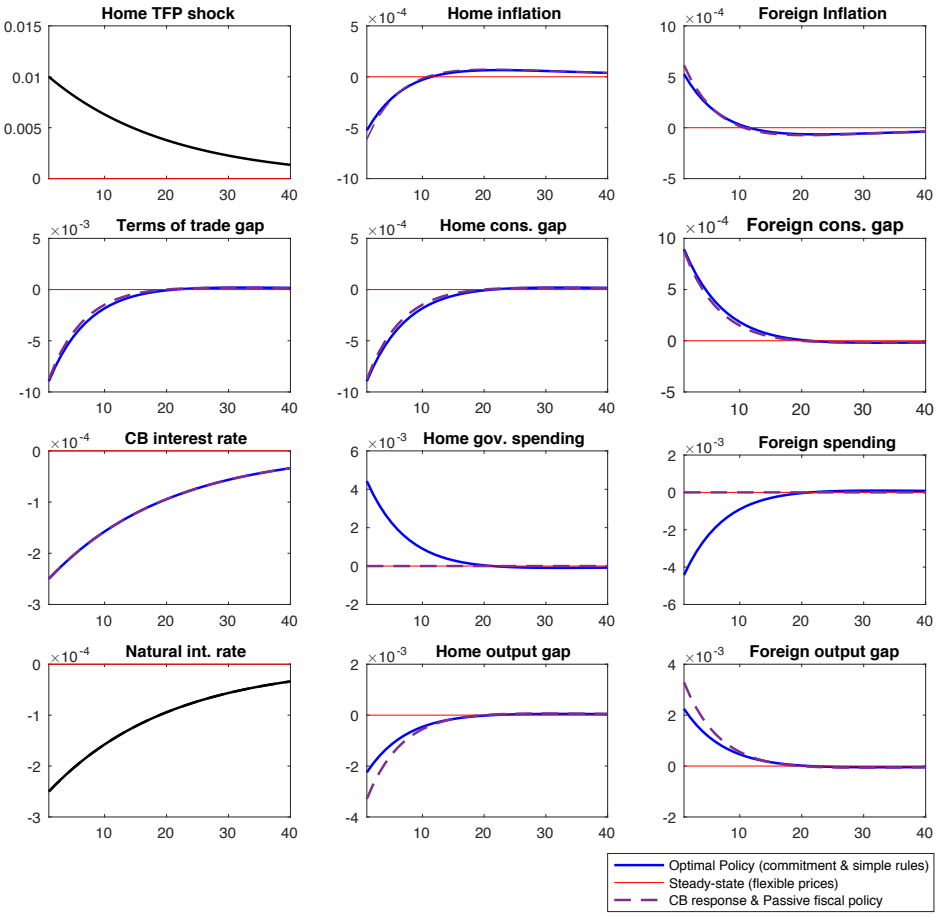
β	0.995025	Discount factor			*Autarkic government*
ρ	0.005	Riskless return per period	α	0.4	Openness in private consumption
φ	3	Inverse Frisch elasticity	α_G	0	Openness in public consumption
χ	0.009	Slope of NKPC	ω	0.18	Output–terms-of-trade elasticity
θ	0.91165	Price stickiness			
ρ_a, ρ_f	0.95	Persistence of shocks			
μ	1.2	Firm's markup			*"Open" government*
ϵ	6	Elasticity of substitution across goods	α	0.35	Openness in private consumption
Γ, Γ^*	0.25	Preference for public goods	α_G	0.25	Openness in public consumption
γ_C, γ_{C^*}	0.375	Private consumption share	ω	0.2175	Output–terms-of-trade elasticity
γ_G, γ_{G^*}	0.125	Government size			

simulate the model with three type of policy: (1) the reaction of monetary policy to inflation and a *passive* fiscal policy, i.e. $\widetilde{g}_t = \widetilde{g}_t^* = 0$, (2) the optimal policy of central bank and fiscal policy, under commitment, and (3) the replication of optimal policy by three simple rules, as described above. The result is shown in fig. 4.

A productivity shock, increasing (Home) economy output is not followed by a rise in consumption. In our setting, the *terms-of-trade gap is also falling*, because relative prices take time to adjust: the Home terms-of-trade is over-appreciated compared to efficient level (i.e. $\widetilde{s}_t < 0$). As Home economy accounts for a large weight of the Union, central bank reacts to the change in productivity, mimicking the decreasing natural interest rate. This drop, added to the terms-of-trade gap, *boosts Foreign consumption* above the efficient level and therefore causes Foreign inflation. Note that these mechanisms do not appear in small-open economy models: union-level variables would not change due to the infinitesimal weight for each country.

From the insights detailed in the previous section, what are the gains from optimal policy? The monetary policy is similar in the two situations, and therefore, fiscal policy can constitute another tool for stabilization. The role of government spending is to "reroute" aggregate demand from the Foreign to the Home country. This prevents Foreign labor markets to be "overloaded" and it reduces the output gap and the welfare loss of the union. Moreover, we compute the welfare gains and the fiscal multiplier from this experiment. The fiscal policy stabilization can reduce the welfare loss four-fold, from 8% consumption-equivalent to 2%. These results are computed in the table 4: we compute the union welfare loss for each experiment in terms of consumption equivalent.

Figure 4: Response to a 1% productivity shock



Technology shock follows a AR(1) process, Central bank reacts to inflation under the rules detailed in table 4, and fiscal policy is either passive or follows optimal policy/fiscal rule

Table 4: Results: Spillovers of shocks, Welfare loss and Fiscal multipliers

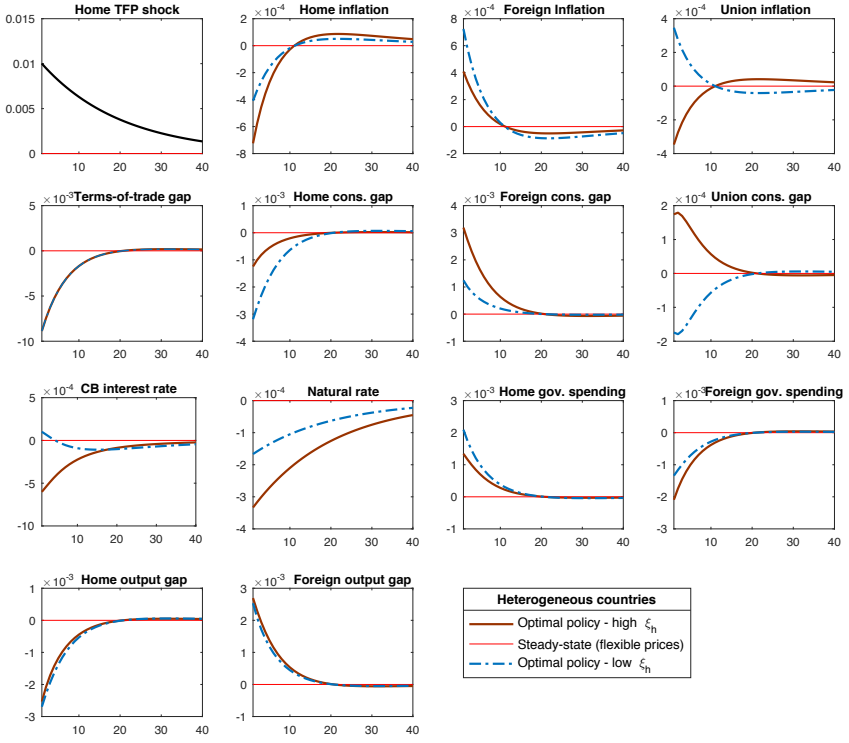
Type of shock	Monetary response	Fiscal policy response	Welfare loss	Fiscal multiplier
TFP shock	*Inflation rule*: $\phi_\pi = 1.5$	Passive	0.083	NA
TFP shock	Optimal policy (commitment)	Optimal policy (commitment)	0.026	0.678
TFP shock	*Inflation rule*: $\phi_\pi = 1.5$	*Fiscal rule*: $\psi_s = 0.5$ & $\psi_c = 2.5$	0.026	0.678
Fiscal shock	*Inflation rule*: $\phi_\pi = 2$	Passive (after the shock)	0.034	0.414
Fiscal shock	*Taylor-rule*: $\phi_\pi = 1.1$ & $\phi_c = 0.5$	Passive (after the shock)	0.035	0.676
Fiscal shock	*Inertial-Taylor-rule*: $\phi_\pi = 1.1$, $\phi_c = 0.5$	Passive (after the shock)	0.036	0.650

- Central Bank follows a simple policy rule: $i_t^* = r_t^{nat} + \phi_\pi\, \pi_{w,t} + \phi_c\, \widetilde{c}_{w,t}$
  Or it may react with inertia: $i_t = \rho_i\, i_{t-1} + (1-\rho_i)\, i_t^*$ (with $\rho_i = 0.95$)
- Fiscal policy is either passive: $\widetilde{g}_t = 0$ or follows a simple policy rule: $\widetilde{g}_t = -1/2\, \psi_s\, \widetilde{s}_t - \psi_c\, \widetilde{c}_t$ (and $\widetilde{g}_t^* = +1/2\, \psi_s\, \widetilde{s}_t - \psi_c\, \widetilde{c}_t^*$)
- Welfare loss is expressed as percent of consumption
- Government spending multiplier is measured as the ratio of integrals of output gaps over spending gaps
- Baseline calibration: countries Home and Foreign are symmetric.

E Structural heterogeneity and productivity shocks

An *asymmetric shock* has a different impact on aggregate variables depending on structural parameters. As we observe, an asymmetric productivity shock have spillover effects on Union inflation and output gap and prevent central bank from following Natural interest rate. We distinguish two cases: in the first (a), Home economy has a high ξ_h and is more affected by price changes: the deflationary episode it experiences after the supply-shock have a faster influence on Union prices, which also adjust downward. Facing deflation at Union-level, monetary policy reacts by cutting interest rate close to two time below the natural rate. A contrario, in (b) when the Foreign country is more subject to inflationary pressure, the Union inflation is pushed upward following the Home supply shock. This is because the terms-of-trade gap worsen in favor of the Foreign country, which attracts the union aggregate demand. Therefore, the central bank is forced to raise policy rate, which is highly damaging for Home consumption gap – three time lower than in the previous case. As we see, the central bank response has changed with country heterogeneity, even though the main dynamics are similar to the ones in the previous section.

Figure 5: Response to a 1% productivity shock, comparison with two heterogeneous countries



TFP follows a AR(1) process. Countries have heterogeneous structural parameters, summarized by $\xi_h \equiv \frac{2\Xi^H \chi \varphi}{\gamma_C + \gamma_{C^*}}$. Monetary and fiscal policies are optimal (commitment). Results are shown in table 5

Considering an *aggregate* productivity shock, even though we do not show the graph, we argue that it does not produce asymmetric spillovers. As we described in the Union IS-equation, the response to an aggregate shock is simply a drop in natural interest rate and Central Bank nominal rate. This affects consumption at Home and Abroad equally, due to the assumption of equal size and risk-sharing. Therefore, there is no spillover on inflation, neither in the individual countries, nor at the Union-level. This is once more rooted in the Taylor principle, (and the "treat" of Central Bank anti-inflation mandate). This is analogous to the simple "one country" NK model.

Table 5: Results: Spillovers of shocks, Welfare loss, Fiscal multipliers and country heterogeneity

Type of shock	Parameter ξ		Monetary	Fiscal policy	Welfare loss	Fiscal multiplier	
	Home	Foreign	response	response		Home	Foreign
Home TFP shock	High (0.064)	Low (0.0093)	Inflation rule	Passive	0.012	NA	NA
Home TFP shock	High (0.064)	Low (0.0093)	*Optimal policy*	*Optimal policy*	0.010	0.956	0.3734
Home TFP shock	Low (0.0093)	High (0.064)	*Optimal policy*	*Optimal policy*	0.010	0.3734	0.956
Home fiscal shock	High (0.064)	Low (0.0093)	Taylor rule	Passive	0.038	0.643	NA
Home fiscal shock	Low (0.0093)	High (0.064)	Taylor rule	Passive	0.034	0.617	NA
Union fiscal shock	High (0.064)	Low (0.0093)	Taylor rule	Passive	0.080	0.770	0.883

Notes: ∘ Central Bank follows a simple policy rule: $i_t^* = r_t^{nat} + \phi_\pi\, \pi_{w,t} + \phi_c\, \widetilde{c}_{w,t}$
Or it may react with inertia: $i_t = \rho_i\, i_{t-1} + (1-\rho_i)\, i_t^*$ (with $\rho_i = 0.95$)
∘ Fiscal policy is either passive: $\widetilde{g}_t = 0$ or follows the optimal policy under commitment.
∘ Welfare loss is expressed as percent of consumption
∘ Government spending multiplier is measured as the ratio of integrals of output gaps over spending gaps
∘ Calibration: Home (resp. Foreign) have either "low" (resp. high) or "high" (resp. low) parameter value ξ_h (resp. ξ_f)

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